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Directorate of Research and Training (DoRT)
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Post Box 25535, Kathmandu, Nepal
Email: info@hicast.edu.np; binayakprajbhandari@gmail.com
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RESEARCH ARTICLES

POST-HARVEST AND QUALITATIVE PERFORMANCE OF HYBRID CULTIVARS OF CAULIFLOWER GROWN AT DANG CONDITION

Manoj Basnet[1*], Arvind Srivastava[2], Kalyani Mishra[2] and Kishor Chandra Dahal[1]

[1]Tribhuvan University, Institute of Agriculture and Animal Science, Kathmandu
[2]Agriculture and Forestry University, Faculty of Agriculture, Rampur, Chitawan
[*]**Corresponding Author**: manoj@iaas.edu.np

ABSTRACT

The study was conducted at Tulsipur, Dang for two years (2021 and 2022 A.D.) to assess postharvest quality performance of hybrid cauliflower. Five hybrid cauliflower cultivars viz. Snow Best, Snow Crown, Super White Top, Rami and Damy were replicated four times in Randomized Complete Block Design. Freshly harvested curds from respective plots were considered in this study. Highest leaf dry matter (13.59%) and TSS (7.060^{0}Brix) was found in Super White Top and Snow Crown, respectively whereas lowest leaf dry matter (11.50%) and TSS (5.12^{0}Brix) in Rami. The color (7.820), compactness score (8.165) in Snow Crown and appearance score (7.846) in Snow Best was highest whereas lowest color (6.290), compactness (6.040) and appearance score (5.39) in Rami. Super White Top showed lowest physiological loss in curd weight with jacket leaves i.e. 13.99%, 20.21% and 27.66% at 5, 7 and 9 days after harvesting (DAH) respectively whereas Rami showed the highest loss i.e. 19.02%, 24.36%, and 30.73% at 5, 7 and 9 DAH, respectively. Lowest physiological losses in curd weight without jacket leaves recorded were 13.29%, 18.15%, and 23.70 3% at 3, 5 and 7 (DAH,) respectively in Snow Crown and 29.78% at 9 DAH in Super White Top whereas, the highest loss i.e. 15.46%, 24.65% and 29.56% at 3, 5 and 7 DAH respectively in Dami and 37.80% at 9DAH Rami. Lowest spoilage loss of curd with and without jacket leaves was recorded in Snow Crown 29.23% and 35.79% respectively whereas the highest in Damy cultivar i.e. 35.31% and 43.60% respectively.

Keywords: Cauliflower, postharvest, hybrid, cultivars, Nepal

INTRODUCTION

Cauliflower (*Brassica oleracea var. botr*ytis L.), queen of winter vegetables, is an important vegetable widely grown in Terai, and Mid Hills (Pradhan et al., 2023) of Nepal and is known to be originated in Mediterranean region (Bose and Som, 1993). The immature flower buds are usually used for consumption which contains carbohydrates, protein, fat, potassium, phosphorous, Sulphur, iron, copper, carotenoids, β-carotene, vitamin-A, B1 and C. In context of Nepal, a total of 574,798 mt of cauliflower is produced in an area of 35,765 ha land with an average productivity of 14.95 mt/ha. In addition, Dang district covers an area of 385 ha of land with total production of 5,899 mt productivity of 15.32 (MOAD, 2020/21). Nepal government has realized the importance and the scope of vegetable farming along with the emerging cauliflower as a good source vegetable enterprise providing income within short period of time.

Several hybrid cultivars from different country have been imported in Nepal in relation to productivity every year because of open boarder situation. Several production trials have been experimented at farmer's field before they reach to the farmers. In spite of this, the productivity of cauliflower has not still reached the desired level. The yield variation among different cultivars might be due to the environmental variations at different regions (Ndiaga, 2000). In addition, genetic and heritable variability also govern the vegetative characteristics and curd yield traits. There is a must need for genetic improvement and research study to develop the cultivars with acceptable and better traits.

Majority of the farmers in Nepal are cultivating cauliflower in winter season and it is a must need to identify the best hybrid cultivars at Nepalese condition. In the same line, this study aims to find out the best hybrid cauliflower cultivars suited for Dang condition of Lumbini province.

MATERIALS AND METHODS

Location and design of the study

The research was carried out at Horticulture department of Campus of Live Sciences situated at Tulsipur, Dang during 2021 and 2022 A.D. Five hybrid cauliflower cultivars viz. Snow Crown, Super White Top, Snow Best, Rami and Damy were replicated four times in Randomized Complete Block Design. Freshly harvested curds from the respective plots were considered in postharvest and sensory study and carried out under laboratory condition. The laboratory research was laid out in Completely Randomized Design (CRD) with four replications.

Determination of dry matter content of leaf and curd

According to Panthi et al. (2020) the harvested curds and leaves from each plot were cut individually and 100 gm sample of leaf and curds were oven dried for 48 hours at 650C in hot air oven (SSU-106 Oven Universal-Memert type, Sanjeev Scientific Udyog, India). The percent dry matter content was calculated by using the formula as;

$$DM = \frac{(Ws-Ds)}{Ws} \times 100$$

Where, DM = Dry matter (%), Ws = curd sample (gm), Ds= Oven dry sample (g)

Determination of vitamin c content of curd

Firstly, 5 ml of working standard solution was prepared by dissolving fresh cauliflower curd sample. Then, 10 ml of 4 % oxalic acid (Fizmerk, Fizmerk India Chemicals, India) added to the standard solution, and titrated against the dye (V1ml) until the appearance of pink color (end-point), thus the amount of dye consumed is equivalent to the amount of ascorbic acid. To make known volume (100 ml), 0.5–5 g sample was extracted on 4 % oxalic acid and centrifuged. Then, 5 ml of supernatant was pipette out (ZI 2066D, Zeal International, India) and 10 ml of 4 % oxalic acid added. It was titrated against the dye (V2 ml) until pink color develops (Basnet et al., 2017). Finally, amount of ascorbic acid (vitamin C) calculated with the following formula:

$$\text{Amount of ascorbic acid (mg/100 gm of curd)} = \frac{1000.5\ \text{mg} \times V2\ \text{ml} \times 100\ \text{ml})}{V1\ \text{ml} \times 5\text{ml} \times \text{wt.of sample})}$$

V1= Titrated volume of standard solution against dye
V2=Titrated volume of sample solution against dye

Determination of Total Soluble Solid (TSS)

The cauliflower curds were ground and the curd juice was kept on prism of Refractometer (RHB 32 ATC, ERMA Refractometer, Japan) to measure TSS in Degree Brix.

Scale	Colors	Compactness	Appearance	Acceptability
1-3	Poor	Loose	Poor	Acceptable
3-5	Good	Slightly loose	Attractive	Preferred
5-7	Better	Compact	More attractive	More preferred
7-9	Best	Very Compact	Highly attractive	Highly preferred

Organoleptic test

An organoleptic test was conducted by involving 50 personnel to evaluate the curd characteristics based on the following parameters and numbering system (Giri et al., 2020).

Physiological loss in weight: The physiological loss in weight (PLW) of randomly selected five sample curds with and without their jacket leaves were examined by keeping them in normal room condition for nine days (Basnet et al., 2017). PLW was calculated by using following formula:

$$\text{PLW} = \frac{\text{Intial weight} - \text{Fresh weight of the sample}}{\text{Final weight of the sample}} \times 100$$

Spoilage loss: The spoilage loss of randomly selected five sample curds with and without their jacket leaves were examined by keeping them in ordinary room condition for nine days (Basnet et al., 2017). It was calculated by using following formula:

$$\text{Spoilage (\%)} = \frac{\text{Weight of the spoiled curds}}{\text{Original weight of the curd}} \times 100$$

Statistical analysis: GenStat for Teaching and Learning (18th Edition) was used for the analysis of variance and other data analysis. Means were compared using Duncan's Multiple Range Test (DMRT) at 0.05 and 0.01 level of significance.

RESULTS AND DISCUSSION

Biochemical parameters of cauliflower

The curd dry matter and vitamin c content on different hybrid cultivars was found to be insignificant whereas, the highest leaf dry matter (13.59%) was found to be significant in Super White Top whereas lowest (11.50%) was found in Rami cultivars. In addition, Snow Crown cultivar showed the significant results with highest TSS (7.060^0Brix) whereas lowest TSS (5.12^0Brix) was found in Rami cultivar (Table 1). The curd and leaf dry matter percent, vitamin c content and TSS were found to be significant on various hybrid cultivars of cauliflower. The variation of these biochemical parameters might be due to both genetic and environmental influences such as nutrient source, climatic condition, soil fertility status, as similar finding was mentioned by Abbey et al. (2002).

Organoleptic test and sensory evaluation

The color score (7.820) and compactness score (8.165) was found to be significantly highest in Snow Crown whereas lowest color score (6.290) and compactness score (6.040) was found in Rami cultivars. Similarly, significantly highest appearance score of 7.846 was found in Snow Best and lowest appearance score of 5.939 was found in Rami cultivars. The acceptance score was found to be non-significant (Table 2).

Table 1 Mean leaf dry matter, curd dry matter, TSS and vitamin c of different hybrid cauliflower cultivars in Tulsipur, Dang (2021 to 2022 AD)

Treatments	Leaf dry matter (%)	Curd dry matter (%)	TSS (^{0}Brix)	Vitamin C (mg/100 g)
Snow Best	11.59^a	14.27^a	5.385^a	36.40^a
Snow Crown	12.50^{ab}	14.71^a	7.060^b	36.82^a
Super White Top	13.59^b	15.08^a	6.988^b	36.74^a
Rami	11.50^a	13.73^a	5.12^a	36.02^a
Damy	11.63^a	14.65^a	5.435^b	36.64^a
Grand mean	12.2	14.5	6.0	36.5
SEM	0.38	0.40	0.32	0.21
F-test	**	NS	**	NS
$LSD_{0.05}$	1.11	1.16	0.93	0.62
CV %	8.9	7.8	15.1	1.6

Means with same letter in column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p < 0.05$), **significant at 1% ($p < 0.01$) and ns: not significantly different at 5% ($p > 0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance

The scoring in terms of color, compactness and appearance showed the significant results in hybrid cultivars of cauliflower. The significant variation was also found in various cauliflower cultivars, might be due to genetic characteristics of the varieties (Giri et al., 2020), The similar results were achieved by Meena et al. (2010); Sharma et al., (2018) & Pun et al. ,(2003).

Physiological loss in weight of cauliflower with jacket leaves

Physiological loss in weight of curd with jacket leaves of cauliflower during storage period showed significant results only after 5 days after harvesting (DAH) whereas it was non-significant at 3 DAH. Super White Top cultivars showed significantly the lowest physiological loss in weight i.e. 13.99%, 20.21% and 27.66% at 5, 7 and 9 DAH, respectively. Moreover, Rami cultivar showed significantly the highest physiological loss in weight i.e. 19.02%, 24.36%, and 30.73% at 5, 7 and 9 DAH respectively (Table 3).

Table 2 Mean color, compactness, appearance, and acceptance of different hybrid cauliflower cultivars in Tulsipur, Dang (2021 to 2022 AD)

Treatments	Color	Compactness	Appearance	Acceptance
Snow Best	7.079^{ab}	6.352^{a}	7.846^{b}	7.257^{a}
Snow Crown	7.820^{b}	8.165^{b}	7.345^{ab}	8.195^{a}
Super White Top	7.696^{ab}	7.477^{ab}	6.938^{ab}	7.850^{a}
Rami	6.290^{a}	6.040^{a}	5.939^{a}	6.915^{a}
Damy	7.105^{ab}	7.287^{a}	7.374^{ab}	7.447^{a}
Grand mean	7.2	7.1	7.1	7.5
SEM	0.34	0.37	0.42	0.32
F-test	*	**	*	NS
$LSD_{0.05}$	1.00	1.06	1.23	0.94
CV %	13.5	14.7	16.9	12.1

Means with same letter in column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p < 0.05$), **significant at 1% ($p < 0.01$) and ns: not significantly different at 5% ($p > 0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance

Physiological loss in weight of cauliflower without jacket leaves

Physiological loss in weight of curd without jacket leaves of cauliflower during storage period showed significant results. The lowest physiological losses in weight recorded in Snow Crown were 13.29%, 18.15%, and 23.70 3% at 3, 5 and 7 days after harvesting (DAH), respectively whereas, Damy cultivars showed significantly the highest physiological loss in weight of curd without jacket leaves i.e. 15.46%, 24.65% and 29.56% at 3, 5 and 7 DAH respectively. In addition, on 9DAH, the lowest physiological loss in weight (29.78%) was found in Super White Top cultivars and highest (37.80%) in Rami cultivars (Table 4).

Spoilage loss in cauliflower with and without jacket leaves

Spoilage loss in relation to jacket leaves and without jacket leaves gave the significant results. The lowest spoilage loss along with and without jacket leaves was recorded to be 29.23% and 35.79% respectively in Snow Crown cultivars whereas the highest spoilage loss was found in Damy cultivar with and without jacket leaves i.e. 35.31% and 43.60% respectively (Table 5).

Table 3 Mean physiological loss in weight with jacket leaves of different hybrid cauliflower cultivars in Tulsipur, Dang (2021 to 2022 AD)

Treatments	Physiological loss in weight of cauliflower with jacket leaves (%)			
	3 DAH	5 DAH	7 DAH	9 DAH
Snow Best	10.14[a]	17.83[c]	23.08[c]	30.06[bc]
Snow Crown	10.85[a]	15.83[b]	20.89[b]	28.00[a]
Super White Top	9.60[a]	13.99[a]	20.21[a]	27.66[a]
Rami	10.45[a]	19.02[d]	24.36[d]	30.73[c]
Damy	10.49[a]	18.61[d]	24.11[d]	29.71[b]
Grand mean	10.3	17.1	22.5	29.2
SEM	0.50	0.15	0.11	0.18
F-test	NS	**	**	**
$LSD_{0.05}$	1.46	0.44	0.31	0.51
CV %	3.8	2.5	1.3	1.7

Means with same letter in column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p < 0.05$), **significant at 1% ($p < 0.01$) and ns: not significantly different at 5% ($p > 0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance

Table 4. Mean physiological loss in weight with jacket leaves of different hybrid cauliflower cultivars in Tulsipur, Dang (2021 to 2022 AD)

Treatments	Physiological loss in weight of cauliflower without jacket leaves %)			
	3 DAH	5 DAH	7 DAH	9 DAH
Snow Best	14.07[b]	21.51[b]	27.74[c]	35.01[c]
Snow Crown	13.29[a]	18.15[a]	23.70[a]	30.64[b]
Super White Top	13.80[b]	18.68[a]	24.78[b]	29.78[a]
Rami	14.59[c]	22.81[c]	29.00[d]	37.80[d]
Damy	15.46[d]	24.65[d]	29.56[d]	34.90[c]
Grand mean	14.2	21.2	27	33.6
SEM	0.12	0.17	0.18	0.17
F-test	**	**	**	**
$LSD_{0.05}$	0.50	0.68	0.53	0.49
CV %	2.4	2.2	1.9	1.4

Means with same letter in column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p < 0.05$), **significant at 1% ($p < 0.01$) and ns: not significantly different at 5% ($p > 0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance

Table 5 Mean spoilage loss with and without jacket leaves of different hybrid cauliflower cultivars in Tulsipur, Dang (2021 to 2022 AD)

Treatments	Spoilage loss in cauliflower	
	With jacket leaves	Without jacket leaves
Snow Best	33.40[c]	41.76[c]
Snow Crown	29.23[a]	35.79[a]
Super White Top	31.00[b]	37.91[b]
Rami	34.49[d]	41.07[c]
Damy	35.31[e]	43.60[d]
Grand mean	32.7	40
SEM	0.10	0.22
F-test	**	**
$LSD_{0.05}$	0.28	0.65
CV %	0.8	1.6

Means with same letter in column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p < 0.05$), **significant at 1% ($p < 0.01$) and ns: not significantly different at 5% ($p > 0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance

The physiological loss and spoilage loss in weight of cauliflower was found to be significant both with and without jacket leaves. This variation on physiological loss in weight and spoilage loss in cauliflower curd among different cauliflower varieties was achieved by Yadav et al. (2013), Kumar et al. (2011); Kido & Singh (2018).

The significant differences on postharvest parameter and sensory quality parameters of different cauliflower genotypes were estimated with each other even on the same growing condition, which might be due to different characteristics of genotypes governed by different genes; and they were greatly influenced by environmental factors and management practices (Khanal et. al., 2022). Similar results were reported by Poudel et. al. (2017); Khatiwada & Chaudhary (2004); Budhathoki et al. (2004).

CONCLUSION

It was found that the biochemical parameters such as leaf dry matter and TSS; organoleptic taste and sensory evaluation, physiological loss in weight and

spoilage loss both with and without jacket leaves were significantly different in different hybrid cauliflower cultivars. The highest leaf dry matter (13.59%) and highest TSS (7.060^0Brix) was found to be significant in Super White Top and Snow Crown respectively whereas lowest leaf dry matter (11.50%) and TSS (5.12^0Brix) was found in Rami cultivars. The color score (7.820) and compactness score (8.165) was found to be significantly highest in Snow Crown whereas lowest color score (6.290) and compactness score (6.040) was found in Rami cultivars. Similarly, significantly highest appearance score of 7.846 was found in Snow Best and lowest appearance score of 5.939 was found in Rami cultivars. Super White Top cultivars showed significantly the lowest physiological loss in weight of curd with jacket leaves i.e. 13.99%, 20.21% and 27.66% at 5, 7 and 9 DAH respectively. Moreover, Rami cultivar showed significantly the highest physiological loss in weight of curd with jacket leaves i.e. 19.02%, 24.36%, and 30.73% at 5, 7 and 9 DAH respectively. The lowest physiological losses in weight of curd without jacket leaves recorded in Snow Crown were 13.29%, 18.15%, and 23.70 3% at 3, 5 and 7 days after harvesting (DAH) respectively whereas, Damy cultivars showed significantly the highest physiological loss in weight of curd without jacket leaves i.e. 15.46%, 24.65% and 29.56% at 3, 5 and 7 DAH respectively. In addition, on 9 DAH, the lowest physiological loss in weight of curd without jacket leaves (29.78%) was found in Super White Top cultivars and highest (37.80%) in Rami cultivars. The lowest spoilage loss of curd along with and without jacket leaves was recorded to be 29.23% and 35.79% respectively in Snow Crown cultivars whereas the highest spoilage loss was found in Damy cultivar with and without jacket leaves i.e. 35.31% and 43.60% respectively. Considering the economically important postharvest attributes Snow Crown and Super White Top were found to be the suitable hybrid mid-season cauliflower cultivars to be grown in Dang condition.

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REFERENCES

Abbey, L., Joyce, D.C., Aked, J., & Smith, B. (2002). Genotype, sulfur nutrition and soil type effects on growth and dry-matter production of spring onion. *The Journal of Horticultural Science and Biotechnology*, 77(3), 340-345. DOI: http://dx.doi.org/10.1080/14620316.2002.11511503

Basnet, M., Shakya, S.M., & Baral, B.R. (2017). Response of organic manures on post-harvest and soil nutrient restoration on cauliflower production. The Journal of Agriculture and Environment, 18, 67-72. DOI: http://dx.doi.org/10.3126/aej.v18i0.19891

Budathoki, K., Pradhan, N.G., & Bhattarai, D.R. (2004). Evaluation of cauliflower varieties for off-season production in the mid hills of Nepal. Fourth national workshop on horticulture, March 2-4; 407-417.

Bose, T. K., & Som. M. G. 1993.Vegetable crops in India, Naya Prakash, Calcutta, 838.

Giri, H.N., Sharma, M.D., Thapa, R.B., Pande, K.R., & Khatri, B.B. (2020). Performance on postharvest quality of late season cauliflower (Brassica oleracea var. botrytis L.) varieties in terai region of Nepal. Archives of Agriculture and Environmental Science, 5(4), 543-547. DOI: https://doi.org/10.26832/24566632.2020.0504017

Kindo, S.S., & Singh, D. (2018). Varietal evaluation of cauliflower (Brassica oleracea var. botrytis L.] under agro-climatic condition of Allahabad. International Journal of Pure and Applied Bioscience, 6(1), 672-677. DOI: http://dx.doi.org/10.18782/2320-7051.5119

Kumar, M., Sharma, S.R., Kalia, P. & Saha, P. (2011). Genetic variability and character association for quantitative and quality traits in early maturing Indian cauliflowers. Indian Journal of Horticulture, 68(2), 206-211. DOI: https://www.researchgate.net/journal/Indian-Journal-of-Horticulture-0974-0112

Meena, M.L., Ram, R.B., Lata, R. & Sharma, S.R. (2010). Determining yield components in cabbage (Brassica oleracea var. capitata L.) through correlation and path analysis. International Journal of Science and Nature, 1(1), 27-30.

MoALD. (2022). Statistical information on Nepalese agriculture. Agri-business Promotion and Statistics Division, MoAD, Singha Durbar, Kathmandu, Nepal.

Ndiaga, C. (2000). Genotype x Row Spacing and Environment interaction of cowpea in semi-arid zones. African Crop Science Journal, 9(2): 359-367. DOI: https://doi.org/10.4314/acsj.v9i2.27606

Panthi, J, Shrestha, R.K., Shrestha, S., Manandhar, B.D., Bhatta, N.P., & Devkota, S. (2020). Response of cauliflower (Brassica oleraceae var. botrytis L.) to different level of boron under maize based cropping system. Journal of Institute of Agriculture and Animal Science, 36, 231-240.

Poudel, K., Ansari, A.R., & Shah, M.K. (2017). Varietal evaluation of cauliflower for early season production in the eastern hills of Nepal. In: IP Gautam, SL Shrestha, GD Subedi, DR Bhattarai, TP Gotame and KP Upadhyay eds. Proc. of 9th National Horticulture Workshop, May 31-June 1, 2017, NARC, HRD, Khumaltar, Lalitpur, Nepal; 316-319.

Pradhan, N.G., Srivastava, A., Shreatha, A.K., & Gautam, I.P. (2023). Evaluation of cauliflower genotypes to different planting dates for early production in Kathmandu valley. Nepal Agriculture Research Journal, 15(1), 82-97. DOI: http://dx.doi.org/10.3126/narj.v15i1.51320

Pun, A.B., Pandey, Y.R. & Yadav, Y.P. (2003). Performance of cauliflower varieties under different agro-ecological domains of western hills of Nepal. Agricultural

research for enhancing livelihood of Nepalese people. In: proc. 2nd SAS-N convention, 30 July-1 August 2003, pp: 235-238.

Sharma, S., Singh, Y., & Sharma, S. (2018). Studies on mean performance for yield and its contributing traits in cauliflower (Brassica oleracea var. botrytis L.) under mid hill conditions of northwestern Himalayas. International Journal of Current Microbiology and Applied Science, 7(2), 3288-3296. DOI: http://dx.doi.org/10.20546/ijcmas.2018.702.395

Yadav, M., Prasad, V.M., & Ahirwar, C.S. (2013). Varietal evaluation of cauliflower (Brassica oleracea var. botrytis L.) in Allahabad agro-climatic condition. Trends in Biosciences, 6(1), 99-100.

Zhan, L. Jinquiang, Hu., Pang, L., Li. Yu., & Shao, J. (2014). Light exposure reduced browning enzyme activity and accumulated total phenols in cauliflower heads during cool storage. Postharvest Biology and Technology, 88, 17-20. DOI: https://doi.org/10.1016/j.postharvbio.2013.09.006.

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PREVALENCE OF ANTIBIOTIC RESISTANCE AGAINST *ESCHERICHIA COLI* ISOLATES FROM BROILER MEAT MARKETED IN KATHMANDU VALLEY

Mahesh Thakur*[1], Md. Bazlar Rashid[1], Rakibul Islam[1], and Md. Mahmudul Hasan[2]

[1]Department of Physiology and Pharmacology, Faculty of Veterinary and Animal Science,

[2]Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

***Corresponding author:** ammavet07@yahoo.com

ABSTRACT

Antibiotic resistance is day by day becoming greater health concern. Tremendous use of antibiotic in poultry is known to be a major cause for antibiotic resistant in human. An experiment of meat samples was purchased from various meat shops and examined for bacterial contamination with resistant E. coli. (Total=384) Samples were taken for the study and among them, 189 isolates were evaluated for their antibiotic susceptibilities and the presence of antibiotic resistance. Results of antibiograms revealed that E. coli isolates were resistant to one or more of the antibiotics tested. Ciprofloxacin (42.32%) is higher resistance from the for-E. coli. Colistin Sulphate (2.11%) is less resistance for E. Coli. Whereas Chroramphenicol (42.32%), Gentamicin (41.79%), Levofloxacin (34.92%), Amikamicin (7.4%), resistance was most frequently observed. Fifteen E. coli strains showed the multidrug resistance phenotypes and harbour at least three antibiotic resistances. The results indicated that production methods influenced the frequency of antibiotic resistant E. coli on poultry products available to consumers. Future research to identify the specific practices that cause the high frequency of antibiotic-resistant E. coli in chicken could promote efforts to reduce consumer exposure to this potential pathogen.

Keywords: *E. coli*, chicken meat, antibiogram, multidrug resistance.

INTRODUCTION

Microorganisms with resistance to antimicrobials can affect people at any stage of life and also the animals (livestock) reared in the veterinary and agricultural

sectors (ECDC 2015). A study conducted in the United States showed that Escherichia coli (E. coli) isolates from livestock were more resistant than those from human clinical isolates (Tadesse *et al*., 2012). Humans are exposed to antimicrobial-resistant microorganisms and their resistance genes are prevalent in animals, both via the food chain and through widespread release into the environment (Silbergeld *et al*., 2008). Pathogenic bacteria from sources such as livestock can interact with other bacteria, boosting the sharing of genes and genetic components that cause antibiotic resistance. These circumstances can cause non-pathogenic bacteria to develop into resistant reservoirs (Ejaz *et al*., 2021). There is indisputable proof that food derived from a variety of animal sources contains large numbers of resistant bacteria and resistant genes (Marshall *et al*., 2011). A past study reported that chicken meat could be one of the potential causes of infection with multi-drug resistant (MDR) E. coli (Parvin *et al*., 2020). Considering the relatively low production cost and absence of cultural and religious restrictions on its consumption, poultry is one of the most widespread foods; chicken meat and eggs being the most common (Nhung e*t al*., 2017). Antimicrobials are used, not only to treat disease in the poultry industry, but also to promote the growth of broiler chickens (Landoni e*t al*., 2015) (Agunos e*t al*., 2012). In Europe, use of avoparcin in food animals as a growth promoter had been linked with resistance to vancomycin, a last resort antimicrobial in human medicine (Wegener e*t al*., 2012). Therefore, European countries have discontinued use of antimicrobials as growth promoters, but other countries in South America, Africa, and Asia still use it abundantly (Allcock e*t al*., 2017). It has been found that approximately 80% of medically important antimicrobials are used as growth promoters in healthy animals, to fulfill the increasing demand for foods of animal origin (WHO 2017). The overall consumption of antimicrobials in livestock was estimated to have increased by 67% between 2010 and 2030 (Van Boeckel e*t al*., 2015). As a result of consumption and accumulation over time, there is higher chance of the development of multiple pathogens insensitive to medically important antimicrobials (Lees e*t al*., 2021).

The World Health Organization's (WHO) global action plan on antimicrobial resistance (AMR) emphasizes the "one health" approach, which recognizes the interconnections between humans, animals, and the environment as a single entity, to tackle resistance (Badau e*t al*., 2021). The one health approach provides important insights to plan and control the burden of AMR (Parmley e*t al*., 2012). Systematic reviews on one health approaches have also shown associations between specific interventions targeting reductions in antibiotic use in food-producing animals and decreases in AMR in animals (Scott e*t al*., 2018) (Hoelzer

e*t al*., 2017). Knowledge on the burden of AMR and resistance patterns in isolates extracted from food-producing animals is imperative to designing targeted interventions to limit antibiotic use. The use of commensal intestinal E. coli as a marker for the presence of resistance in bacterial flora is a critical component of AMR surveillance programs in both food-producing and wild animals (Wasyl e*t al*., 2013). The chicken gut micro biota constitutes a major source of antibiotic resistance genes that encode several drug efflux pumps, leading to resistance to fluoroquinolones and tetracyclines (Juricova e*t al*., 2017).

In Nepal, the use of antimicrobials has increased in recent times, in order to decrease the morbidity and mortality of chickens (Shrestha., 2022) (Ramdam., 2015). A study conducted in Nepal under the Global Antibiotics Resistance Partnership (GARP) has shown that 46% of veterinary drugs were sold under self-prescription and about 12% on farmer's demand (Ramdam., 2015). Surveillance of animal pathogens commenced in 2011, with a collaboration between the National Public Health Laboratory and various veterinary laboratories. The Ministry of Health and Population, Nepal, attempted to address such issues with National Antibiotics Treatment Guidelines in 2014 (Acharya and Wilson., 2019). There is no clear regulation for control of the use of antimicrobials in animals for human consumption.

Very few studies have assessed AMR in the poultry sector in Nepal. A study conducted on bacteriological quality of poultry meat in Nepal showed that various bacteria, such as E. coli, Staphylococcus, and Klebsiella showed higher resistance to commonly found antibiotics on the market, such as amoxicillin and tetracyclines (Neupane and Kaphle., 2019). While in other study, E. coli was found in 76.1% of poultry meat samples, and resistance to tetracycline was highest (87.7%) and lowest for ceftriaxone (1%) (Acharya., 2022). However, there is no published literature on the pattern of AMR in isolates from chicken meat samples in Nepal. Raw meat samples provide a better insight into the resistance pattern in the microbiota of the chicken and also are not prone to cross-contamination from the environment in the slaughter house.

Majority of Nepalese population consume meat products processed in small shops that store the product at ambient temperature and improper handling, both of which increase microbial growth and contamination.

The present study is designed to investigate the prevalence of antimicrobial drug-resistant bacteria from raw meat sample from Kathmandu, an ancient city and capital city of Nepal.

MATERIALS AND METHODS

Study area

The study area was Kathmandu valley. Sampling was done from different slaughter houses, slaughter places and live bird markets distributed across the market. This study was carried out from July 2022 to December 2022.

Sample size

Sample size was calculated using the statistical software Epi Info 7.2 used in the CDC. The assumptions made were population size of one million broilers in Kathmandu valley; prevalence of AMR to be 50%, and confidence interval of 95%. These yields a sample size were 384. These samples were collected to represent different areas of Kathmandu valley, covering different slaughter houses and live bird markets. Samples were collected following the standard laboratory protocol.

Sample collection protocol

The fresh meat samples were collected together with epidemiological information such as farm size, location of slaughter house, age of birds, and hygienic practices of butcher. Samples were collected to represent large, medium and small sized slaughter places as well as to represent samples from small, medium and large poultry farms. A detailed questionnaire was developed to collect epidemiological information; and the butchers / workers in slaughter places were interviewed during the sample collection.

Laboratory analysis

Sample processing for identification of bacterial pathogens

The samples collected were transported to the laboratory maintaining cold chain using the cool box. The samples were then cultured in selective media (Nutrient, MacConkey and Eosin methyl blue) and then incubated for 24- 48 hours. The media were checked for bacterial growth, and identified by morphology of colony characteristics and appropriate biochemical tests. If there was growth, the identified colony was taken, and antimicrobial susceptibility test was performed according to modified Kirby Bauer disc diffusion method in Mueller Hinton agar. Antibiotic sensitivity testing by the Kirby Bauer's disc diffusion method was performed for the isolates using commercially available antibiotic discs on Muller–Hinton agar (MHA). Standard suspensions of the isolates were adjusted to 0.5 McFarland Standard. Immediately after standardization a sterile cotton

swab was immersed into bacterial suspension; and a lawn culture was performed on the surface of MHA plate. Commercially available antibiotic discs were arranged on the surface of inoculated plates. The plates were incubated at 37^0C for 16-18 hours. After incubation the zone diameter was measured for each antimicrobial agent. Thereby the zone of inhibition was interpreted as sensitivity (S), Intermediate (I) or resistant (R) (Bauer *et al.*, 1997). In this study, the main focus was on common bacteria *E. coli*. The panel of antibiotics was including commonly used antibiotics in animal health and critically endangered antibiotics listed by the World Health Organization.

The sample processing, isolation and identification of bacterial pathogens and antimicrobial susceptibility test was carried out in the pharmacology and microbiology laboratory of Institute of Agriculture and Animal Science, Paklihawa Campus and related government laboratory.

Statistical Analysis

Descriptive analysis and other appropriate statistical procedures were also used to analyse the antimicrobial resistance pattern of bacterial isolates. The data was stored in Excel sheet and Epi Info 7.2 software to analyze the data.

RESULTS

Antimicrobial resistance (AMR) is a global growing issue and several reports suggest that it is an increasing problem of phenomenal proportions, affecting both developed and developing countries.

E. coli prevalence

Total 384 poultry meat samples were obtained from the market. Among the sample obtained, total 189 samples were found contaminated with *E. coli* . The contamination was found to be 49.29 %.

Table 1. Result of sensitivity analysis among *E. coli* Isolates

	Cipro	Chloramphenicol	Gentamicin	Amikacin	Levofloxacin	Colistin
S	64	55	50	92	81	185
I	31	54	60	83	41	0
R	94	80	79	14	66	4
Total Sample	189	189	189	189	188	189

Antibiotic resistance among *E. coli* isolates

Resistance was detected to 6 antibiotics tested. None of the isolates were multi drug resistant. Among the total meat samples obtained, there were 189 samples positives with E. coli. These samples were subjected to antibiotic susceptibility test. Among the antibiotic, Ciprofloxacin had 64 samples were Sensitive, Chloramphenicol had 55 samples sensitive, Gentamicin had 50 samples sensitive, Amikamicin had 92 samples sensitive, Levofloxacin had 81 samples sensitive, Colistin Sulphate had 185 samples sensitive.

Figure 2. *E. Coli* growth in growth media

Table 2. Sensitivity to different drugs

Drugs	Sensitive (f)
Ciprofloxacin	64
Chloramphenicol	55
Gentamicin	50
Amikacin	92
Levofloxacin	81
Colistin	185

Prevalence of resistance among *E. coli* isolates

The prevalence of antibiotic resistance in *E. coli* strains simultaneously isolated from marketed broiler meat. Among the samples, ciprofloxacin had resistance in 94 samples of E.coli, Chloramphenicol had 80 samples resistance, Gentamicin had 79 samples resistance, Amikacin had 14 samples resistance and Colistin Sulpahte had only 4 samples resistance.

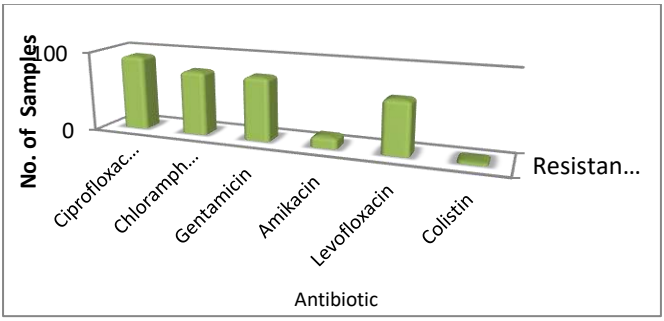

Figure 4. Graph showing resistances of different antibiotics

Ciprofloxacin

Ciprofloxacin is a broad-spectrum antibiotic widely prescribed in clinical and hospital settings. The emergence of antimicrobial resistance against effective antibiotics is a global issue. In the present study among the total 189 positive culture, there were 94 samples resistance, 31 samples were intermediate and 64 were sensitive.

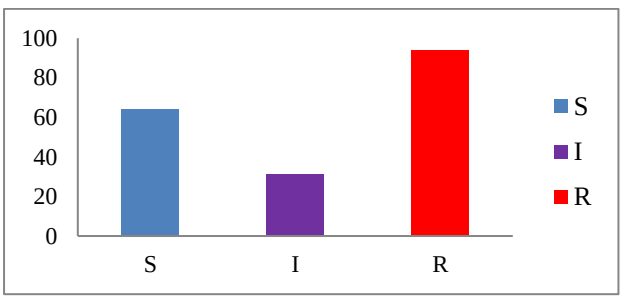

Figure 5. Graph showing the Ciprofloxacin resistance and sensitive pattern

Amikacin

Amikacin is a broad-spectrum antibiotic widely prescribed in clinical and hospital settings. The emergence of antimicrobial resistance against effective antibiotics is a global issue. In the present study among the total 189 positive culture, there were 14 samples resistance, 83 samples were intermediate and 92 were sensitive.

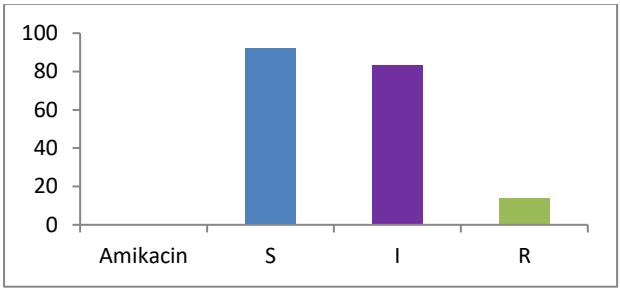

Figure 6. Graph showing sensitivity of Amikacin Anitibiotics

Chloramphenicol

Chloramphenicol is a broad-spectrum antibiotic widely prescribed in clinical and hospital settings. The emergence of antimicrobial resistance against effective antibiotics is a global issue. In the present study among the total 189 positive culture, there were 80 samples resistance, 54 samples were intermediate and 55 were sensitive.

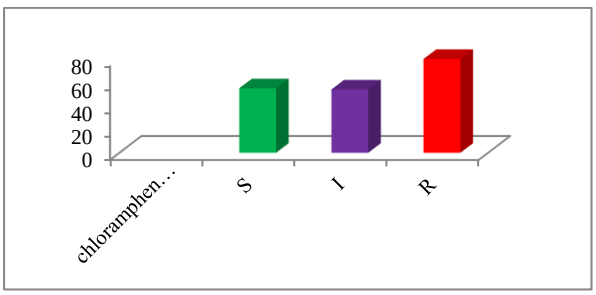

Figure 7. Graph showing sensitivity of Chloramphenicol Anitibiotics

Colistin Sulphate

Colistin Sulphate is a broad-spectrum gut acting antibiotic widely prescribed poultry sector. The emergence of antimicrobial resistance against effective antibiotics is a global issue. In the present study among the total 189 positive culture, there were 4 samples resistance, 0 samples were intermediate and 185 were sensitive.

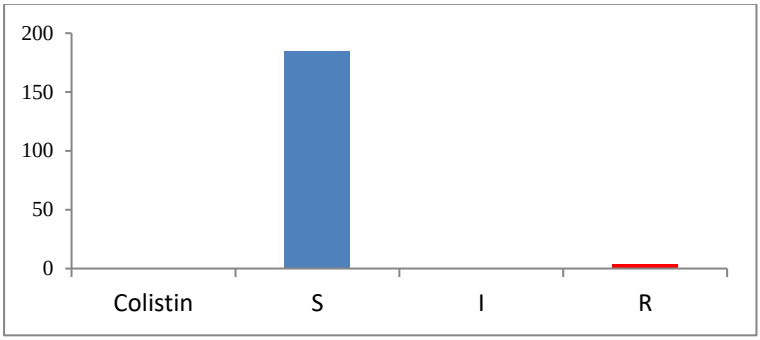

Figure 8: Graph showing sensitivity of Colistin sulphate Anitibiotics

Gentamicin

Gentamicin is a broad-spectrum antibiotic widely prescribed in clinical and hospital settings. The emergence of antimicrobial resistance against effective antibiotics is a global issue. In the present study among the total 189 positive culture, there were 79 samples resistance, 60 samples were intermediate and 50 were sensitive.

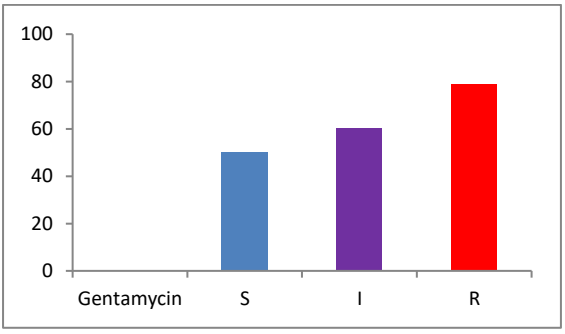

Figure 9. Graph showing sensitivity of Gentamicin Anitibiotics

Levofloxacin

Levofloxacin is a broad-spectrum antibiotic widely prescribed in clinical and hospital settings. The emergence of antimicrobial resistance against effective antibiotics is a global issue. In the present study among the total 189 positive culture, there were 66 samples resistance, 41 samples were intermediate and 81 were sensitive.

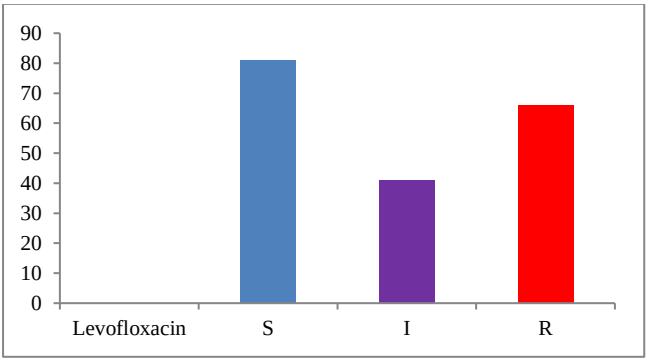

Figure10. Graph showing different drugs and their resistance

DISCUSSION

In the present study, out of 384 samples, 49.21% samples had *E. coli* bacterial growth in different culture medium. A similar but with higher prevalence was reported from Kathmandu, where they found more than 80.0.

In this study, out of 189 isolates of *Escherichia coli* from both chicken meats, 30 % were MDR. A study conducted in chicken breast sample in the United States showed 83.5% prevalence of *Escherichia coli*, of which 38.9% isolates were MDR [Zhao *et al*, 2012]. High number of *Escherichia coli* in retail meats indicates fecal contamination at slaughter or during processing.

The present study provides an assessment of the occurrence of multidrug resistance of *E. coli* from raw chicken meat collected from local market. The results indicated that production methods influenced the frequency of antibiotic-resistant *E. coli* on poultry products available to consumers. Future research to identify the specific practices that cause the high frequency of antibiotic-resistant *E. coli* in chicken could promote efforts to reduce consumer exposure to this potential pathogen.

Nepal being an agriculture-based country, in recent years is known to have increasing production and rise in population dependency on chicken poultry products for meat, egg and manure (Poudel *et al*. 2020). The study shows less than one fourth (14.82%) of the operating poultry farms are registered. The commercial poultry survey 2071/72 has recorded 14% of the registered poultry farm in Kathmandu valley having 16% of trained owner (CBS, 2015).

Multi- drug resistant *E. coli* isolates were found for 10 commonly used and market available antibiotics. Although we did not check the pathogenicity of the isolates, the gene responsible for multi-drug resistance may transfer to consumer via food and results in serious public health hazard as because (Boarlin *et al*., 2005) reported antimicrobial resistance is more frequent in pathogenic than in other porcine E. coli strains, and also shows that the resistance genes found in ETEC isolates are different from those of other porcine *E. coli* isolates and that clear associations exist between specific resistance and virulence genes. Jhonson *et al*., (2007) also reported that the drug resistant human isolates were similar to poultry isolates and thus, concluded that many drug-resistant human fecal *E. coli* isolates may be originated from poultry. This resistance occurs due to possessing of resistant gene found in single and multiple size plasmids in *E. coli* isolates.

The highest prevalence of multi-drug resistant E. coli isolates was obtained from chicken meat 76%. (Adesiyun *et al*., 2007) reported E. coli which was resistant to at least three or more antimicrobial agents. (Álvarez and Fernández *et al*.,2013) reported that 91.7 % E. coli isolates of poultry were multi-drug resistant. Indiscriminate use, improper selection, improper dose, incorrect duration of antibiotics at flock level may be responsible for such a higher occurrence of MDR. (Hassan *et al*., 2013) reported 22.7% MDR *E. coli* isolates from bird samples.

In conclusion, the result of this study provides preliminary data on antimicrobial resistant bacteria from raw chicken meat of Kathmandu valley. From the study, it is evident that meat products are biologically contaminated with various pathogens which have developed various microbial resistance. Extensive researches on this issue that also involve the molecular dynamics should be conducted longitudinally to have a better understanding of the exact scenario throughout the nation and thereby help curb the possible threats. Training and awareness program should be conducted in order to minimize the irrational use of antimicrobials and hence reduce drug resistance evolution via poultry and livestock.

CONCLUSION

Results of antibiograms revealed that *E. coli* isolates were resistant to one or more of the antibiotics tested. Resistance was most frequently observed against Ciprofloxacin (49.73%), Chloramphenicol (42.32%), Gentamicin (41.79%), Levofloxacin (34.92%), Amikacin (7.4%), and Colistin sulphate (2.11%). Fifteen *E. coli* strains showed the multidrug resistance phenotypes and harbored at least three antibiotic resistance genes.

***E. coli* prevalence**

Total 384 poultry meat samples were obtained from the market. Among the sample obtained, total 189 samples were found contaminated with *E. coli*. The contamination was found to be 49.29 %.

Resistance was detected to 6 antibiotics tested. None of the isolates were multi drug resistant. Among the total meat samples obtained, there were 189 samples positives with E.coli. These samples were subjected to antibiotic susceptibility test. Among the antibiotic, Ciprofloxacin had 64 samples were Sensitive, Chloramphenicol had 55 samples sensitive, Gentamicin had 50 samples sensitive, Amikacin had 92 samples sensitive, Levofloxacin had 81 samples sensitive, Colistin Sulphate had 185 samples sensitive.

The prevalence of antibiotic resistance in *E. coli* strains simultaneously isolated from marketed broiler meat. Among the samples, ciprofloxacin had resistance in 94 samples of *E. coli*, Chloramphenicol had 80 samples resistance, Gentamicin had 79 samples resistance, Amikacin had 14 samples resistance, Levofloxacin had 66 samples resistance and Colistin Sulpahte had only 4 samples resistance.

REFERENCES

Acharya K.P., Wilson R.T. (2019). Antimicrobial Resistance in Nepal. Front. Med. 2019; 6:105. doi: 10.3389/fmed.2019.00105. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Acharya K.R. (2011). *Antimicrobial Residue and Prevalence of Indicator Bacteria Having Antimicrobial Resistance Isolated from Marketed Poultry in Kathmandu, Nepal.* Ph.D. Thesis Chiang Mai University and Freie Universität Berlin; Berlin, Germany: 2011. [(accessed on 13 March 2022)]. Available online: http://cmuir.cmu.ac.th/bitstream/6653943832/35850/2/vph20911ak_abs.pdf [Google Scholar]

Adesiyun A, Offiaha N, Seepersadsingha N, Rodrigoa S, Lashley V and Musai L (2007). Antimicrobial resistance of Salmonella spp. and Escherichia coli isolated from table eggs. *Food Control* 18: 306-311.

Agunos A., Léger D., Carson C. (2012). Review of antimicrobial therapy of selected bacterial diseases in broiler chickens in Canada. *Can. Vet. J.* 53:1289. [PMC free article] [PubMed] [Google Scholar]

Allcock S., Young E.H., Holmes M., Gurdasani D., Dougan G., Sandhu M.S., *Solomon L., Török M. (2017). Antimicrobial resistance in human populations: Challenges and opportunities*. Glob. Health Epidemiol. Genom; 2nd:ed. doi: 10.1017/gheg.2017.4. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Álvarez-Fernández E, Cancelo A, Díaz-Vega C, Capita R and Alonso-Calleja C (2013). Antimicrobial resistance in E. coli isolates from conventionally and organically reared poultry: A comparison of agar disc diffusion and sensi test Gram- negative methods. *Food Control* 30: 227-234.

Badau E. A (2021). One Health perspective on the issue of the antibiotic resistance. *Parasite.* 28:16. doi: 10.1051/parasite/2021006. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Bauer AW, Kirby WMM, Sherris, J.C, Turck M. (1997). Antibiotic susceptibility testing by a standardised single disk method. *Am J Clin Pathol*; 45:493-496.

Central Bureau of Statistics (2014). Summary Report & Major Findings: Nepal Commercial Poultry Survey 2071/72, Thapathali, Kathmandu

Ejaz H., Younas S., Abosalif K.O., Junaid K., Alzahrani B., Alsrhani A., Abdalla A.E., Ullah M.I., Qamar M.U., Hamam S.S. (2021). *Molecular analysis of bla SHV, bla TEM, and bla CTX-M in extended-spectrum β-lactamase producing Enterobacteriaceae recovered from fecal specimens of animals*. PLoS ONE. 2021;16: e0245126. doi: 10.1371/journal.pone.0245126. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

European Centre for Disease Prevention and Control. (2015). Antimicrobial Resistance Surveillance in Europe. ECDC; Stockholm, Sweden: 2017. [(accessed on 8 February 2022)]. *Annual Report of the European Antimicrobial Resistance Surveillance Network* (EARS-Net) Available online: https://www.ecdc.europa.eu/sites/default/files/media/en/publications/Publications/antimicrobial-resistance-europe-2015.pdf [Google Scholar]

Hassan M and Alireza J, (2013). Shiga toxin-producing Escherichia coli isolated from chicken meat in Iran: Serogroups, virulence factors, and antimicrobial resistance properties. *Poultry Science,* 92: 1305-1313.

Hoelzer K., Wong N., Thomas J., Talkington K., Jungman E., Coukell A. (2017). *Antimicrobial drug use in food-producing animals and associated human health risks: What, and how strong, is the evidence*? BMC Vet. Res. 2017; 13:1–38. doi: 10.1186/s12917-017-1131-3. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Johnson JR, Sannes MR, Croy C, Johnston B, Clabots C and Kuskowski MA (2007). Antimicrobial drug-resistant Escherichia coli from humans and poultry products, Minnesota and Wisconsin, 2002-2004. *Emerging Infectious Disease,* 13: 838-846.

Juricova H., Matiasovicova J., Kubasova T., Cejkova D., Rychlik I. (2021). The distribution of antibiotic resistance genes in chicken gut microbiota commensals. *Sci. Rep.* 11:1–10. [PMC free article] [PubMed] [Google Scholar]

Landoni M.F., Albarellos G. (2015). The use of antimicrobial agents in broiler chickens. *Vet. J.* 205:21–27. doi: 10.1016/j.tvjl.2015.04.016. [PubMed] [CrossRef] [Google Scholar]

Lees P., Pelligand L., Giraud E., Toutain P.L. (2021). A history of antimicrobial drugs in animals: Evolution and revolution. *J. Vet. Pharmacol. Ther.* 2021; 44:137–171. doi: 10.1111/jvp.12895. [PubMed] [CrossRef] [Google Scholar]

Marshall B.M., Levy S.B. (2011). Food animals and antimicrobials: Impacts on human health. *Clin. Microbiol. Rev.* 24:718–733. doi: 10.1128/CMR.00002-11. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Neupane R., Kaphle K. (2019). *Bacteriological Quality of Poultry Meat in Nepal*. [(accessed on 2 August 2022)]. Available online: https://www.veteri.narypaper.com/pdf/2019/vol4issue5/PartA/4-2-22-316.pdf

Nhung N.T., Chansiripornchai N., Carrique-Mas J.J. (2017). Antimicrobial resistance in bacterial poultry pathogens: *A review. Front. Vet. Sci.*, 4:126. doi: 10.3389/fvets.2017.00126. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Parmley J., Leung Z., Léger D., Finley R., Irwin R., Pintar K., Pollari F., Reid-Smith R., Waltner-Toews D., Karmali M. (2012). One health and food saftey-the Canadian experience: A holistic approach toward enteric bacterial pathogens and antimicrobial resistance surveillance. In: *Wegner H.C., editor. Improving Food Safety through a One Health Approach: Workshop Summary*. The National Academies Press; Washington, DC, USA: 2012. [(accessed on 17 July 2022)]. p. 176. Available online: https://www.ncbi.nlm.nih.gov/books/NBK114511/ [Google Scholar]

Parvin M., Talukder S., Ali M., Chowdhury E.H., Rahman M., Islam M. (2020). Antimicrobial resistance pattern of Escherichia coli isolated from frozen chicken meat in Bangladesh. *Pathogens*. 9:420. doi: 10.3390/pathogens9060420. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Poudel U., Dahal U., Upadhyaya N., Chaudhari S., Dhakal S. (2020). Livestock and poultry production in Nepal and current status of vaccine development. *Vaccines.* 8:322. doi: 10.3390/vaccines8020322. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Ramdam N. (2015). *Study of Antimicrobial Use Pattern, Residue and Resistance in Poultry of Nepal.* Master's Thesis. Agriculture and Forestry University; Rampur, Nepal [(accessed on 20 March 2022)]. Available online: https://www.nepjol.info/index.php/nvj/article/download/25240/21155/76480 [Google Scholar]

Scott A.M., Beller E., Glasziou P., Clark J., Ranakusuma R.W., Byambasuren O., Bakhit M., Page S.W., Trott D., Del Mar C. (2-18). Is antimicrobial administration to food animals a direct threat to human health? A rapid systematic review. *Int. J. Antimicrob. Agents*. 52:316–323. doi: 10.1016/j.ijantimicag.2018.04.005. [PubMed] [CrossRef] [Google Scholar]

Shrestha K. (2022). *Potential Antimicrobial Resistance Threat–Nepal*. [(accessed on 17 July 2022)]. Available online: https://www.academia.edu/86635748/POTENTIAL_ANTIMICROBIAL_RESISTANCE_THREAT_NEPAL

Silbergeld E.K., Graham J., Price L.B. (2008). Industrial food animal production, antimicrobial resistance, and human health. *Annu. Rev. Public Health*. 29:151–

169. doi: 10.1146/annurev.publhealth.29.020907.090904. [PubMed] [CrossRef] [Google Scholar]

Tadesse D.A., Zhao S., Tong E., Ayers S., Singh A., Bartholomew M.J., McDermott P.F. (2012). Antimicrobial drug resistance in Escherichia coli from humans and food animals, United States, 1950–2002. *Emerg. Infect. Dis*. 18:741. doi: 10.3201/eid1805.111153. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Van Boeckel T.P., Brower C., Gilbert M., Grenfell B.T., Levin S.A., Robinson T.P., Teillant A., Laxminarayan R. (2015). Global trends in antimicrobial use in food animals. *Proc. Natl. Acad. Sci. USA*. 12:5649–5654. doi: 10.1073/pnas.1503141112. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Wasyl D., Hoszowski A., Szulowski K., Zając M. (2013). Antimicrobial resistance in commensal Escherichia coli isolated from animals at slaughter. *Front. Microbiol*. ;4:221. doi: 10.3389/fmicb.2013.00221. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Wegener H.C. (2012) A15 Antibiotic resistance—Linking human and animal health. In: *Wegner H.C., editor. Improving Food Safety through a One Health Approach: Workshop Summary*. The National Academies Press; Washington, DC, USA: 2012. [PubMed] [Google Scholar]

World Health Organization, (2017). *Critically Important Antimicrobials for Human Medicine: Ranking of Antimicrobial Agents for Risk Management of Antimicrobial Resistance Due to Non-Human Use.* [(accessed on 19 July 2022)]. Available online: https://apps.who.int/iris/handle/10665/2550279

World Health Organization. (2017). *Stop Using Antibiotics in Healthy Animals to Prevent the Spread of Antibiotic Resistance.* World Health Organization Media Center. [(accessed on 19 July 2022)]. Available online: http://www.who.int/mediacentre/news/releases/2017/antibiotics-animalseffectiveness/en.

Zhao S., Blickenstaff K., Bodeis-Jones S., Gaines S. A., Tong E., and McDermott P. F., (2012). Comparison of the prevalences and antimicrobial resistances of Escherichia coli isolates from different retail meats in the United States, 2002 to 2008, *Applied and Environmental Microbiology*, 78(6), 1701–1707.

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EVALUATION OF EGG QUALITY PARAMETERS OF TURKEY (*MELEAGRIS GALLOPAVO*) EGGS AT NATIONAL AVIAN RESEARCH PROGRAM, KHUMALTAR, LALITPUR

Maheshwar Dahal[1], Niraj Baskota[2] and U. Paneru[3]
[1] Nepal Agricultural Research Council, Kathmandu, Nepal
[2] National Avian Research Program, Khumaltar, Lalitpur
[3] National Cattle Research Program, Rampur, Chitwan
Corresponding author: *dr. maheshwardahal@gmail.com*

ABSTRACT

Turkey (Meleagris gallopavo) is an important avian species in Nepal contributing in the nutrition security and income generation. Present study was carried out in the National Avian Research Program (NARP), Lalitpur, Nepal from August to November 2021 to evaluate selected morphological characteristics of turkey eggs. A total of forty eggs from 45-48 weeks hens were examined for different internal and external egg quality parameters. Further, the effects of different egg quality parameters on egg weight in Turkey were examined. The data were recorded in MS-Excel and analyzed through Statistical Package for the Social Sciences (SPSS) 25. The mean egg weight, length, breadth, fresh shell weight, shell thickness, albumin height, yolk diameter, yolk weight and yolk height of turkey was 72.32±3.29 g, 6.36±0.20 cm, 4.70±0.12 cm, 9.68±0.33 g, 0.47±0.03 mm, 6.88±0.73 cm, 5.62±0.19 cm, 25.15±1.87 g and 0.98±0.20 cm, respectively. There was significant difference in almost all traits of external and internal traits of egg weight, fresh eggshell thickness, albumen height, yolk diameter and yolk height. This research provides important information about the egg quality parameters of Turkey raised in Nepal and serves as a reference for further investigation.

Keywords: Turkey, Avian species, Egg quality parameters

INTRODUCTION

Turkey (*Meleagris gallopavo*) is an important poultry species reared mainly for meat production around the globe. The egg and meat production per turkey bird has doubled during the last four decades, mainly due to the high selection pressure imposed on economically important traits such as body weight, meat quality, and

egg production (Anna Anandh et al., 2012). The domesticated turkey, *M gallopavo*, which originated in North America, is raised throughout the world, but its wild progenitor descends from the Eastern and Southern United States and central and northern Mexico (Thornton et al., 2012). Turkey is popular in Western countries for those who love white meat and is also associated with Christmas and Thanksgiving among the Christian population. The breeds reported include commercial and industrial strains, local types, and recognized breeds in many countries. The American Standard of Perfection has recognized eight distinct varieties: Beltsville small white, Black turkey, Bourbon Red, Bronze, Narragansett, Royal palm, slate, and white Holland. The present domesticated turkey has been developed by crossbreeding and line-breeding programs and is characterized as a single breed with eight distinct varieties based on the plumage colour (Kennamer et al., 1992).

History of turkey breeding in Nepal goes back to January 2001, with import of 200 embryonated eggs from the Central Avian Research Institute, Izantanagar, India. Performance of these turkeys was 11.34± 1.30 kg and 5.99 ± 0.83 kg for male and female, respectively at 43 weeks of age in Khumaltar of Nepal **(**Karki et al., 2002). Commercial turkey farming is becoming more popular in Nepal because of demands and farmer's interest. The bird is suitable for the upliftment of small and marginal farmers as it can be easily reared with little investment in housing, equipment, and management. One of the main objectives in turkey breeder production is to increase the number of poults.

Egg yield in turkeys is lower than that of other poultry species. In addition to low egg yield, unsatisfactory egg fertility and hatchability constitute a major problem for turkey breeding enterprises (Ozcelik et al., 2009). The age of the first puberty of Tom and Hen was 198.95 ± 7.3 and 200 ± 3.1 days, respectively. Similarly, the average weight of the tom and hen at puberty was 7.6 ± 0.67 and 5.3 ± 0.36 kg, respectively. The hatchability of eggs ranged between 10 and 90%, with an average of 52.4 ± 6.9% (Bhattarai et al., 2018). Quality has been defined by Kramer (1951) as the properties of any given food that have an influence on the acceptance or rejection of this food by the consumer. Egg quality is a general term that refers to several standards that define both internal and external quality. External quality is focused on shell cleanliness, texture, and shape, whereas internal quality refers to egg white (albumen) cleanliness and viscosity, size of the air cell, yolk shape, and yolk strength. The proportions of components for fresh eggs are 32% yolk, 58% albumen, and 10% shell (Leeson, 2006). The egg yolk from a newly laid egg is round and firm. As the egg gets older, the yolk absorbs

water from the egg white, increasing its size. This produces an enlargement and weakness of the vitelline membrane; the yolk looks flat and shows spots. As soon as the egg is laid, its internal quality starts to decrease, the longer the storage time, the poorer the internal quality. It is believed that the chemical composition of the egg (yolk and white) does not change much.

There are few studies that are focused on factors affecting egg weight of Turkey. Egg weight is an important parameter that will affect the resulting fertility, and optimum egg weight increases fertility and hatchability. Further, a small number of studies are focused on egg quality parameters of Nepalese turkey. Therefore, the main objective of this research is to evaluate the external and internal egg quality parameters of the egg weight of a turkey. Further, the correlation between different egg quality parameters will be studied to find out their association.

MATERIALS AND METHOD

Study site

The study was carried out under the National Avian Research Program (NARP) Khumaltar, Lalitpur, Nepal, during the months of August till November 2021. The poultry unit at NARP lies at a mean elevation of about 1350 masl. The yearly average temperature in Khumaltar is 15-20 °C, and it receives a yearly average rainfall of 2000–2400 mm.

Experimental birds and their management

Turkeys were reared in deep litter pens and fed conventional starter, grower, and layer rations. A lighting schedule of 16 hours per day was applied during the laying period. Standard procedures with respect to preventive vaccination and medication were followed during the study period. Altogether, 150 eggs were evaluated, and the eggs of 45, 46, 47, and 48 weeks were taken as samples. The eggs were collected in the early hours of the day, placed in the egg tray, and stored at room temperature until parameters were measured.

Measurement of external egg parameter

The individual egg was weighed using an electronic digital balance to the nearest 0.00 gm accuracy. The length (L) and breadth (B) of the egg were measured with the help of digital Vernier calipers, and the shape index was calculated as the ratio of breadth to length times 100, as suggested by Anderson et al. (2004). The fresh shell was weight by digital balance in gram. The thickness of eggshell was measured to the nearest of 0.01 mm with the help of screw gauze micrometer and averaged record.

Measurement of internal egg parameter

The length and width of the albumen and yolk were measured in mm with the help of vernier caliper (least count 0.01 mm). The height of yolk and albumen were measured with the help of triphoid spherometer. The yolk index percentage was calculated as the ratio of the yolk height to yolk diameter times 100.

Statistical analysis

All the egg quality data was entered in MS-Excel sheet. Least square means with standard errors (LS±SEM) were analyzed through Statistical Package for the Social Sciences (SPSS) 25.

RESULTS AND DISCUSION

The results on comparative of mean value of internal and external parameters of turkey eggs is presented in Table1 and Table 2, respectively.

External quality traits

Egg weight

The mean egg weight of turkey was observed 72.32±3.29 gm on weekly basis, egg weight of turkey on 45 weeks was 70.12±0.74 gm. The egg weeks in succeeding weeks of 46, 47 and 48 were 71.71±0.46 gm, 71.79±0.47 gm and 75.67±1.35 gm respectively. Egg weight differ significantly ($p< 0.001$) at different weeks of recording.

Table 1. Comparison of Mean value of different parameters of Egg weight, length, breadth, fresh shell weight and shell thickness of Turkey birds in different age (N=40)

Weeks	No.	Egg Weight (g)	Length (cm)	Breadth (cm)	Fresh shell weight (g)	Shell thickness (mm)
45	10	70.12±0.74	6.31±0.05	4.64±0.03	9.53±0.19	0.46±0.016
46	10	71.71±0.46	6.38±0.07	4.65±0.02	9.65±0.024	0.48±0.006
47	10	71.79±0.47	6.32±0.05	4.68±0.02	9.69±0.029	0.47±0.010
48	10	75.67±1.35	6.43±0.06	4.85±0.03	9.86±0.072	0.48±0.013
Mean	10	72.32±3.29	6.36±0.20	4.70±0.12	9.68±0.33	0.47±0.03
P value		0.000**	0.532	0.408	0.000**	0.182

** p value significant at 1% level of significance and No. refers to the number of eggs taken for observation

Salgado *et al.* (2020) observed the egg weight of 75.54±8.07 gm for Mexican native turkey, which were higher than our present finding. Our finding agrees with finding from (Rodrigo *et al.* 2020), who observed egg weight of Mexican turkey to be 75.54±8.07. Mroz *et al.* (2014) was observed egg weight of turkey to be 101.40 gm, higher than this study. However, Yahaya *et al.* (2021) observed egg weight of Turkey to be 69.12±8.4 gm, which was lower than the present study.

Egg length

The overall mean of egg length of turkey was observed to be 6.36±0.20 cm. Results of this study indicated that mean egg length of turkey was 6.31±0.05 cm at 45 weeks of age and 6.38±0.07 cm, 6.32±0.05 cm, 6.43±0.06 cm and 6.43±0.06 cm respectively in 46, 47 and 48 weeks. There were non-significant differences in egg length of turkey in different weeks. Our finding corresponds to the research from previous researcher, who observed egg length of black strain of Nigerian turkey to be 48.0±1.02 mm and white strain 54.1±1.02 mm (Yahaya *et al.*, 2021), which was lower than the present study.

Egg breadth

Mean egg breadth of turkey egg in our present study was observed to be 4.64±0.03 cm, 4.65±0.02 cm, 4.68±0.02 cm and 4.85±0.03 cm, respectively. There were significant increments ($p<0.001$) in egg breadth across weeks. Egg breadth of turkey egg at 48th week of egg was significantly higher than preceding weeks. This could be due to more mature hen, which facilitates egg laying of higher weight. Yahaya *et al.* (2021) observed egg breadth of 31± 0.91 mm for turkey egg at early stage of production in Nigeria.

Fresh shell weight

Average fresh shell weight of turkey bird in this study was found in different weeks were 9.53±0.19 g, 9.65±0.024 g, 9.69±0.029 g and 9.86±0.072g. According to the results there was not significantly different in different weeks but somehow more weight as week increases. The Nigerian Turkey shell weight was found to be 9.11±1.22 gm in black strain and 9.45±1.20 g in white strain which was lower than the current study. Shell weight of turkey from the current study agree with the finding from (Yahaya *et al*., 2021), 9.11± 1.22 g in Nigeria.

Shell thickness

The average mean of different weeks of eggshell thickness of Turkey birds in this study was 0.46±0.016 mm, 0.48±0.006 mm, 0.47±0.010 mm and 0.48±0.013 mm respectively. The eggshell thickness is closely correlated with the deposition of calcium, which is metabolized from the skeleton of the birds and dietary sources (Melesse *et al*., 2010). The Nigerian turkey shell thickness was found to be 0.27±0.001mm in black strain and 0.27±0.002 mm in white strain which was lower than this study (Yahaya *et al*., 2021).

Table 2. Comparison of means and standard Error (SE) of albumen weight, yolk diameter, yolk weight and yolk height of Turkey birds at different age

Weeks	No.	Albumen height (cm)	Yolk diameter (cm)	Yolk weight (g)	Yolk height (cm)
45	10	6.38±0.092	5.49±0.05	24.50±0.72	0.85±0.03
46	10	6.70±0.101	5.50±0.05	25.41±0.45	0.84±0.05
47	10	6.73±0.019	5.70±0.04	24.76±0.66	1.06±0.06
48	10	7.70±0.330	5.77±0.03	25.91±0.45	1.18±0.070
Mean	10	6.88±0.73	5.62±0.19	25.15±1.87	0.98±0.22
P value		0.000**	0.000**	0.335	0.000**

** p value significant at 1% level of significance and No. refers to the number of eggs taken for observation

Internal quality traits

Albumen height

Albumen height of turkey eggs in this study was observed to be 6.38±0.092 cm, 6.70±0.101 cm, 6.73±0.019 cm and 7.70±0.330 at 45, 46, 47 and 48 weeks, respectively as shown in the Table 2. The internal egg quality of albumen height of Mexican native turkey hens was 5.74±1.05 cm which was lower value as compared to this study. Rodrigo *et al.* (2020) observed the height of albumin to be 5.74 ± 1.05 cm, which is similar to the finding from the current research.

Yolk diameter

Results of this study reflected that the comparison of mean of different weeks egg yolk of Turkey was 5.49±0.05 cm, 5.50±0.05 cm, 5.70±0.04 cm and 5.77±0.03 cm respectively. Higher age significantly differs ($p<0.0001$) in the yolk diameter in this study. The Nigerian turkey yolk diameter was found to be 2.49±0.03 cm in

black strain and 2.83±0.02 cm in white strain which was lower than the current study.

Yolk weight

The average mean of the egg yolk weight of Turkey birds in 45, 46, 47 and 48 weeks 24.50±0.72g, 25.41±0.45 g, 24.76±0.66 and 25.91±0.45 g correspondingly. The Nigerian Turkey yolk weight was found to be 22.36 ±1.58 g in black strain and 23.24±1.60 g in white strain which was lower than the current study whereas yolk weight of Mexican native Turkey hens found to be 25.44±5.19 gm which was higher than this study. Yolk weight from the current study is similar to finding from (Rodrigo et al., 2020), who observed yolk weight of 25.44 ± 5.19 gm.

Yolk height

Results from the present study demonstrated that egg yolk height of turkey were 0.85±0.03 cm, 0.84±0.05 cm, 1.06±0.06 cm and 1.18±0.070 at 45, 46, 27 and 48 weeks, respectively. Results showed that yolk height increased significantly ($p<0.001$) with the age of maturity of the birds. Rodrigo *et al.* (2020) observed the yolk height of 1.55±0.23 cm for Mexican native turkey, which was lower than the present finding.

CONCLUSION

The results of this study provide support to suggest that both external and internal egg quality parameters increase with increasing age up to 48 weeks of age. We did not measure egg quality parameters before 45 and after 48 weeks and cannot extrapolate outside that window period. This study gives the ideas about the egg quality of Turkey birds available in NARP farms.

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REFERENCES

Anna Anandh, M, Richard Jagatheesan P.N., Senthil Kumar P, Rajarajan. G and Paramasivam A. 2012. Effect of Egg Weight on Egg Traits and Hatching Performance of Turkey (Meleagris gallopavo) Eggs. *Iranian Journal of Applied Animal Science*, 4 , 391-395.

Adeyeye, E. I. 2009. Comparative study on the characteristics of eggshells of some bird species. *Bulletin of the Chemical Society of Ethiopia*, 23: 159-166.

H. Tazawa, G.2000. *Incubation physiology Sturkie's Avian Physiology* (5th ed), Academic Press, San Diego, CA pp. 617-634.

Jankowski, J. 1983. Effect of growing condition and reproduction cycle of turkey hens on egg quality. *Zeszyty Naukowe Akademii Rolniczo- Techniczej w Olsztynie* 25:95–105.

Jankowski, J. 1989. Response of four turkey populations to applied methods of breeding. Acta Acad. Agriculture. *Tech. Olst. Zoot. 31(Suppl. F)*:1–57.

Mroz E, Monika .Stepinska M. and Krawczyk (2014). Morphology and chemical composition of turkey eggs, Poultry Science Association, *Inc. J. Appl. Poult.Res*.23:196-203 http://dx.doi.org/10.3382/japr.2013-00871.

MKennamer, J`.E.,M. Kennar and R.Brenneman. 1992. History. *In: Wild Turkey: Biology and Management*, Dickson, J.G.(ED,). Stackpole Books, Mechanicsburg, PA., USA., pp:6-17.

Karki M., T. Dhaubhadel and N. Osti 2003. Production performance of Turkey at Parwanipur". Agricultural Research for Enhancing livelihood of Nepalese People *Proceeding of 2nd SAS-N Convention*, 30 July-1 Aug 2003, Kathmandu.

Karki M.2005. Growth, efficacy of utilization and economics of different rearing periods of Turkey. "*Nepal Agricultural Research Journal* 6:88-89.

Leeson, S. 2006. Defining and Predicting Changes in Nutrient Requirements of Poultry. *World's Poultry Science Journal*, 62, (Abstracts & Proceedings CD).

Mroz, E., Stepinska, M. and Krawezyk, M. 2014. Morphology and chemical composition of turkey eggs. *Journal of Applied Poultry Research*, 23: 196–203.

N. Bhattarai. R. Ghimire, S. Sapkota and K. Bhandari. 2019. Current Status of Turkey (Meleagris Gallapavo) Production and Management in Chitwan, Nepal". *Acta Scientific Medical Sciences* 3.1: 47-53.

Malago J.J. and Baitilwake M.A. 2009. Egg traits, fertility, hatchability and chick survivability of Rhode Island Red, local and cross bred chickens. *Tanzania Vet. J.* 26: 24-36.

Moges, F., Melesse, A. & Dessie, T., (2010), Assessment of village chicken production system and evaluation of the productive and reproductive performance of local chicken ecotype in Bure district, North West Ethiopia. *Afr. J. Agric. Res.*, 5(13): 1739–1748.

Mroz E., Orlowska A. and Stepinska M. 2010. Hatchery waste and Hatchability of turkey eggs. *Pol. J. Natur. Sci*. 25, 143- 153

Narushin V.G. and Romanov M.N. 2002. Egg physical characteristics and hatchability. *World's Poult. Sci. J*. 58 : 297-303.

Ozcelik , M.,Ekmen, F.and Elmaz,O. 2009. Effect of location of eggs in the incubator on hatchability of eggs from Bronze turkey breeders of different ages. *South Africa J Ani Sci*., 39:214-222.

Popoola, M. A., Alemede, C. I., Aremu, A. and Ola, S. I. 2015. Morphometric parameters of whole egg and egg yolk of five Nigerian domesticated avian species. *IOSR Journal of Agriculture and Veterinary Science*, 8(3): 41-45.

Salgado R.P., Sesma BR, Nazar p.M., Haro J.G.H, Ortega J.B. and Vazquez A.C (2020). *Journal of Food and Agriculture*, 2020. 32 (9): 647-652 doi: 10.9755/ejfa.2020.v32.i9.2143, http://www.ejfa.me/.

Thornton E.K, KF Emery DW Steadman, C Speller,R.Matheny and D.Yang. 2012. Earliest Mexican turkeys (Melegagrisgallopavo) in the Maya region: Implications for pre-hispanic animal trade and the timing of Turkey domestication, *journal. pone.0042630.PLoS ONE*, Vol.7.10.1371.

Turkoglu M, Urkoglu M, Akbay R, Kocak C, Eleroglu H. 1990. New approaches on turkey breeding in Turkey. *International Poultry Congress*-90: 296-302.

Wilson, H. R. 1991. Interrelationships of egg size, chick size, post-hatching growth, and hatchability. *World's Poult. Sci. J.* 47:5–20.

Yahaya, H.K., Olutunmogun, A.K., Mohammad, Y.B., Shettima, M.M., and Kabir, M, (2021). Evaluation of egg quality charecteristics of two strains of local turkey (Meleagris gallopavo) in Zaria, Kaduna State. Nigerian Journal of Animal Production *Nig,J.Anim. Prod*.2021, 48 (1):1-11.doi.org/10.51791/njap.v48i1.2891.

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ECONOMICS OF PRODUCTION AND VALUE CHAIN OF KIWI IN DOLAKHA DISTRICT OF NEPAL

Hari Bahadur Lamtange
HICAST, Kathmandu
Corresponding Author: lamtangehari@gmail.com

ABSTRACT

This research was conducted to analyze the economics of production and value chain of Kiwi in Dolakha district of Nepal. A pre tested questionnaire was administrated to survey 165 randomly selected respondents from two municipalities and four rural municipalities by using simple random sampling for collecting primary data relevant for the study. Focus group discussion, various value chain actors and key informants' interview was also done during November to December, 2021 A.D. Total cost of production and gross return was found NRs.480128.40. and NRs. 902222.22 per hectare respectively. Similarly gross profit margin was found 60.7 percentages. On an average benefit cost ratio was found 1.84. The study reveals that on an average B:C ratio of Kiwi per hectare was found 1.84. Kiwi production is higher from 6th year onward to 20th year which has an average B/C ration found 2.47. The marketing margin, producer's (farmer's) share and marketing efficiency of Kiwi was found NRs 213.67 per kg and 19.67 percent and 0.34 respectively. Similarly, Price spread was found 80.33 percent in the Kiwi value chain. Total cost involved in Kiwi production by the farmers was found as NRs. 53 per kg which is 17.99 percent of total cost of actors in the value chain of Kiwi in the study area. Processing and packaging, actors took the average profit of NRs. 96.67 per kg which was 45.24 percent of total profit for the whole chain. In total 42 percent margin was found. The entire channels of Kiwi value chain the total average cost incurred were NRs. 294.67/kg and which came to 58 percent of total cost. While profit margin NRs/kg was 213.67 which was equals to 42 percent as a whole in value chain process. Major production constraint faced by the farmers was no availability of saplings on time and having huge gap between farm gate and retail price.

Key Words: *Kiwi, B:C ratio, Value chain, Producer's share, Marketing margin*

INTRODUCTION

Kiwi is a spreading type of fruit plant (shrub) which bears egg-shaped fruit. This fruit is considered to be the native to China but massive cultivated in New Zealand having a thin brown skin and tart green flesh. Fruits are covered with light and thin fur like hairs. Once it planted it can grow and thrive for 30-40 years and gives continue fruiting. Kiwi *(Actinidia deliciosa)* farming is gaining popular among Nepalese farmers in recent years. High value cash crop farming is the only option to increase the income through agriculture-oriented livelihood system. It is an emerging perennial fruit crop becoming popular across the mid hills and high hills of Nepal. It has gained a worldwide popularity in recent few years because of its unique taste, wide climatic adaptability along with its high nutritive and medicinal values. It can be grown well at an altitude of 1200 m. to 2400 m. in the hills of Nepal. Hayward, Alison and Montie are the major cultivated varieties. The fruits range in weight from 40 to 90 g. Kiwi can be consumed as a fresh fruit, juice, jam, wine, biscuit, ice-cream etc. The fruit has a good source of vitamin C, exceeding that of orange, pear and apples. Thus, it is described as "King of fruit" due to its high vitamin C content. Kiwi generally ripens from October to December, which is the lean period for other fruits in the market, so the price for kiwi fruit is always high. The fruits can be stored for longer period of time which makes it possible to supply for extended period. ICIMOD knowledge park Godavari Lalitpur (1998) plays very important role for the extension of kiwifruit in the country. International Centre for Integrated Mountain Development (ICIMOD) is said to be the first doing research work on kiwi fruits in Nepal. Government farms such as Dolakha, Kirtipur, Solukhumbu and Daman started to produce saplings and training for the extension of kiwifruit in the hill areas of the country. Commercial kiwifruit growing started since 2009 AD in Nepal.

MATERIALS AND METHODS

Selection of the study area

The present study was conducted in four Rural Municipalities (Kalinchowk, Bigu, Gaurishankar and Sailung) and two Municipalities (Bhimeshwor and Jiri) of Dolakha District. These areas were highly potential for Kiwi production because of PMAMP PIU program has given focused and working in these areas as a zone program.

Selection of respondents

Actors of Kiwi producer and value chain were of eight categories, namely; Input

suppliers, Kiwi producer, Collector, wholesalers, Processor/ conditioner/ packagers, retailer, consumer. Service provider and KII were the major enablers. Therefore, the selection of input suppliers, key chain actors, service provider, enablers and Kiwi consumer were done by following techniques. Out of 995 farmers, 95 farmers (10 percent of the total population) and 25 value chain actors were selected as sample for the study. Altogether 165 samples were selected for the study. List of farmers and major value chain actors were obtained from PMAMP PIU Dolakha and Agriculture section of Bhimeshwor Municipality.

Sources of data collection

Primary data were obtained from Kiwi producing farmers, wholesalers, processors, traders and retailers. The entire information was collected through a household survey using interview schedule. Focus Group Discussion (FGD), in depth interview was held with various value chain actors and Key Informant Interview (KII) was used to triangulate the data. The secondary information were obtained through reviewing different publication mainly produced by GOs, NGOs, market studies of study areas, research articles from national and international journals along with the previous studies in the study areas.

Methods and techniques of data analysis

Both statistical and none statistical tools were used for analyzing the collected data after editing for missing and incomplete. The information collected from the field were first coded and entered into the computer. Data entry and analysis was done by Microsoft Excel. Data were analyzed by computing descriptive statistics to determine frequencies, percentages and means. For the objective of mapping Kiwi value chain were used to determine cost flow and involvement of different actors and enables to the final consumers. Similarly, problem ranking formula was used to determine major factors influencing production and marketing of Kiwi in the study area.

Cost of production

For analyzing the cost of production, the variable cost items and fixed cost items were considered. The variable cost includes expenditure on saplings, field preparation, labor, fertilizers, irrigation, plant protection chemicals, micronutrients, harvesting, packaging, transportation, etc. Total cost of production was calculated by using following formula.

Total cost =Total variable cost+ Total fixed cost

Gross margin analysis

Gross margin analysis was used as to determine profitability and as a means of selecting farm plan. The gross margin depends on the service provided, market structure, market price, perish ability of the product and distance between producers and consumers. Gross margin was calculated using following formula:

$$GM = \Sigma P_i Q_i - \Sigma C_j X_j$$

Where,

GM=Gross Margin

P_i=Unit price of production

Q_i=Quantity produced of product iC_j = per unit variable cost of input jQ_j=quantity of input used

$\Sigma P_i Q_i$=Gross Return

$\Sigma C_j X_j$=Variable cost

Benefit cost analysis (B/C ratio)

Benefit cost ratio was analyzed by two methods. First total gross return was compared with total variable cost and second, total gross return was compared with total cost.

$$\text{B/C } (Overtotalvariblecost) = \frac{\text{Gross return}}{\text{Total variable cost}}$$

$$\text{B/C } (Overtotalcost) = \frac{\text{Gross return}}{\text{Total cost}}$$

Marketing margin, producer's share and return on investment (ROI)

Marketing margin (MM) is the difference between the farm gate price and the retailer's price which was calculated as:

Marketing margin (MM) was calculated by subtracting farm –gate from Mill gate price.MM= Retailer price (PR) – Farm gate price (PF)

Producer's share is the price received by the producer's (farmers) expressed as a percentage of the retailer price, that is, price paid by the consumers. It was calculated by using following formula:

$Ps = (pf/pr) \times 100$

Where,

Ps = producer share

Pr = Retail price

Pf = producer's price (farm- gate price)

Return on investment on per kg of seed/ sapling per piece was calculated to understand the strength of the value chain to attract investment indifferent value streams.

$$\text{ROI (\%)} = \frac{\text{Total revenue-Total cost/Total cost}}{\text{Where ROI = Return on investment \%}} \times 100$$

Price spread

Price-spread is the difference between the actual price received by the producers, the price paid by the consumers, costs incurred and margins earned by the various market intermediaries in the process of marketing of Kiwi. The net price received by the producers, total marketing costs and margins were analyzed separately for Kiwi producer in order to evaluate the marketing efficiency of different marketing channels.

Price spread (%) = (PF-PC)/PC*100

Where, PF=Price received by the farmers PC=Price paid by the consumer

Marketing efficiency

Marketing efficiency is the ratio of net price received by farmers to the sum of marketing cost and marketing margin. For each production system, marketing efficiency was estimated by following formula. (Acharya and Agrawal, 2001)

ME= NPF/ΣMC+ΣMM
Where,
ME =Marketing Efficiency
NPF= Net price received by the farmers
ΣMC=Sum of marketing cost

ΣMM=Sum of marketing margin of the intermediaries

Problems on production and marketing

For identifying major problems of production and marketing, index was prepared based on response frequencies. Production and marketing problems were ranked by using five-point level of influence comprising most serious, serious, moderate, low and very low or no problem at all using scores of 1.00, 0.80, 0.60, 0.40 and

0.20 respectively. The formula given below was used to find the index for intensity of production and marketing problems faced by Kiwi growers. The priority index for each variable was calculated by weighted average mean in order to draw valid conclusion and making responsible decision.

Index of influence is calculated by using following formula:

$$I_{inf} = \sum \frac{s_i f_i}{}$$

Where,

I_{inf}=index of influence

Σ= summations_i=scale value

f_i=frequency of influence given by respondentsN=total number of respondents

RESULTS AND DISCUSSION

Cost of production of Kiwi (Quintal per hectare)

Variable cost and Fixed cost

The study showed that total average cost of production per hectare of Kiwi was NRs.480128.40. Total variable cost was obtained higher (NRs. 354628.40) followed by the total fixed cost (NRs. 125500.00).

Table 1. Average cost of production of Kiwi per hectare

	Particular	1st 5 Years	2nd 5 Years	3rd 5 Years	4th 5 Years	5th 5 years	Average Total
A	Variables Cost	456460.69	581974.012	577860	97998	59119	354682.34
B	Fixed Cost	125500	125500	125500	125500	125500	125500
C	Total cost (A+B)	581960.69	707474.012	703360	223498	184619	480182.34

Cost of production over various cost concepts

The table showed the cost of production with various cost concepts. In total 235 Kiwi plant were planted in average land 43.09 ha. Individuals had an average landholding size was 7.18. Similarly, Average production per plant Yield (Kg) was found 38.9 with production was 90222 kg/ha. Average cost of production of 1 kg of Kiwi was found NRs 53 at the rate of NRs 100 per kg.

Table 2. Cost of production over various cost concepts

Productive number of Kiwi plant (Ha)	235
Total area (Ha)	43.09
Area of individual farms (Ha.)	7.18
Average production per plant Yield (Kg)	38.9
Average production per hector Yield (Kg)	90222
Average cost of production of 1 kg Kiwi	53
Sales price per kg of Kiwi at farm (NRs)	100

Cost and Return from Kiwi

The study revealed that the total gross return from the Kiwi production was NRs. 902222.22/-.ha. The study reveals that on an average B/C ratio of Kiwi per hectare was found 1.84. This indicates that Kiwi farming is somewhat worthy business. In other word the Kiwi farming returns **1.84** times till the 25 years of farming which is two times greater than investment on it. Kiwi production is higher from 6^{th} year onward to 20^{th} year which has an average B/C ration found **2.47**. Thus it can be concluded that Kiwi farming across the study areas was profitable business. The study revealed that the gross margin of Kiwi was NRs. 547593.82 per hectare or 60.7 percentages. This indicates that the variable cost for the production of Kiwi high at the study areas of Dolakha district.

Value addition analysis of Kiwi value chain

Total cost involved in Kiwi production by the farmers was found as NRs. 53 per kg which is 17.99 % of total cost of actors in the value chain of Kiwi in the study area. Total margin for the Kiwi producer was found as NRs. 47/kg which was 22 percent of the total profit in the chain. Kiwi producer usually sell randomly without grading or categorized and sold average price at NRs. 100/kg of Kiwi. After purchasing from the Kiwi producing farmers, collectors, processors and packages had performed sorting, grading, boxing, branding and storage in cold room and finally packaging of conditioned Kiwi. During those processes total average value-added cost incurred was NRs. 120/kg which is almost 40.27 % of total value addition cost. After the processing and packaging, they sold their product to the traders. In this node of processing and packaging, actors took the average profit of NRs. 96.67 which is almost 45.24 % of total profit for the whole chain.

Table 3. Cost and Return from Kiwi

A	Total Gross Income (NRs/ ha)	902222
B	Cost of production (NRs/ ha)	480128
C	Net Return (A+B)	422094
	BC Ratio	1.84
D	Variables Cost	354628
E	Gross Profit Margin	60.7 %

After the processing and packaging, activity to carryout was trading. Average cost of trading was NRs. 294.67/kg which is almost 71.83 % of total cost. In this node of value chain, total profit gained by traders was NRs.70 which is almost 32.76 %of the whole chain. In total 42 percent margin was found in Kiwi value chain with 58 percent value added cost of production. The marketing efficiency was found 0.34. There was higher price spread in the Kiwi value chain mainly due to the higher cost incurred in the process of processing, conditioning, packaging, branding, promotion and advertisement and trading. Kiwi producing farmers are getting only NRs.100/kg for selling whereas final consumers were paying average price of NRs. 508.33/kg, which resulted the total price, spread of 80.33% in the Kiwi value chain.

Flow of Cost and value in the Kiwi value chain in the study area

Kiwi producing farmers had the production cost of NRs. 53/kg and sold at an average price that was NRs 100/kg. Collectors and wholesalers buy from farm gate of farmers at an average price i. e. NRs. 100/kg. Then soon after sorting and grading was done at three different grade "A", grade "B" and grade "C". When accomplished the grading they moved for further processing and packaging process.

The major cost involving chain in kiwi value chain is processing, conditioning, boxing, branding and tagging. In which value chain they added an average cost NRs. 20/kg for each grade A, B and C and sold at NRs. 150/kg, NRs. 200/kg and NRs. 300/kg respectively. A study showed that these phases had incurred higher cost in as a whole value chain of Kiwi. They had received on an average 45 percent margin which was quite handsome margin. After that they added some additional cost on it, which was on communication and promotional activities cost and received around 24 percent of margin from that. The entire channels of Kiwi value chain the total average cost incurred was NRs. 294.67/kg and which came to 58 percent of total cost. While profit margin NRs/kg was 213.67 which was

equals to 42 percent on as a whole value chain process. Considering the amount of value addition and share of profit margin in each chain of Kiwi value chain, higher value in terms of price was added NRs/kg 180, 80 & 30 in grade A, B & C, respectively.

Table 4. Value addition analysis of Kiwi value chain in the study area

Actors	**Cost Involved on**	**Procurement cost**	**Value added cost NRs./Kg**	**Margin NRs./Kg**	**Selling NRs./Kg**	**Grade**
Kiwi producing farmers	Purchase agri inputs, production, interculture operation and harvesting and packaging (local materials)	0	53(53)	47 (47)	100	No
Collectors, processor and packagers (commercial farmers/collectors/wholesalers and PMAMP unit	Collection, sorting, grading. Boxing, branding and Storage in cold room.	100	20 (80)	30 (20)	150	**C**
		100	20 (60)	80 (40)	200	**B**
		100	20 (40)	180 (60)	300	**A**
Subtotal (A)		***100***	***20 (55)***	***96.67 (45)***	***216.67***	***Average***
Traders	Handling, losses, tagging, promotional activities, communication and Taxes	150	5	45 (23)	200	**C**
		200	5	75 (25)	275	**B**
		300	5	95 (24)	400	**A**
Subtotal (B)		***216.67***	***5 (48)***	***70 (24)***	***291.67***	***Average***
Total (A+B)		***216.67***	**78 (58)**	**213.67 (42)**	**508.33**	
Price Spread (%)					***80.33***	

Major constraint regarding production and value chain of Kiwi

Production related problems

The value obtained from the ranking scale revealed that no availability of sapling on time was the major problems related with Kiwi production with highest index value of 0.78. Similarly, farmers had faced serious problems of lack of storage facility farmers compelled to sell at lower price from farm gate in the study area, which ranked second most serious problem among the categorized problems with

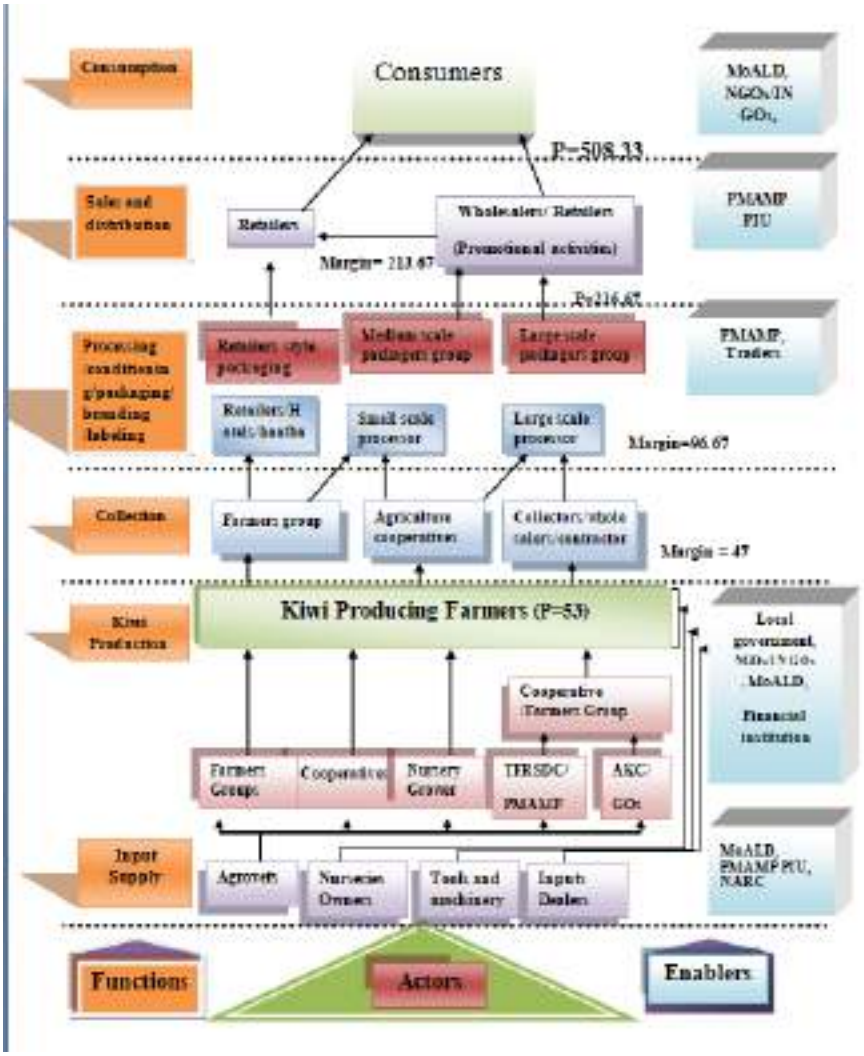
index value of 0.74. Likewise Lack of technical knowledge regarding training and pruning of Kiwi resulted in low quantity of production ranked third among the categorized problems with index value of 0.73 followed by lack of post-harvest technology like, stage of harvesting, grading and packaging resulted post-harvest losses and fetch lower price at market with index value of 0.68 and problem of Inadequate subsidies from government sectors with index value of 0.67 (Table 11). In the study area, thus all these problems were faced in the production stages of Kiwi by farmers.

Table 11. Various problems on Kiwi production in the study area

Problems	Major problem (1) to medium problem (0.2)					Weight	Index	Rank
	1	0.8	0.6	0.4	0.2			
No availability of saplings on time	57	22	19	14	8	93.2	0.78	I
Lack of storage facility farmers compelled to sell at lower price from farm gate	46	26	25	12	11	88.8	0.74	II
Lack of technical knowledge regarding training and pruning of Kiwi resulted in low quantity of production	42	29	23	17	9	87.6	0.73	III
Lack of post-harvest technology like, stage of harvesting, grading and packaging resulted post-harvest losses and fetch lower price at market	40	25	22	10	23	81.8	0.68	IV
Lack of subsidies from government sectors	35	28	15	25	17	79.8	0.67	V

Major problems on value chain of Kiwi

The value obtained from the ranking scale revealed that the major value chain problem of huge gap between farm gate and retail price had the highest index value of 0.76 and ranked as major marketing problem among categorized problems followed by fewer number of processor, packagers index value of 0.75,



Insufficient transportation facility to the market showing index value of 0.72, problem of market information system with index value of 0.71 and the last problem was sell bulk volume without grading in same price transportation and inaccessible market with index value of 0.70.

Table 12. Various value chain related problems of Kiwi producing farmers

Problems	Major problem (1) to medium problem (0.2)					Weight	Index	Rank
	1	0.8	0.6	0.4	0.2			
Huge gap between farm gate and retail price	52	25	19	14	10	91	0.76	I
Fewer number of processors, packagers	40	34	27	12	7	89.6	0.75	II
Lack of appropriate transportation facility to the market	43	27	21	18	11	86.6	0.72	III
Lack of market information system	38	28	27	16	11	85.2	0.71	IV
Sell bulk volume without grading in same price	45	22	18	23	12	85	0.70	V

CONCLUSION

Kiwi is the most promising and profitable high value medicinal cash crop having potential to significantly contribute to improve the rural livelihood through income generation and self-employment. Nepal has a special and unique topography and wide climatic adaptability for Kiwi production, kiwi having unique taste, high nutritive and medicinal values. The study reveals that on an average B/C ratio of Kiwi per hectare was found 1.84. This indicates that Kiwi farming is somewhat worthy business. Production is higher from 6th year onward to 20th year which has an average B/C ration found 2.47. Thus it can be concluded that Kiwi farming across the study areas was profitable business. Considering the amount of value addition and share of profit margin in each node of Kiwi value chain was found higher value. Higher price incurred during the process of processing and packaging may be due the less equipped structure and low level of technical advancement in processing and packaging equipment's. Also, there was a higher price spread. The main challenges include timely unavailability of saplings, Lack of storage facilities, inadequate scientific research on kiwi

production technology, insufficient investment, access of credit, Inconsistent quality of product (no grading) to meet buyers' demand, Lack of few processing industries and value addition activities, Lack of organized marketing and post-harvest infrastructure, unstable prices and high profit margins along with inappropriate market channels. Strengthen the farmers for group-marketing of kiwi fruits, increase farm gate price, increase farmer's share and operation efficiency in sale. Further research has to be done on Kiwi production and its value chain and supply chain approaches for more appropriate to all actors involved in marketing systems. To reduce the market margin and price spread in Kiwi value chain, shorten the marketing channels with possible one-way outdoor system. For that farmers should be engaged in cooperative base marketing system and use of new technology to reduce the production cost and make profit maximization.

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REFERENCES

Acharya, S.S. and Agrawal, N.L. (2001). *Agricultural Marketing in India.* Oxford & IBH Publishing Company, New Delhi

Adhikari, B.H. (2014). *Production Technology for Kiwi fruit*. Communication and Publication Division, NARC, Khumaltar, Lalitpur.

Agrawal, G. R. (1999). *Marketing in Nepal*. Modern Printing Press, Kathmandu. pp. 70-80.

Belrose, Inc. (2006). *World Kiwifruit Review*. 2006 Edition. Pullman. United States of America.

Belrose, Inc. (2006). *World Kiwifruit Review*. 2006 edition. Pullman, WA, Belrose, Inc.

Bhandari, N. B., &Aryal, M., (2014/15), *A report on average cost of production and gross profit of fruit farming in Nepal*; MoAD; Agribusiness promotion and marketing development directorate, Market research and statistics management program, Hariharbhawan, Lalitpur.

CBS (2021). *Statistical year book Nepal (Sixteenth).* Central Bureau of Statistics(CBS).http://cbs.gov.np/image/data/2022/StatisticalYear Book2021.pdf

Celik H (2006). Enhancing germination of kiwifruit seeds with temperature, medium and gibberellic acid. *Horticultural Science (PRAGUE)* **1:** 39-45. DOI:10.17221/3738-HORTSCI

Collins, R. C., Dent, B. & Bonney, L. B. (2016). *A guide to value-chain analysis anddevelopmentforOverseasDevelopmentAssistanceprojects*.AustralianCentref or International Agricultural Research: Canberra

Dhakal S.P. (2018).*An Introduction of Kiwifruit & Cultivation Technology.* Temperate Fruit Rootstock Development Center.

FAOSTAT(2020).*Retrieved0718,2021,fromStatisticsdivision,foodandagricultureorganiz ationoftheUnitedNations.:*http://www.fao.org/faostat/en/#data.

Ferguson AR and Bollard EG (1990). Domestication of the kiwifruit. Kiwifruit: *Science and Management* 165-246.

Ferguson AR, Huang H. (2007). Genetic resources of kiwifruit: domestication and breeding. *Horticultural reviews* **33**:1- 21. DOI: 10.1002/9780470168011.ch1

Fournier, Jean-Michel and Hassan, Daniel. (2003). *Economic aspects of the French kiwifruit sector: impact of profit margin policy on channel operation*. International Society for Horticultural Science. V International Symposium on Kiwifruit. Wuhan, China.

Gautam IP &Gotame TP (2020). Diversity of Native and Exotic Fruit Genetic Resources in Nepal. *Journal of Nepal Agricultural Research Council* **6**: 44-55. DOI: https://doi.org/10.3126/jnarc.v6i0.28114

Guroo I, Wani S, Wani S, Ahmad M, Mir S &Masoodi F (2017) A Review of Production and Processing of Kiwifruit. *Journal of Food Processing & Technology* **8**(10): 699. DOI: 10.3126/jnarc.v6i0.28114

ICIMOD, (2013), Kiwifruit Cultivation, ICIMOD Knowledge Park, Godavari, Lalitpur, Nepal

Jindal KK and Sharma L (2016). Kiwi: A Potential Fruit Crop, in North East India.

John L. Dillon, J. B. Hardaker, Food and Agriculture Organization of the United Nations FAO, 1993

Joshi, P.K. & Kumar, P. (2016). Food demand and supply projections for India. In: International trade and food security- the future of Indian agriculture (Floor Brower & P.K. Joshi, eds.). CAB International, Wallingford, UK.

Kaini, B.R. & Singh, P.B. (1998). Status of Horticulture Marketing Research and Extension in Private and Public Sectors, *Proceeding of the National Seminar on Fruit and Vegetable Marketing in Nepal* held from 15-16 September, Kathmandu, Support on New Kalimati Market Project, FAO.

Kaplinsky,R.&M.Morris.(2001).Ahandbookforvaluechainresearch.PreparedfortheInternat ional Development Research Centre(IDRC).

Kofoed A (2015) *A quantitative analysis of global kiwifruit trade.* Uppsala: Swedish University of Agricultural Sciences.

Kohls, R. L. and J. N. Ohl. 1985. *Marketing of Agricultural Products*. *Sixth edition.* Macmillan Publishing Company Inc, New York. Pp. 5-10.

Lees, Nic. (1993). *Kiwifruit Industry 1980-1992: an Examination of the Development of the New Zealand Kiwifruit Industry under High Product Prices, its Subsequent Restructuring under Falling Returns, and the Effects of Government Policy*. MAF Policy: 50. Ministry of Agriculture. Wellington.

Mani G, Kundra A &Haque A (2018). Kiwi value chain in Arunachal Pradesh: issues and prospects. *Agricultural Economics Research Review* **31**(1): 123-130. DOI: 10.5958/0974-0279.2018.00012.5

Mayeux, L. & Mackie, G. (2007). Making the Strongest Links: A Practical Guide to Mainstreaming Gender Analysis in Value Chain Development. Addis Ababa: International Labor Office.

MDD (1999). *Agricultural Marketing System in Nepal.* Annual Report. Marketing Development Division, Kathmandu, Nepal.

MOAD (2021). *Statistical Information on Nepalese Agriculture*.

Obare, G., Shiferaw, B., Muricho, G. (2006). *Leveraging Rural Institutions for Collective Action to Improve Markets for the Poor: Lessons and Policy Options*. Policy Brief No. 8. ICRISAT

Peterson, Hikaru. H. and Willett, Lois. S. (2000). *U.S. Kiwifruit Industry Model: Annual Supply and Monthly Demand*. Journal of Agricultural and Applied Economics 32(2000): 479-491.

Prime minister agriculture modernization project. PIU. (2077/78). *Annual progress report*. Dolakha.

Rhodes, V.J. and Dauve, J.L. (1998). *The Agricultural Marketing System*. 5th ed. Holcomb Hathaway Publishers, Scottsdale, Arizona, USA.

Scott, G.J., (1995*). Prices, products and people: Analyzing agricultural markets in developing countries*. Lynne Reiner Publishers, Boulder, London. 36p

Shrestha, C. M, and D. B. Thapa. (2013). Commercial kiwifruit production. Kathmandu: Krishakra Prabidhi, (Nov/ Dec 2013) 11-19.

Taylor,D.H.(2005).Supply Chain Analysis: an approach to value chain improvement inagri-food chains; *The International Journal of Physical Distribution and Logistics Management*, 35 (10): 744-761

TEPC (2019). Retrieved from Trade and Export Promotion Centre: Government of Nepal:www.tepc.gov.np
wikipidia.org.wiki/kiwifruit.www.hort.prudue.edu/newscrop/morton/kiwifruit-ars.html ww.lib.icimod.org/record/28277/files/technology%20(5).pdf

Xu X& Zhang, Q (2003). Researches and utilizations of germplasm resource of Kiwifruit in China. *Chinese Bulletin of Botany* 20(6):648-655.

Yerex, David and Haines, Westbrook. (1983). *The Kiwifruit Story*. Masterton, Agricultural Publishing Associates. New Zealan

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EFFICIENCY OF MAIZE (*ZEA MAYS*. L) VARIETIES FOR SEEDLING ESTABLISHMENT UNDER DROUGHT STRESS

Avinash Shrestha[1], Shreena Pradhan[1], Mahesh Subedi[2], and Jenny Shrestha[1]

[1]Agriculture and Forestry University, AFU, Chitwan
[2]Nepal Agriculture Research Council (NARC), Khumaltar
Corresponding author: shresthaavinas99@gmail.com; avishres@ttu.edu

ABSTRACT

Drought stress is one of the major abiotic factors affecting seed germination and plant growth, especially in arid and semi-arid regions. The effect of drought stress on seed germination and seedling growth of four varieties of maize was studied using randomized complete block design with three replications. Germination percentage (GP), germination index (GI), mean germination time (MGT), root length (RL), shoot length (SL) and dry root weight (DRW) were measured to evaluate the varieties' response to field drought stress. Drought stress, variety, and the interaction drought × variety had a significant effect on all studied parameters. GP and GI decreased with the increase in stress level, while MGT increased. Shoot length decreased with increasing drought stress but different varieties show different performance under stress environment. Root length decreased with increasing level of severe drought stress. Water stress was found to affect the growth of roots the most. The varieties 'Paheli local' and 'Manakamana 3' exhibited the highest germination percentage and the best early seedling growth, given their higher biomass and longer root length. Thus, they could be recommended for environments with early cropping cycle drought.

Keywords: Drought, dry root weight, germination, growth trend, rainfed

INTRODUCTION

Maize is the second most important staple food crop both in terms of area and production after rice in Nepal (MOAD, 2017). It is a traditional crop cultivated as food, feed, and fodder on steep lands in the hills (Shrestha et al. 2019). It is grown under rainfed conditions during the summer (April-August) as a single crop or relayed with millet later in the season. Under the rainfed condition, drought severely limits plants' growth, development and productivity, particularly in arid and semi-arid regions, where the rainfall varies from year to year. This is also the

case for the research site, which is in a semi-arid region of Nepal. However, depending upon plant species, certain stages such as germination, seedling or flowering could be the most critical stages for drought stress (Pena & Hughes, 2007). Proper seed germination depends on the availability of appropriate moisture contents for metabolic activation to breakdown the dormancy or to convert stored food into consumable form (Hadas, 2004). Among different stages, critical crop establishment is accomplished up to the development of 7th or 8th leaf. Crop density or number of emerged seeds, meantime for emergence and synchronization of emergence are characteristic features which determined the efficacy of seedling establishment (Finch-Savage, 1995).

Seedling growth after germination is another important stage for the life cycle of plants, which would affect the size, development and genetic variation ability of plant population (Woltz et al., 2006). Successful establishment of plants depends on their germination quality which in turn depends on water availability (Ma, Liang, & Kong, 2008).

Global warming is likely to increase the incidence of drought in many established maize growing areas (Zaidi et al., 2004). Drought can be defined as a period of below-normal precipitation that limits plant productivity in a natural or agricultural system (Kramer and Boyer, 1995). Understanding the physiological behavior of plants under drought conditions may result in predicting drought-tolerant varieties of crops (Kerepesi and Galiba, 2000). Differences in resistance to drought are known to exist within genotypes of plant species and were found in many studies of maize (Lorens et al., 1987; Adhikari et al., 2021). The objective of this study was to determine the effects of deficit water stress on germination and seedling establishment of maize genotypes. Germination is regulated by the duration of wetting and the amount of moisture in the growth medium (Gill et al., 2002). Seedling growth after germination is another important stage for the life cycle of plants, which would affect the size, development and genetic variation ability of plant population (Woltz et al., 2006).

MATERIALS AND METHODS

Site of the research

The research was conducted at two locations;

- Farmer's Field (Gyan Bahadur Gurung), Sidhhicharan MP 4, Okhaldhunga. The site was at an elevation of 1750 masl with 28^{o} 65' N latitude and 82^{o} 16' E longitude

- Plastic house in District Agriculture Development Office, Siddhicharan MP 4, Okhaldhunga. The site was also at an elevation of 1750 masl with 27º30' N latitude and
  86º50' longitude.

The soil type is sandy loam and climatically upper-tropical with an average annual rainfall of 1868.5 mm. The research location is characteristics of sub-tropical to a temperate climate. Rainfall in Okhaldhunga during the time of the study March to May 2018 was 700 mm while the average temperature was 20^0C as obtained from mfd.gov.np

Table 1. Name of varieties, recommended site and site of collection used in the study

SN	Name of Variety	Recommended site	Collected from
1.	Manakamana-3	Inner terai to Mid hills	Siddhicharan Municipality Office, Okhaldhunga
2.	Khumal-Hybrid 2	Inner terai to Midhills	NARC, Khumaltar
3.	Arun 6	Inner terai to Foothills	NMRP, Chitwan
4.	Nutan IL60 (Comm. Hyb)	1000 to 1800 masl	Seed Distributor, Khumaltar
5.	Paheli local	Okhaldhunga	Local farmer, Siddhicharan, Okhaldhunga

The experiment was a double factorial randomized complete block design, with three replications. The first factor was the variety, with five levels, and the second was the induced water condition with two levels namely rain-fed and water stress-induced. Water stress was induced by choosing a plastic house raised above the ground and restricted water. Seeds were sown in both conditions at 75 X 30 cm^2spacing with 20 plants per row and 3 rows per plot.

Germination parameters were counted after 8, 14, 18- and 21-days following sowing. Seeds were considered germinated when they appeared above the soil profile. For germination percentage, the number of seeds germinated by day 21 was considered.

Germination Percentage (GP) = (No. of germinated seeds/ Total no. of seeds sown) x 100

Germination index (GI) = $(\text{No. of germinated seed})/(\text{Days of the first count}) + \cdots + (\text{No. of germinated seed})/(\text{Days of the last count})$

(Moradi, Akbari, Ramshini, & Khorasani, 2012)

Mean Germination Time (MGT) = $(\sum TiNi)/\sum Ni$

Where, Ti = Total time for germination

Ni = number of seedlings emerged

Unit = day

Shoot length was measured from the cotyledons to the collar, and the root length was measured from the collar to the root tip.

Statistical analysis was conducted with the software package Agricolae in R studio. Data were subjected to an analysis of variance (ANOVA) to determine statistically significant differences among varieties, drought stress, and their interaction levels. Duncan's multiple range test (DMRT) was applied to compare treatment means. A multivariate ANOVA was also conducted to study the growth profile in different conditions of water availability.

RESULTS AND DISCUSSION

Drought stress effects on germination

Results of analysis of variance indicated that drought stress significantly affected maize seed germination percentage (GP), germination index (GI) and mean germination time (MGT). There was also a significant effect of variety and its interaction with drought on these parameters (Table 1). GP and GR decreased, while MGT increased with the increase in water stress (Figure 1 & 2).

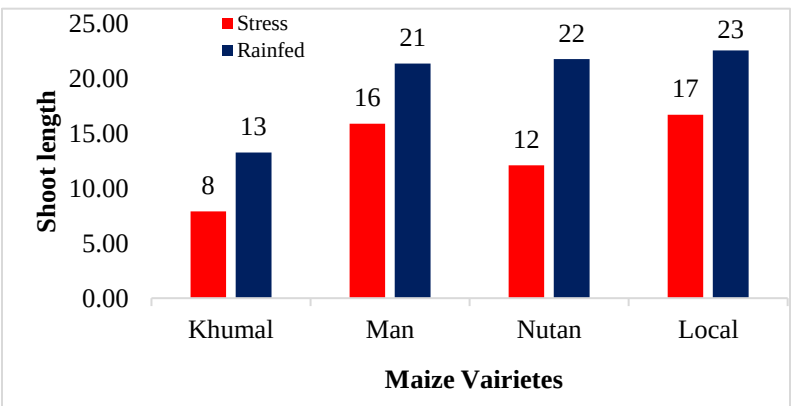


Figure 1. Germination percentage of different maize varieties in response to field water condition

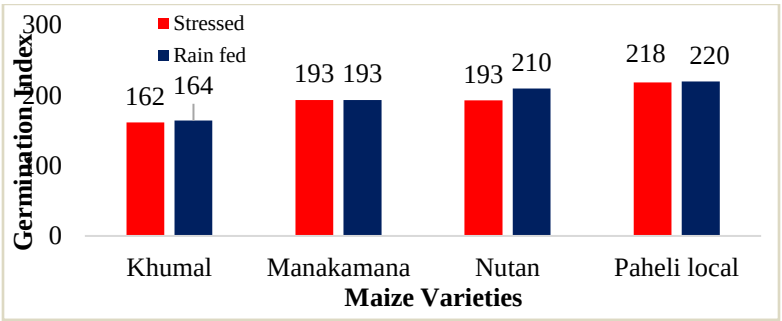


Figure 2. Germination indices of different maize varieties in response to a field water condition

The highest GP (75 %) was observed under rainfed condition, and the most significant decline was seen in Nutan IL60 which is also a commercial hybrid.

Germination index of drought resistance

The Paheli local showed similar GI for both rain-fed (217.3) and stressed condition (217.7). The varieties showed higher GI for rainfed condition compared to stress condition. The best one was Paheli local followed by Nutan IL60, Manakamana 3 and Khumal Hybrid 2.

Table 2. Analysis of variance (mean squares) for seed germination and seedling growth-related traits of maize varieties vs. field water condition

SOV	df	GP	GI	MGT	SL	RL	DRW
Variety	3	213.90***	2203.4***	1.80	52.22***	9.18**	0.01***
Condition	1	973.92***	112.4***	0.50	389.81***	7.27*	0.27***
Vareity X Condition	3	7.1	63.9***	0.70	15.51*	0.59	0.00***

Abbreviation: SOV: Source of Variation GP: Germination Percentage; GI: Germination Index; MGT: Mean Germination Time; SL: Shoot Length; RL: Root Length; DRW: Dry Root Weight

Shoot length and root length

hanges in morphological characters are the ultimate determinants of stress effects on plants (Jaleel *et. al*., 2009). Following germination, cellular growth appears to be the most sensitive response to drought stress (Rezaeieh & Eivazi, 2012). A study has shown that water shortage declines corn canopy height, leaf area index and root growth (Hirich, Fatnassi, Ragab, & Choukr-Allah, 2016) Paheli local, Manakamana 3 and Nutan IL60 performed better than Khumal Hybrid 2 regarding shoot length which means that drought inhibited the cellular growth the most in Khumal Hybrid 2.

Genotypes could be declared as tolerant and susceptible based on traits like root length, dry root weight, fresh root weight, fresh shoot weight, etc (Naveed et. Al., 2015). In this study, the highest root length under drought stress belonged to Paheli local and the shortest one belonged to Khumal Hybrid 2. Manakamana 3 and Nutan IL60 were at par considering their root lengths at both stressed and rainfed condition. Higher root length of Paheli local followed by Manakamana 3 and Nutan IL60 theoretically signifies higher chances of exploration and absorption of water and nutrients from the soil under drought stress. Therefore, in an unfavorable environment, with water deficit, root growth is very important to allow greater exploration of the soil in search of water, without excessive energy consumption. Decreased root length in Khumal Hybrid 2 was probably because of low photosynthetic assimilates devoted to parts of the plant due to diminished photosynthesis. This was mentioned in a study by (Moradi, Akbari, Ramshini, & Khorasani, 2012).

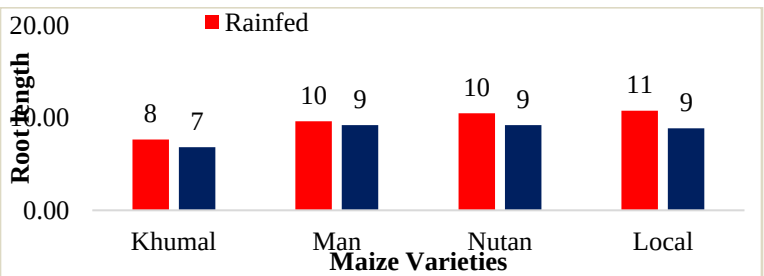


Figure 3. Root length of different maize varieties in response to a field water condition

Dry root weight

Khumal Hybrid 2 having less dry weight in both the conditions least tolerant to water stress. On the other hand, Paheli local could be utilized in a breeding

program considering its morphological traits are most tolerant to drought. A study by Horne, Ross & Hughes (1992) reported that maize genotypes with low root dry weight are less tolerant to drought stress. So,

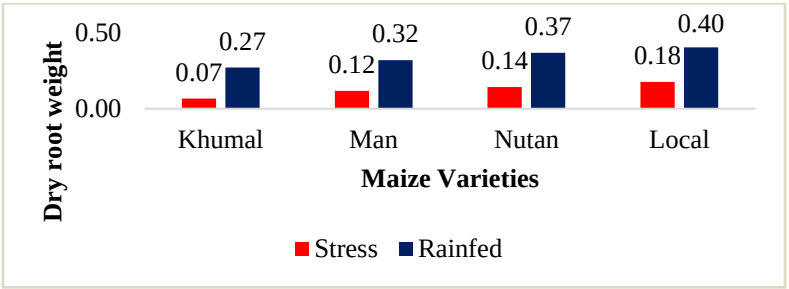


Figure 4. Dry root weight of different maize varieties in response to field water condition

Growth profile study

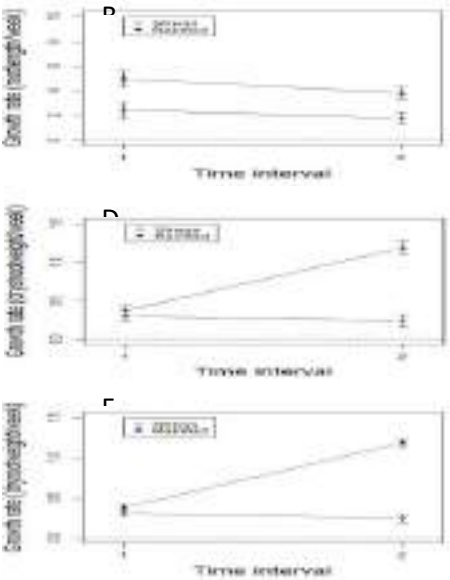


Figure 5. Growth curve of traits per week in stressed and rainfed condition. (A: Shoot length; B: Root length; C: Fresh shoot weight; D: Dry shoot weight; E: Fresh root weight; F: Dry root weight)

The growth profile curve (Figure 5) shows the gain in shoot length every week steadily increased in rainfed condition except in the last two weeks. While in the stressed condition, there was a constant fluctuation in the gain in shoot length throughout the 5 weeks. It decreased during the interval between 2nd and 3rd week and again in the interval between 4th and 5th week. The gain in shoot length every week steadily decreased as the plant matured for both rain-fed condition and stressed condition. There is a significant gain in shoot length for both conditions especially when the plant is of the knee-high stage (4th to 5th week). Similarly, the gain in fresh shoot weight gradually increased from the 1st week to 2nd and then from 2nd to 3rd in both rain-fed and stressed condition. The only difference was that in the case of the rainfed condition, there was a more gain/week. The gain in dry shoot weight per week steadily increased as it is supposed to for the rainfed condition. But for the stressed condition, the gain in dry shoot weight decreased from 2nd week to 3rd week. The gain in dry root weight per week increased for the rain-fed condition while it decreased slightly for stressed condition suggesting a lowered tolerance for drought.

CONCLUSION

Based on the results of this study, the varieties 'Paheli local' and 'Manakamana 3' germinated better than the other varieties under drought conditions. The observed variation among varieties is a reliable indicator of genotypic differential for drought tolerance in maize. This suggests that the choice of the maize variety to be planted in a given environment should depend upon the presence and the degree of the stress observed in such an environment. In drought-stressed environments, the varieties 'Paheli local' and 'Manakamana 3', exhibiting the highest germination percentage, should be recommended. These varieties contain traits like longer root length and higher root dry biomass which, according to previous studies, are most linked with drought tolerance ability. Furthermore, it can be identified whether these traits have a role in reducing/altering the grain yield and breeding programs can be designed accordingly.

REFERENCES

Adhikari, I. P., Osti, B., Kunwar, C. B., & Ojha, B. R. (2021). Study of different germplasm of early summer maize in Rampur, Chitwan, Nepal. *International Journal of Social Sciences and Management*, *8*(2), 391-395.

Finch-Savage, W. E. (1995). Influence of seed quality on crop establishment, growth and yield. *Seed quality: Basic mechanisms and agricultural implications*, 361-384.

Gill, P. K., Sharma, A. D., Singh, P., & Bhullar, S. S. (2002). Osmotic stress-

induced changes in germination, growth and soluble sugar content of Sorghum bicolor (L.) Moench seeds. *Plant Physiology*, 28, 12-25.

Grzesiak, M. T., Marcińska, I., Janowiak, F., Rzepka, A., &Hura, T. (2012). The relationship between seedling growth and grain yield under drought conditions in maize and triticale genotypes. *Acta physiologiae plantarum*, 34(5), 1757-1764.

Hadas, A., Kautsky, L., Goek, M., & Kara, E. E. (2004). Hadas, A., Kautsky, L., Goek, M., & Kara, E. E. (2004). Rates of decomposition of plant residues and available nitrogen in the soil, related to residue composition through simulation of carbon and nitrogen turnover. *Soil Biology and Biochemistry*, 36(2), 255-258.

Hirich, A., Fatnassi, H., Ragab, R., &Choukr-Allah, R. (2016). Prediction of climate change impact on corn is grown in the south of Morocco using the Saltmed model. *Irrigation and drainage*, 65(1), 9-18.

Horne, D. J., C. W. Ross, and K. A. Hughes. (1992). Ten years of a maize/oats rotation under three systems on a silt loam in New Zealand. 1. A comparison of some soil properties. *Soil and Tillage Research* 22.1-2: 131-143.

Jaleel, C. A., Manivannan, Wahid, A., Farooq, M., Al-Juburi, H. J., Somasundaram, &Paneerselvam, R. (2009). *Drought stress in plants: a review on morphological characteristics and pigments*.

Kerepesi, I., & Galiba, G. (2000). Osmotic and salt stress-induced alteration in soluble carbohydrate content in wheat seedlings. *Crop Science*, 40(2), 482-487.

Kramer, P. J., & Boyer, J. S. (1995). *Water Relations of Plants and Soils*. San Diego: Academic Press.

La Pena, R. D., & Hughes, J. (2007). *Improving vegetable productivity in a variable and changing climate.*

Lorens, G. F., Bennett, J. M., & Loggale, L. B. (1987). Differences in Drought Resistance between Two Corn Hybrids. I. Water Relations and Root Length Density 1. *Agronomy Journal*, 79(5), 802-807.

Ma, H. Y., Liang, Z. W., & Kong, X. J. (2008). Effects of salinity, temperature and their interaction on the germination percentage and seedlings growth of Leymuschinesis (Trin.) Tzvel. in Chinese with English abstract). *Acta Ecologica Sinica* 28(10), 4710-4717.

MOAD. (2017). Statistical information on Nepalese agriculture 2017/18 (2073/074). Singhadurbar, Kathmandu, Nepal: Government of Nepal, Ministry of Agricultural Development, agribusiness promotion and Statistics Division.

Moradi, H., Akbari, G. A., Ramshini, H. A., &Khorasani, S. (2012). Evaluation of drought tolerance in corn (Zea mays L.) new hybrids with using stress tolerance indices. European *Journal of Sustainable Development*, 543-560.

Naveed, S., Aslam, M., Maqbool, M. A., Bano, S., Zaman, Q. U., & Ahmad, R. M. (2014). Physiology of high temperature stress tolerance at r eproductive stages in maize. *J. Anim. Plant Sci*, 24(4), 1141-1145.

Rezaeieh, K. A., &Eivazi, A. (2012). Evaluation of morphological characteristics

in five Persian maize (Zea mays L.) genotypes under drought stress. *RevistaCientífica UDO Agrícola*, 12(2), 241-244.

Shrestha, A., Pradhan, S., Shrestha, J., & Subedi, M. (2019). Role of seed priming in improving seed germination and seedling growth of maize (Zea mays L.) under rain fed condition. *Journal of Agriculture and Natural Resources*, *2*(1), 265-273.

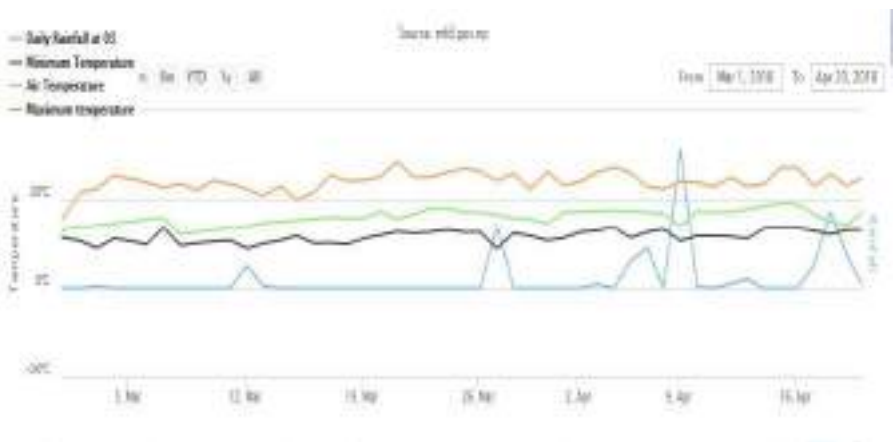
Woltz, J., TeKrony , D. M., & Egli, D. B. (2006). Corn seed germination and vigor following freezing during seed development. *Crop Science* 46, 1526-1535.

Woltz, J., TeKrony, D. M., & Egli, D. B. (2006). Corn seed germination and vigor following freezing during seed development. *Crop science*, 46(4), 1526-1535.

Zaidi, P. H., Srinivasan, G., Cordova, H., & Sa. (2004). Gains from improvement for mid-season drought tolerance in tropical maize (Zea mays L.). *Field crops research*, 89(1), 135-152.

ANNEX

Annexe 3: Agrometeorological data during the research period (Source: www.mfda.gov.np)



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EVALUATION OF GROWTH PERFORMANCE AND GENETIC PROGRESS IN SAANEN GOAT BREED AT NATIONAL GOAT RESEARCH PROGRAM BANDIPUR, TANAHU, NEPAL

Maheshwar Dahal, Raju Kadel, A. Shrestha and P. B. Shrestha
National Goat Research Program, Bandipur, Tanahu
Corresponding Author's email: *dr.maheshwardahal@gmail.com*

ABSTRACT

A study was conducted in National Goat Research Program, Bandipur, Tanahu, Nepal to evaluate the growth performance of Saanen pure goats. A total 19 off spring born on FY 2074/075 were used for the analysis of mean of birth weight, weaning weight and eight-month weight. Out of all born 12 kids were male and 7 kids were female and the twining percentage and mortality rate were 58.33 % and 5.26%, respectively. The birth weight for Saanen pure kids were 3.75±1.24 kg for male and 3.60± 1.84 kg for female kids. The mean weaning weight and eight-month weight were 16.14±2.67kg, 29 ±2.95kg for males and 15.50 ±2.29 kg and 22.2 ±3.12 kg for females, respectively. The body weight gain from birth to eight-month age was 107.29 g per day for male and 77.50 g per day for female kids, respectively. These results indicated a genetic progress of the breed.

Keywords: Birth weight, Saanen, Growth performance, Weaning weight

INTRODUCTION

Saanen is the milk producing breed in the world. Goat production is regarded as a feasible means to improve the income and nutrition of rural communities and to bring these communities in to bring these communities into commercial marketing systems (Braker *et al*., 2002). Goats are important for both commercial and subsistence farming system in Nepal. Saanen is the most popular milk breed of world. The Saanen Goat is a Swiss breed, originating in the Valley Switzerland. Commercial farmer's rears goats primarily for meat production and subsistence farmers use them as a source of meat and milk, as well as cash for other expenses (Casey and Van Niekerk, 1988). The dairy goat's popularity continues to increase rapidly as more people discover the dairy goat's appeal, utility and

productiveness. The Saanen breed originates from Switzerland, from the Saanen Valley, where the annual average temperatures are 9.5° C (Silva et al. 2006). Saanen does are heavy milk producers and usually yield between 3% and 4% fat. The Saanen is a typical dairy-type animal, it has a dished or straight facial line and a wedge-shaped body. Saanens are of medium height when compared with the other Alpine breeds in Australia. Does weigh at least 64 kg. The average height measured at the withers is about 81 cm for does and 94 cm for bucks. The coat is all white or all cream and the hair is generally short and fairly fine although some may have longer hair along the spine, hindquarters, or both. Between different goats available it occupies the place that the Holstein-Friesian has among cattle breeds (Weppert, 1998). The present paper aims to know the growth performance of Saanen pure goats at research station.

MATERILAS AND METHODS

Study site and selection of experimental kids

This study was conducted at National Goat Research Program, Bandipur of Tanahu district which is located 135km from capital city Kathmandu, at an altitude of 8 0 masl and at 2 ˚ 6' 8" N and 8 ˚2 ' "E. The mean annual temperature is 21.01˚C and annual rainfall is 340.8mm with average relative humidity of 74.65%.This study was performed in FY 2074/75 of GRS, Bandipur. A total 19 off spring born kids were used for the analysis of mean of birth weight, weaning weight and eight-month weight. Out of all born 12 kids were male and 7 kids were female. Kids were weaned at the age of four month

Shed and health management and feeding regime

Saanen goats were kept in semi-intensive system and improved farm managed condition of Goat Research Station. Seasonal mix fodder (provide name of fodder) was provided to experimental kids in groups twice daily during noon and evening. Concentrate mixture was given @ 1% of body weight. Anthelmintics was provided based on fecal examination at regular interval and kids were dipped in malathion solution against external parasites. Vaccination was performed against PPR, FMD and Clostridium Perfringens Types C & D- Tetanus Toxoid.

Data collection and analysis

All the weight was measured using electronic weighing machine. Weight were taken from birth weight , weaning weight and eight month weight were recorded

in morning before feeding and watering at monthly interval. The data were analyzed using Statistical Package for the Social Science (SPSS). Means were compared using Ms-excel.

RESULTS AND DISCUSSION

Growth performance of experimental kids

The birth weight of pure Sannen kids were 3.75 kg for male and the 3.60 kg for females, respectively which was higher than that of study made by Khandoker *et.al*.(2018) as in Malaysian condition (3.07±0.58 kg for male and 2.75±0.62 kg for females). Weaning weight (age) for male was 16.17kg and female for 15.50 kg, respectively. Tek *et al*. (2011) reported that the average live weight of Saanen kids on birth was 3.29 kg, which was lower than the value found in the present study. In addition, higher birth weight was recorded in male (3.23±0.62kg) than that of the female (2.75±0.58 kg) in the present study whic was supported by the previous study of Wenzhbong *et al*. (2005) and Djemali *et al*.(1994). Eight month weight were 29.5kg for male and 22.2 for females. Weight gain from birth to 8 month weight gain for male was 107.29 g/day and 77.50 g/day for female, which is more than that of Khari and other Boer crosses breeds (Ref) (Table 1).

Table 1. Body weights gain of pure Saanen kids

Parameter	**Male**		**Female**	
	Weight (kg)	**Weight gain g/day**	**Weight (kg)**	**Weight gain g/day**
Birth Weight	3.75 ±1.24		3.60 ±1.84	
Weaning weight	16.14 ± 2.67	103.25	15.50 ±2.29	99.16
Eight-month weight	29.5 ±2.95	107.29	22.2 ±3.12	77.50

Figure 1. Saanen kid weight measurement

Kid mortality and twinning percentage

During fiscal year 2074/75, at NGRP, Bandipur a total of 19 kids were born from does at kidding rate of 1.58 kids/doe. Out of all born kids 12 were males and 7 were females. Tthe kid mortality rate was found to be 5.26 % on an average up to the eight months. Does with single kids accounted for 41.66% and twins 58.33%, respectively (Figure 2).

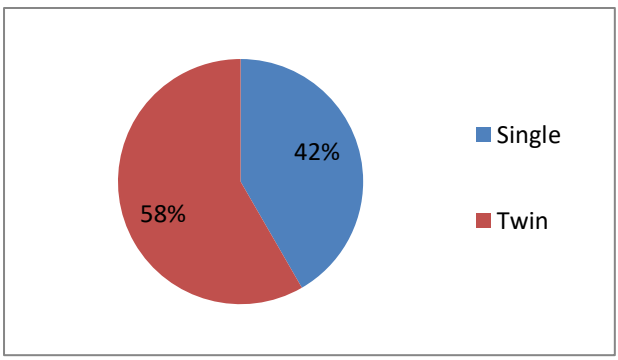

Figure 2. Does with single kids and twins

CONCLUSION

From this study, it can be concluded that Saanen kids have good growth performance. The significant effect of sex at different ages indicates potential of the breed for better productivity under improved management system. Moreover, continuous improvement in genetic selection, feeding method and management system may contribute to faster growing rate.

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REFERENCES

ADA (2019). American dairy association retrieved from https://en.wikipedia.org/wiki ./search. on 1st June 2019.

Braker MJE, HM Udo and EC Webb (2002). Impacts of intervention objectives in goat production within subsistence farming. *South African Journal of Animal Science* 32:185-191.

Casey and Van Niekerk, (1988). The Boer goat. origin, adaptability, performance testing, reproduction and milk production. *Small Ruminant Research* 1:291-302.

Djemali, M., Aloulou, R., Ben Sassi (1994). Adjustment factors and genetic and phenotypic parameters for growth traits of Barbarine lambs in Tunisia. *Small Ruminant Research* 13,41-47.

Khandoker, MAMY, A. Afini and A. Azwan (2018). Productive and reproductive performance of Saann goat at AZ-Zahra farm of Sandakan in Malaysia. *Bangladesh Journal of Animal Science* 47 (1): 1-12.

Silva WE, Da, Leite JHGM, Sousa JER, Costa WP, Silva WST, Guilhermino MM, Asensio LAB, Façanha DAE. (2017). Daily rhythmicity of the thermoregulatory responses of locally adapted Brazilian sheep in a semiarid environment. *Int J Biometerol*. 61:1221–1231.

Teke B, F Akdag and S. Arslan (2011). Some fertility, growth and behavioral traits of Saanen goats raised on private farm condition. *Faculty of veterinary Medicine Istabul University 37:18*

Weppert, M. (1998). Variation due to Direct and Maternal Genetic Effects in Canadian Dairy Goats, M.Sc.Thesis, Canada University.

Wenzhbong L ,Z. Yuan and Z. Zhongxiao (2005). Adjustment for non –genetic effects on body weight and size in Angora goats. Small Ruminants Research 59:25-3. Check all reference are they listed above in text.

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COMPARATIVE PROFITABILITY AND TECHNICAL EFFICIENCY OF SMALL-SCALE RICE FARMERS WITH AND WITHOUT ACCESS TO IMPROVED PRODUCTION TECHNOLOGY IN NORTH CENTRAL NIGERIA

***Lawal[1], A. F; A.S.I. Gudugi[2]; M.A. Paiko[3]; M.A. Bwala[1]; B.M. Sule[1]; A. M. Bello[2]; A. Ubandoma[1] and Y. Garba[2]**

[1]Department of Agricultural Economics and Extension Services, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[2]Department of Crop Production, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[3]Department of Biochemistry, Ibrahim Badamasi Babangida University, Lapai, Nigeria
***Corresponding Author-**lafolorunso@ibbu.edu.ng

ABSTRACT

This study evaluated comparative profitability and technical efficiency of small-scale rice farmers with and without access to improved production technology in North Central Nigeria. Multistage sampling technique was adopted for this study, Data were collected through the use of a well-structured questionnaires from 1500 sampled smallscale rice farmers with access to technology and also 1500 sampled smallscale rice farmers without access to technology making a total of 3000 rice farmers in the study area. The following statistical and econometrics tools were used to achieve the stated objectives; descriptive statistics, budgetary technique, stochastic production frontier and F-Chow test statistics. The results showed that the average age of the sampled rice *farmers with technology was 36 years, while those without access to technology was 46 years. About 53.2% of the farmers with technology had formal education and also about 65.4% of the farmers without technology also had formal education. The results further showed that rice production was profitable for both catagories of the farmersThe average technical efficiency obtained by smallscale farmers with access to technology was higher (81.1%). The statistical significant (P<0.01) factors influencing rice production for both catagories of the smallscale farmers access to technology*

were: land size, labour, fertilizer and agrochemicals. The statistical significant (P<0.01) factors influencing technical inefficiency of both catagories of the the farmers were education), land size, experience, household size and extension contact or cooperative. The major challenges faced by smallscale rice farmers with access to technology were: poor credit facilities, shortage of farm input, inadequate rainfall season, high cost of labour and instability in planting calendar. The smallscale rice farmers without access to technology also faced with the following constraints: soil fertility, attitude of farmers towards adoption of innovation, poor credit facility, high cost of labour and instability in planting calendar and ineffectiveness of agricultural chemicals used due to delay in rainfall. The F-Chow test showed that there was significant impact on technical efficiency, productivity and profitability of rice farmers with access to improved technology. The study has recommended that inputs such as improved seed varieties, fertilizers, chemicals and extension services should be provided timely to the farmers by the government of Nigeria or NGOs at affordable price or subsidized rate.

Keywords: Profitability, Technical Efficiency, Rice Farmers, Small-Scale, Access to Technology

INTRODUCTION

Rice (*Oryza sativa)* is an important food crop in Nigeria; it is one of the major staples and a strategic commodity to Nigeria's economy. Nigeria's demand for rice is about 7.9 million Metric tonnes per year out of which an average of about 2 million metric tonnes are imported; the country spends between $500 million and $1 Billion on rice importation per annum since 2002 (RMM, 2017). Furthermore, the yield per hectare of locally produced rice stands at about 2 metric tonnes compared to global average of 6.0 metric tonnes; due to poor seed quality, low soil fertility, low use of fertilizer, iron toxicity, poor adoption of improved technology, in addition to problems of pests and diseases (Adesina,2012). Rice consumers in Nigeria generally perceive local rice as poor in quality. Therefore, achieving the rice self-sufficiency goal of the government requires changes in the level of production, processing and marketing of rice that meets the quality demand of local consumers. Rice production is a vital component of Nigeria's agricultural sector, particularly in the North Central region, where small-scale farmers constitute a significant portion of the farming population (FAO, 2020). However, small-scale rice farming in the region faces challenges, including low productivity, resource constraints, and limited access to modern agricultural technologies (Adeyemo & Arokoyo, 2018). To address these challenges, the

adoption of technology has been identified as a potential solution to improve the profitability and efficiency of small-scale rice farming. This study aims to investigate the comparative profitability and technical efficiency of small-scale rice farmers in North Central Nigeria, focusing specifically on the utilization of technology. By comparing farmers who have adopted improved production technology with those who have not, this research seeks to provide insights into the potential benefits and challenges associated with technological interventions in the rice farming sector. The use of technology in agriculture has the potential to enhance productivity by improving resource allocation, reducing production costs, and increasing yield levels. Technological interventions, such as improved seed varieties, use of agrochemicals mechanization, and precision farming techniques, can contribute to higher yields and improved farm profitability. Additionally, technology adoption may lead to increased technical efficiency by enabling farmers to optimize the use of inputs and achieve higher output levels per unit of resources employed. However, the adoption of technology by small-scale rice farmers may face several barriers, including limited access to capital, lack of awareness and knowledge about available technologies, and inadequate infrastructure. These challenges can hinder the adoption process and limit the potential benefits that technology can offer to small-scale rice farmers. The profitability and technical efficiency of small-scale rice farmers in North Central Nigeria can vary significantly depending on their adoption or non-adoption of technology. However, there is a gap in empirical research examining the comparative performance of these two groups.

MATERIALS AND METHODS

Area of Study

The study was conducted in North Central Nigeria which comprises of six states namely, Kwara, Kogi, Niger, Nasarawa, Plateau and Benue states. Niger State, and Nasarawa State were selected for the study. Niger State lies between Latitudes 3^0 20' and $7^0$40' North of the equator and Longitudes 8^0 11´ and $11^0$2´ East of the Greenwich Meridian (Niger State Ministry of Information and communication,2008). The State shares boundaries in the North with Zamfara, Kebbi States and Federal Capital Territory, Abuja. It also shares common boundary with Republic of Benin at Babana in Borgu Local Government Area in Niger state. It is located in the Guinea Savannah agro ecological zone in Nigeria, with annual rainfall of 1100 mm in the north and 1600mm in the south (Niger State Ministry of information and communication, 2008).Nasarawa State is bounded in the North by Kaduna State, in the West by the Abuja Federal Capital Territory, in the South by Kogi and Benue States and in the East

by Taraba and Plateau States. The State lies between Latitudes7° 45' and 9° 25' North of the equator and between Longitudes7° and 9° 37° East of the Greenwich meridian. The average annual temperature is 28.4 °C and about 839 mm of precipitation falls annually. Most of crops produced by farmers in these states are rice, cowpea cassava, groundnut sesame seed, sorghum etc and also reared livestock like goats, pigs, cows and sheep.

Method of Data Collection

Data used for this study were obtained from primary sources. The relevant primary data was obtained from rice farmers in two selected states in the study area. The main instrument for data collection was pre-tested structured interview schedule administered on respondents by trained enumerators under the supervision of the researchers.

Sampling Technique and Sample Size

The target populations for this study were rice farmers in North Central Nigeria. Multi stage simple random sampling technique was used for the study. Two States randomly selected were Niger and Nasarawa State. A cross sectional data was used for the study comprising of 1500 rice farmers that were exposed to improved rice production. Furthermore, another set of 1500 that were not expose to the technologies were selected as well. Therefore, a total of 3000 rice farmer were used for the study.

Method of Data Analysis

Descriptive statistics such as frequency distribution, mean, and standard variation were used to capture the socio-economics characteristics of the respondents.

Budgetary Technique

Farm Budgetary Analysis were used to capture costs, returns and profitability ratios of rice farmers. The Budgetary Analysis involved the estimation of net farm income and return on Naira (ROI) invested which was used to determine the profitability of rice production of respondents with and without access to improved production. Following Olukosi and Erhabor (1988), the net farm income was estimated on per hectare basis as follows: -

$$GM = TR - TVC \ldots\ldots (1)$$

$$GM = \sum_{i=1}^{n} P_i Q_i - \sum_{i=1}^{n} P_j X_j \ldots\ldots (2)$$

$$NFI = GM - TFC \ldots\ldots.(3)$$

Where,

NFI= Net Farm Income; GM = Gross Margin (₦/ha); TR= Total Revenue Py . Y (₦); P_i = Price Rice in (₦), Q_i = Total quantity of rice (Kg/ha); P_j= Price of Input (₦/Kg); X_j = Quantity of Input Used (Kg/ha), Py = Price per unit output (₦); Y = Total quantity of output (Kg)/unit/Ha
TFC = Total Fixed cost per hectare (₦) (Average annual depreciation cost for all input was used)

Financial Analysis: According to Alabi et al. (2020), gross margin ratio is defined as follows:

$$\text{Gross Margin Ratio} = \frac{\text{Gross Margin}}{\text{Total Revenue}} \ldots\ldots\ldots\ldots.(4)$$

According to Olukosi and Erhabor (1989), operating ratio (OR) is defined as follows:

$$\text{Operating Ratio} = \frac{\text{TVC}}{\text{GI}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Following Lawal (2008) return on Naira invested (ROI) was obtained as follows:

$$RORI = \frac{NI}{TC} \ldots\ldots\ldots(6)$$

Where,
RORI= Rate of Return per Naira Invested (Units);
NI= Net income (Naira);
TC= Total Cost (Naira).
Decision rule: ROI value should be greater than one for an enterprise to be profitable.

Stochastic Production Frontier Model

Stochastic frontier model was used to estimate technical efficiency values and identify factors determining inefficiency. Productivity of resource use estimate would be calculated from the coefficients of the stochastic frontier model. The explicit model form is presented as:

$$Y_i = f(X_i, \beta)\epsilon, i = 1, \ldots, N \ldots\ldots\ldots\ldots(7).$$

$$LnY_i = \beta_0 + \sum_{i=1}^{6} \beta_i \, LnX_i + \cdots \beta_n LnX_n + V - U_i \ldots\ldots\ldots..(8)$$

$$LnY_i = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + V_i - U_i. (9)$$

Where,

LnY_i = Rice Output (Bags)

X_1= Land size (ha)

X_2= Labour (Man days)

X_3= Rice Seed (Kg)

X_4= Quantity of Fertilizer (Kg)

X_5= Agro Chemical Input (Litres)

β_0 = Constant Term

$\beta_1 - \beta_6$ = Parameters to be Estimated

The Technical Inefficiency Component of the Stochastic Frontier Model is stated thus:

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 \ldots\ldots (10)$$

Where,

$$U_i = \text{Technical Inefficiency Compone}nt$$

Z_1= Education (Years Schooling)

Z_2= Age of Farmers (Years)

Z_3= Farm size (Hectares)

Z_4= Farming Experience (Years)

Z_5= Household Size (Number)

Z_6 = Extension contact (Number)

Z_7 = Sex (1, Male; 0, Otherwise)

α_0 = Constant Term

$\alpha_1 - \alpha_7$ = Regression Coefficients

F-Chow Test Statistics

According toDoughery (2007) and Chow, (1960) F-Chow test statistics is often used in determining the equality of error variances in two linear regression equations this is the main restriction assumed in Chow test.

The pooled Regression model is specified as;

$$Y_{ij} = \alpha + \beta X_{1ij} + \varphi X_{2ij} + \epsilon_{ij} \ldots\ldots\ldots\ldots (11)$$

If we split the data into two groups, then we have,

$$Y_{ij} = \alpha_{1ij} + \beta_1 X_{1ij} + \varphi_{1ij} X_{2ij} + \epsilon_{ij} \ldots\ldots\ldots\ldots (12)$$

$$Y_{ij} = \alpha_{2ij} + \beta_2 X_{2ij} + \varphi_{2ij} X_{2ij} + \epsilon_{ij} \ldots\ldots\ldots (13)$$

Where,

Y_{ij}

$= Output\ of\ Rice\ from\ farmers\ with\ and\ without\ access\ to\ technology$

Chow test is an application of the F-distribution test, if F-Chow is greater than the F-table, then there is a significant difference between the output of rice farmers with and without technology or otherwise. The model is specified as follows:

$$\mathrm{F} * -\text{Chow Test} = \frac{RSS - (RSS_1 + RSS_2)/K}{RSS_1 + RSS_2/[\mathrm{N}_1 + \mathrm{N}_2 - 2K]} \ldots\ldots\ldots\ldots\ldots (14)$$

Where,

$\mathrm{RSS} =$ Sum of Square Residual from Pooled Data,

RSS_1 =Sum of Squares from the rice producers with access to technology

RSS_2

$=$ Sum of Squares from rice producers without access to technology,

$K =$ Total Number of Parameter ,

N_1 , $\mathrm{N}_2 =$ Number of Observation in Each Group ,

Study Hypothesis

H_0:$\beta_1 ij = \beta_{2ij}$: There is no significant differences of productivity between rice farmers with and without access to improved technology. The main hypothesis in the Chow test is that the coefficient (Rice output) s are equal for both sub-samples.

RESULTS AND DISCUSSION

Socio-economic characteristics of the smallscale rice farmers with and without access to improved production technology

The results of the socio-economic characteristics of the sampled scale rice farmers with and without technology is presented in Table 1. The average age of the sample rice farmers with technology was 36 years while those without technology was 46 years, this implies that the rice farmers from both categories were still energetic and in their active age of productivity but rice farmers that adopt technology were much younger than those without technology, there is a difference of 9 years between farmers with technology and those without technology, the younger the rice farmers the higher the chances for them using technology and innovation in rice production that would lead to increase in efficiency and profit maximization. This is in consonance with Okello et al. (2019) who reported an average age of 38 years for rice farmers and contrary to the findings of Aboaba, (2020) who reported the mean age of rice farmers to be 54 years. The study also shows that majority (84.2%) of the sampled rice farmers with access to technology were male while majority (83.3%) of the sampled rice farmers without technology were male rice farmers, this indicates that majority of

the rice farmers using technology and without technology were male rice farmers. This result in in line with Oladele et al. (2020) who reported that the male dominancy in agriculture is expected especially due to great energy required in carrying out farming activities. About 83.1% of the sampled rice farmers using technology were married and 83.3% of those without technology were also married implying that most of the sampled rice farmers from both categories have labour supply for rice production in the study area. Furthermore, the results show that majority of the sample farmers were literate, only 10.5% and sampled farmers with access to technology and 3.4% of farmers without access to technology has no formal education. The average household size of the sample rice farmers with and without technology was 7 and 9 persons respectively. On average farmers without access to technology had larger household size than those with access to technology with a difference of 2 persons per household. While the average length years of rice cultivation by farmers with and without technology was 10 and 13years respectively. There is a difference of 3 years in the average years of farming experience between farmers with access to technology and those without access to technology. Length of years in rice cultivation makes farmers to accumulate experience and knowledge about rice cultivation which could make farmers to maximize profit. About 44.2% of the sampled farmers with technology were members of the cooperative association while majority (61.5%) of the sampled rice farmers without technology were also members of the cooperative association.

Cooperative association makes farmers to organize themselves in such way that they can contribute their resources and pull it together which could enable them to purchase inputs in bulk at lower price rate. The study also shows that majority 74.7% and 76.9% of the sampled rice farmers with and without technology had no access to formal credit facilities respectively. More so, most (63.2%)of the rice farmers with technology and 67.9% of the farmers without technology source their capital or finance through personal savings. Majority of the sample rice farmers with access (73.7%) and without access (70.5%) to technology has land size of less than 2 ha with average land size of 1.5 ha and 1.4 ha for farmers with access to technology and without technology respectively. This is in line with the findings of Abdul et al. (2017) who reported farmers with similar farm size for farmers.

Table 1. Socio-economic characteristics of the sampled small-scale rice farmers in the study area

Variables	**Rice Farmers with Technology n =1500**		**Rice Farmers without Technology n=1500**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Age (Years)				
21 – 30	300	20.0	250	17.7
31 – 40	789	52.6	442	29.5
41 – 50	363	24.2	596	39.7
> 50	47	3.2	212	14.1
Mean	36		46	
Sex				
Male	1263	84.2	1250	83.3
Female	237	15.8	250	16.7
Marital Status				
Single	205	13.7	231	15.4
Married	1247	83.1	1250	83.3
Widow	47	3.2	19	1.3
Education Level				
Quaranic	174	11.6	96	6.4
Primary	253	16.9	269	17.9
Secondary	615	41.1	500	33.3
Tertiary	189	12.6	480	32.1
Adult Education	110	7.4	96	6.4
No Formal Education	158	10.5	58	3.8
Household Size (Number)				
1-5	474	31.6	538	35.9
6-10	805	53.7	480	32.1
11-15	221	14.7	480	32.1
Mean	7		9	
Length of RiceCultivation				
1-5	174	11.6	404	26.9
6-10	710	47.4	500	33.3
11-15	410	27.4	154	10.3
>15	205	13.7	442	29.5
Mean	10		13	
Member Cooperative				
Members	663	44.2	923	61.5
Not Member	837	55.8	577	38.5
Access to Credit				
With access	379	25.3	346	23.1
No access	1121	74.7	1154	76.9

Source Finance				
Personal	947	63.2	1019	67.9
Bank	32	2.1	38	2.5
Friend Relative	221	14.7	19	1.3
Cooperative	300	20.0	423	28.2
Farm Size (Ha)				
0.1-2	1105	73.7	1058	70.5
2.1-4	221	14.7	250	16.7
4.1-6	174	11.6	192	12.8
Mean	1.5		1.4	

Source: Field Survey Data (2023)

Costs, Returns and Profitability of Small-Scale Rice Farmers with and Without Access to Improved Production Technology

Table 2 presents the results of costs, returns and profitability of rice producers with and without access to improved rice production technology in the study area. The results show that the total variable cost incurred by the small-scale rice producers with technology was ₦175,354.76 and those without technology incurred a total variable cost of ₦123,857.34 with cost incurred on labour having the highest proportion of 43% for farmers with access to technology and 49% for those without technology while the total variable cost incurred by the small-scale rice farmers without access to technology carries 79.3% proportion of total cost of production. The total fixed cost incurred by the small-scale rice farmers with and without technology ₦39474.28 and ₦22,427.42, respectively. The estimated total revenue realized by the rice farmers with access to technology was ₦830,244.75 while the revenue obtained by small-scale rice farmers without technology was ₦350,287.55.

The gross margin estimated for small-scale rice farmers with technology was ₦ 615,415.71 while those without technology obtained ₦194,002.79 and the net profit of about ₦575,941.43 and ₦171,575.37 for both small-scale rice farmers with access to technology and without technology respectively. The gross margin ratio obtained was 0.75 and 0.55for small-scale farmers with and without technology respectively while the operating ratio obtained by small-scale producers with technology was 0.26 and small-scale producers without technology was 0.35. The rate of return on investment realized by farmers with technology was estimated to be 2.75 while the small-scale rice farmers without technology was 1.10.

Table 2. Average costs, returns and profitability per hectare of rice producers with and without access to improved production technology

Variables	Rice farmers with Technology			Rice farmers without Technology		
	Average Value (₦)/ha	Financial Ratios	Proportion (%)	Average Value (₦)	Financial Ratios	Proportion (%)
Variable Cost						
Seed	30,080.82		0.140	22,459.02		0.0.144
Fertilizer	48,000.00		0.22	6500.00		0.0142
Manure	**********		**********	4,857.14		0.031
Herbicide	19,236.30		0.089	6,830.34		0.044
Pesticides	3,926.80		0.018	*****		****
Cost of Labour						
Land preparation	24,722.41			13,103.33		
Planting cost	15,223.73			9,581.72		
First weeding	*****			3500.00		
Second weeding	11,279.63			18,124.39		
Fertilizer Application	18,72.34			8,831.71		
Harvesting	25,503.39			11,762.07		
Threshing/winnowing	14,272.41			12,012.05		
Total	**92,873.91**		0.432	**76,915.27**		0.492
Transportation	8,308.93			6,295.57		
Total Variable Cost	**175,354.76**		**0.816**	**123,857.34**		**0.793**
Fixed Cost						
Depreciation on Farm Implement	9,474.28			17,427.41		
Interest on capital	30.000			15,000		
Total Fixed Cost	39, 474.28		0.184	22,427.42		0.144
Total Cost	214,829.04			156,284.76		
Total Revenue	830,244.75			350,287.55		
Gross Margin	615,415.71			194,002.79		
Net Profit	575,941.43			171,575.37		
Gross Margin Ratio		**0.74**			**0.55**	
Operating Ratio		**0.26**			**0.35**	
RORI		**2.75**			**1.10**	

Source: Field Survey Data (2023)

This study shows that rice production with technology and without technology is profitable but rice production with access to technology was more profitable than those without access to technology the rate of return on investment of 2.75 for small-scale rice producers with technology and 1.10 for those without access to technology implies that every 1 naira invested 2.75 kobo and 1.10 kobo was

obtained as profit respectively which covers interest cost of capital, fees and commission. This is in line with Alabi et al. (2023) who reported that rice production is a profitable enterprise that worth investing in and undertaking.

Distribution of Technically Efficiency Scores among Rice Farmers with and without Access to Improved Production Technology

Table 3 presents the results of summary distribution of the technical efficiency score of the sampled rice producers with and without access to technology in the study area. The results show that technical efficiency varies among the sampled rice farmers with and without access to technology. The study also revealed that about 42.1% of the rice producers with technology attained technical efficiency score between 0.81-1.0 while only 6.4% of the rice farmers without technology were able to attain 0.81-1.0 level of technical efficiency score. The minimum technical efficiency level attained by rice farmers with access to technology and without those without access to technology were 0.001 and 0.011 respectively while the maximum technical efficiency level obtained by each category was 0.999 and 0.9821 respectively with average technical efficiency of about 81.1% for farmers with access to technology and 52.7% for farmers without access to technology. This indicated that rice farmers with access to technology were technically more efficient than those without access to technology. This study is in line with the findings of Okello et al. (2019) who reported technical efficiency of 78% and asserted that rice farmers level of technical efficiency is less than 100%. Several other studies found similar result Ahmed and Melesse (2018), Aboba (2020) and Biara et al. (2023).

Table 3. Distribution of technically efficiency scores among rice farmers with and without technology

Technical Efficiency Score	**Farmers with Technology**		**Farmers without Technology**	
	Frequency	**Percentage**	Frequency	**Percentage**
0-0- 0.20	16	1.1	58	3.8
0.21-0.4	300	2.0	134	8.9
0.41-0.6	395	26.3	1096	73
0.61-0.8	158	10.5	115	7.7
0.81-1.00	632	42.1	96	6.4
Minimum	0.001		0.011	
Maximum	0.999		0.9821	
Mean TE	0.8129		0.5270	

Source: Field Survey Data (2023)

Estimates of the Factors Influencing Total Output and the Technical Efficiency of Rice

Production among Smallscale Rice Farmers with and without Access to Improved

Production Technology

Table 4 shows the results of the maximum Likelihood estimates of the factors influencing technical efficiency of the smallscale producers with and without technology, the first stage of the stochastic frontier production function show that the statistically significant factors influencing total output of rice production for smallscale rice producers with technology were: land size, labour, seed, fertilizer, and agrochemical while the factors influencing total output of rice producers without technology were: land size, labour, and fertilizer. This is consistent with Amaechina and Eboh, (2017) who reported that land size, labour and fertilizer had positive influence on rice production in Anambra State, Nigeria. Land size influence total output of rice production positively for rice producer with and without access to technology and was statistically significant at ($P<0.01$). The coefficient of land size for rice producers with technology (0.2076) and 0.3177) for rice producers without access to technology implied that a unit change in the land size will result in the increase in the total output of rice producers with access to technology and without technology by 20.8% and 31.8% respectively. This result is consistent with Abdulai et al. (2018) and Amaechina &Eboh, (2017) who reported that farm size has a positive influence on total output of rice production. Labour influence total output of rice production positively for both smallscale rice farmers with access to technology and those without access to technology and it was statistically significant at $P<0.01$ probability level. The magnitude of the coefficient of labour for smallscale rice farmers with technology (0.9695) and (0.1764) for smallscale rice farmers without access to technology, this implies that percentage change in labour supply for rice production will result in the increase in total output of rice production by 96.9% and 17.6% for smallscale rice farmers with access to technology and without technology respectively. Rice seed influence total output of rice positively for smallscale rice farmers with access to technology and was statistically significant at ($P<0.01$) but wasn't significant for farmers without access to technology, the coefficient of rice seed for rice farmers with access to technology was (0.3033) implying that percentage change in the quantity of rice seed planted by smallscale rice farmers will result in the increase in the total output of rice production by 30.3% for rice farmers that has accessed to technology. Access to improved seed variety could be the reason why seed influence total output of rice production among the farmers that had access to

technology. Fertilizer has a positive influence on the total output of rice production among smallscale rice farmers that had access to technology while for farmers without access to technology fertilizer influence total output of rice negatively and it was statistically significant at (P<0.01) and (P<0.10) respectively. The coefficient of fertilizer for farmers with access to technology was (0.2102) while for farmers without access to technology was (-0.1002), this signifies that percentage change in the quantity of fertilizer applied to rice farm by rice farmers will technology will result in the increase in the total output of rice production by 21.1% and those without access to technology will experience a decrease in total out of rice by10.1%. This finding conforms to the results of Amaechina & Eboh (2017) and Mabe et al. (2018)who posited that fertilizer had positive effect on total output of rice production but contrary to the result of Abdulai et al. (2018) who reported negative influence of fertilizer on rice production output and in confirmation to the results of the farmers without access to technology. Agrochemical was statistically significant and influence the total output of rice production positively for farmers with access to technology only, the magnitude of the coefficient of agrochemical (0.3053) implying that percentage change in the use of agrochemical by smallscale rice farmers with access to technology will result in the increase in the total output of rice production by 30.5%.The technical inefficiency component of the stochastic frontier which is the second stage of the production function show that the statistically significant factors influencing technical inefficiency of the smallscale rice farmers with access to technology and without technology were: Age of the farmers as seen in Table 4 influence technical inefficiency of the smallscale rice farmers with access to technology negatively and positively for rice farmers without technology and it was statistically significant at (P<0.01) and (P<0.10) respectively. The estimated coefficient of the age of the smallscale farmers with access to technology (-57.1175) and those without access to technology (0.0718) implying that a unit change in the age of the farmers with access to technology will result in the decrease in technical inefficiency of the smallholder rice farmers by 57.1% while for those without access to technology will result in the increase in technical inefficiency by 0.7%. The result connotes that younger farmers are technically efficient than old farmers because younger farmers are risk takers and adopt new innovation. This conforms to the finding of Ishiaku et al. (2017).Education of the sampled smallscale rice farmers had negative influence on technical inefficiency of the smallscale rice farmers that had access to technology while smallscale farmers without access to technology education had positive influence on technical inefficiency and was statistically significant at (P<0.01) for both smallscale farmers with access to technology and without. The

coefficient of education level of the rice farmers with access to technology was (-0.2024) and for those without access to technology was (0.0213) this result revealed that a unit change in the level of education of smallscale rice farmers will result in the decrease in technical inefficiency for farmers with access to technology by 20.2% and increase in technical inefficiency (decrease in technical efficiency) for rice famers without access to technology by 2.1%. The implication of the positive sign for farmers without technology is that they are not well educated as a result they don't consider technology as a means that will improve their productivity, they prefer to stick to their traditional method of rice production thereby resulting in technical inefficiency. This is in line Dominic et al. (2019) who reported negative association of education with technical inefficiency. This means that an increase in the year of education of farmers increases the level of technical efficiency in production. The results also conforms with the finding of Danso-Abbeam et al. (2015) who also found that access to education affects technical inefficiency negatively. Land size influence technical inefficiency negatively for smallscale rice farmers with and without access to technology negatively ($P<0.01$) and ($P<0.10$) respectively. The coefficient of land size for both categories of smallscale rice farmers implies that a unit change in land size will result in the increase in technical efficiency of rice production among smallscale rice farmers by 63.3% and 62.5% respectively. Experience influence technical inefficiency of rice production for smallscale rice farmers with access to technology negatively and was statistically significant at ($P<0.01$) while for farmers without access technology was positive. The coefficient of farming experience for both smallscale rice farmers was (-1824) and (0.0394) respectively meaning that a unit increase in the years of farming experience will result in the decrease in technical inefficiency for smallscale farmers with access to technology by 18.2% while those without technology will lead to decrease in technical efficiency by 3.9%. This is in conformity with the Nwahia et al. (2020) who reported that farmers with more experience tends to be technically efficient than those that has less farming experience. Household size influence technical efficiency of smallscale rice farmers with access to technology positively and negatively for farmers without technology and it was statistically significant at ($P<0.05$) and ($P<0.01$) respectively. The coefficient of household size for farmers with access to technology (0.0269) and those without technology was -0.0628. This show that a unit change in the number of household size per person for farmers with access to technology will result in the decrease in technical efficiency (increase in inefficiency) of rice production by 2.7. The number of persons in a household could have negative relationship with technical efficiency

in the sense that available resources may be diverted for solving family problems rather than farm activities.

Table 4. Maximum likelihood estimates of the stochastic frontier of rice production function for producers with and without technology

Variable	Farmers with Technology			Farmers without Technology		
	Coefficients	**Std Error**	**Z-Score**	**Coefficients**	**Std Error**	**Z-Score**
Land Size	0.207577*	0.0359482	5.77	0.3177182*	0.1221348	2.60
Labour	0.9694883*	0.3839501	2.53	0.1764158*	0.1127985	6.78
Rice Seed	0.3033543*	0.0186010	16.31	0.153018	0.2862165	0.53
Fertilizer	0.2109786*	0.0309272	6.28	-0.170330***	0.1001697	-1.70
Agrochemical	0.3052799*	0.0422674	7.22	-0.3556807	0.2018589	0.76
Constant	4.099452	5.895435	0.70	0.3712768	0.6059639	0.61
Inefficiency Model						
Education	-0.202436*	0.0072075	-28.09	0.0212888***	0.0432501	2.93
Age	-57.11753*	19.18636	-2.98	0.0717677***	0.0072658	1.66
Land Size	-0.6330422*	0.2192555	-2.89	-0.624897***	0.3553213	-1.76
Experience	-0.1823747*	0.0381327	-4.78	0.0393537***	0.0206194	1.91
Household Size	0.0268977**	0.012722	2.11	-0.0628044*	0.0193691	-3.24
Extension Contact	-0.030728***	0.0159691	-1.92	-0.0663106	0.0495128	-1.34
Cooperatives	-0.3051075**	0.0139493	-2.19	-0.257457***	0.129831	-1.98
Sex	0.0037830	0.0143900	0,26	-0.028159	0.0178288	-1.58
Diagnostic Statistics						
Log likelihood	-95.8000			834.7854		
Sigma square	71.5117			0.05654		
Gama	0.544071			0.22177		

Source: Field Survey Data (2023)

***Significant at the 1%, ** Significant at the 5%, *** Significant at the 10% Probability Levels**

This is in line with Okello et al. (2019) who reported that larger household size could result in the decline in technical efficiency in rice production while for farmers without access to technology will result in the increase in technical efficiency by 6.3%.Extension contact influence technical efficiency for smallscale rice farmers with access to technology negatively and it was statistically significant at (P<0.01) probability level, it was not significant for farmers without

access to technology. The coefficient of extension contact for smallholder rice farmers with access to technology was (-0.0307) which signifies that a unit increase in access to extension contact for services will result in the increase in technical efficiency of rice production by 3.1% for farmers with access to technology. These results indicated that rice farmers with access to technology who have access to extension service are more technically efficient than their counterparts that do not have access to technology. This result is consonance with the findings of Dominic et al. (2019), Danso-Abbeam et al.(2015); Abdulai et al.(2018).Cooperative association influence technical efficiency for smallscale rice farmers with access to technology negatively and was statistically significant at ($P<0.05$) and ($P<0.10$)probability level. The coefficient of cooperative association for smallscale rice farmers with access to technology was -0.3051 while for farmers without technology was -0.2575 implying that a unit change in the possibility of being a member of cooperative association by smallscale rice farmers will result in the increase in technical efficiency of rice production among smallscale rice farmers by 30.5% and 25.7% respectively. This is in line with Alabi et al. (2023) who reported that cooperative membership makes farmers to have access to farm inputs at a low cost because they may purchase the inputs in bulk at a lower price which could make them to be efficient and maximize profit.

Constraints Faced by Smallscale Rice Producers with Access to Improved Production

Technology

Table 5 presents the constraints faced by sampled smallscale rice farmers with access technology. The results show that majority 95.8% of the sampled smallscale rice farmers with access to technology encountered poor access to credit facilities as the major constraints faced in rice production and it was ranked first 1st based on the number of rice farmer's opinion. Also most of the farmers with access to technology encountered shortage of farm input as a challenge and was ranked second 2nd while 91.6% of the rice farmers were faced with the challenge of inadequate rainfall season and high cost of labour respectively. The results also revealed that about 90.1% of the sampled smallscale rice farmers with access to technology encountered instability in planting calendar as a major constraint militating against rice production in the study area and it was ranked 4th in the order of severity among the smallscale rice farmers. Other constraints encountered by smallscale farmers with access to technology were: 83.2% of the rice farmers encountered ineffectiveness of agricultural chemicals used due to delay in rainfall and Attitude of farmers

towards adoption of innovation respectively. Furthermore, about 81% of the sampled smallscale rice farmers with access to technology were faced with the challenges of small size of farm land while 76.8% of rice farmers encountered poor soil fertility and poor access to market centers due to bad roads in the study area. This result is in line with Parveen et al. (2016); Cooker et al. (2018) and Alabi et al. (2023) who reported similar problems of rice production faced by farmers in their respective study areas.

Table 5. Constraint faced by rice producers with and without access to technology in the study area

Constraints Faced by Farmers with Technology	Frequency	Percentage	Rank
Poor credit facilities	1437	95.8	1st
Shortage of farm input	1405	93.7	2nd
Inadequate rain fall season	1374	91.6	3rd
High cost of labour	1374	91.6	3rd
Instability in planting calendar	1358	90.1	4th
Ineffectiveness of agricultural chemicals used due to delay in rainfall	1247	83.2	5th
Attitude of farmers towards adoption of innovation	1247	83.2	5th
Small Farm Size	1167	81.0	6th
Poor soil fertility	1153	76.8	7th
Poor access to market centers due to bad roads	1153	76.8	7th
Problem of land ownership	1026	68.4	8th
Inadequate extension contact	458	30.5	9th
Total	1500	100	

Source: Field Survey (2023)

Constraints Faced by Smallscale Rice Producers without Access to Improved Production Technology

Table 6 presents the constraints faced by smallscale rice farmers without access to technology in the study area, the results show that majority (97.4%) of the sampled rice farmers identified poor soil fertility and attitude of farmers towards adoption of innovation were both ranked 1st while 96.2% of the respondents ranked poor access to credit facilities as 2nd,high cost of labour as the most important constraints to rice production in the order of severity. This result is in line with Alabiet al. (2020) and Alabi et al. (2023).

Table 6: Constraint faced by rice producers without access to technology

Constraints Faced by Farmers	Frequency	Percentage	Rank
Poor soil fertility	1462	97.4	1st
Attitude of farmers towards adoption of innovation	1462	97.4	1st
Poor credit facilities	1442	96.2	2nd
High cost of labour	1385	92.3	3rd
Instability in planting calendar	1365	91.0	4th
Ineffectiveness of agricultural chemicals used due to delay in rainfall	1327	88.5	5th
Inadequate rain fall season	1250	83.3	6th
Shortage of farm input	1134	75.6	7th
Problem of land ownership	1115	74.4	8th
Small Farm Size	1115	74.4	8th
Poor access to market centers due to bad roads	769	51.0	9th
Inadequate extension contact	711	47.4	10th
Total	1500	100	

Source: Field Survey Data (2023)

Table 7: F-Chow Test Outcome

RSSP	RSS1	RSS2	F*	F(K, T-K) at 5% significance level	Decision
5818.887	9323.600	4858.988	26.44	2.495	There is Significant Impact on Productivity of Rice Farmers with Access to Improved Technology in the Study Area

Source: Field Survey Data (2023)

Chow Test Result to Determine the Difference between Rice Producers with and without Access to Improved Production Technology in the Study Area.

The results of Chow-test are presented on Table 7. The residual sum of square for pooled sample was 5818.887, while the residual sum of square for farmers with access to technology was 923.600 and that of famers without technology was 4858.988 with calculate F* Value of 26.44 and the Table F-Value of 2.495. In the Chow test, if there is no significant statistical difference between two sub-samples (i.e., if $\sigma_I^2 = \sigma_R^2$), then the regression test statistic in Equation (11) follows an F(K, T-2K) distribution. However, if the test statistic (F*) is greater than the

respective F-statistic at 5% level of significance (as in this study), the null hypothesis should be rejected. Consequently, the relevant conclusion is that the sub-samples are significantly different. This was the statistical evidence which justifies the decision to estimate separate models for the sub-samples. The coefficients of the rice farmers with access to technology were more significant than those without access to technology.

CONCLUSION

The general conclusion drawn from this study is that access to improved rice production practices increases yield, profit and technical efficiency of the farmers. Farmers with access to technology have Return on Naira Investment and mean technical efficiency that is significantly higher than that of rice farmers without access to technology The average technical efficiency obtained by smallscale farmers with access to technology was 81.1% while those without access to technology obtained 52.7% indicating that farmers with access to technology were more technically efficient than the smallscale rice farmers without technology. The factors influencing total output of rice production for smallscale farmers with access to technology were: land size, labour, fertilizer and agrochemical while the statistically significant factors influencing total output of rice production for smallscale farmers without access to technology were land size, labour and agrochemical. It was also discovered from the study that statistically significant factors influencing technical inefficiency of the farmers with access to technology were education, Age, land size, experience, household size and extension contact. The statistically significant factors influencing technical inefficiency for farmers without access to technology were: education, land size, experience, household size and cooperatives. The major challenges faced by smallscale rice farmers with access to technology were poor credit facilities, shortage of farm input, and inadequate rainfall. The smallscale rice farmers without access to technology were faced with the following major constraints poor soil fertility, attitude of farmers towards adoption of innovation, and poor credit facility.

POLICY RECOMMENDATIONS

The study recommends the following policy implications: Theere is need to expose all small-scale rice farmers to improved production practices. Inputs such as mechanization of land predation use of improve seed varieties, precision planting, fertilizers and agro chemical inputs. These inputs should be provided to farmers by government of Nigeria or Non-Governmental Organizations at

affordable price or subsidized rate and timely. Extension services should be provided to smallscale rice farmers on the improved rice production, technologies utilization advices should be provided to farmers with training and farm demonstration on how to use technology appropriately, workshops, seminars including media broadcasting through television, radio and internet/social media and symposium should be properly organized for adequate training of smallscale farmers to understand the technicalities of rice production using technology. Farmers should be encouraged to join cooperative organizations for them to have access to credit facilities in order to boost their production capacity that will make them have the ability to adopt rice production technologies which will in turn increase their output, income and improve their livelihood and welfare in the study area.

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REFERENCES

Abdul, M. Tashikalma, A. K, Maurice, D.C and Shittu, F.M. (2017). Analysis of Cost Efficiency Rainfed Maize Production in Yola North and Yola South Local Government Areas of Adamawa State, Nigeria. *Global Journal of Agricultural Sciences 16.65-73.*

Abdulai, S., Nkegbe, P. K., Donkoh, S. A. (2018). Assessing the technical efficiency of maize production in northern Ghana: The data envelopment analysis approach. *Cogent Food and Agriculture*, 4, 1512390. doi:10.1080/23311932.2018.1512390 *Agricultural and Biosystems Engineering*, 12(8), 223–232. doi:10.1999/1307-6892/10009379

Aboaba K. O. (2020). Economic efficiency of rice farming: a stochastic frontier analysis approach. J. Agribus. Rural Dev., 4(58), 423–435. http://dx.doi.org/10.17306/J.JARD.2020.01377

Adeyemo, R., &Arokoyo, T. A. (2018). Profit efficiency among smallholder rice farmers in Nigeria: A stochastic frontier analysis. International Journal of Food and Agricultural Economics, 6(4), 69-81.

Ahmed, M &Melesse, K. 2018). Impact off-farm activities on technical efficiency: evidence from maize production of eastern Ethiopia. *Agricultura and Food Economics* 6(3): 1-19

Alabi O.O., Safuga, G.F. & Aluwong J.S. (2023). Cost Efficiency and Profitability

Analysis of Rice (Oryza sativa) Production among Smallholder Farmers in Federal Capital Territory, Nigeria. *Australian Journal of Science and Technology* 7(1):1-9

Alabi, O.O., Oladele, A.O., &Oladele, N.O. (2020). Socio-Economic Factors Influencing Perception and Adaptability of Rural Rice Farmers to Climate Change, Abuja, Nigeria: Applications of Heckman Two –stage Model. *Russ. J. Agric. Soc.-Econ. Sci.*, 8(104), 45–56

Amaechina, E. C. and Eboh, E. C. (2017). Resource use efficiency in rice production in the lower Anambra irrigation project, Nigeria. Journal of Development and Agricultural Economics. 9(8), 234-242, August 2017
DOI: 10.5897/JDAE2016.0764

Biara E, Mezgbu A. Adugnaw, A. &Habtamu M. (2023). Sources of Wheat Production Technical Inefficiency Among Smallholder Farmersin Northern Ethiopia: Beta Regression Approach, Congent Economics & Finance, 11:1 2208895, Doi: 10.1080/2332039.2023.2208895

Coker, A.A.A,Ibrahim, F.D., Ibeziako, U.N. (2018). Influence of Agricultural Technology Utilization on Technical Efficiency of Cowpea Farmers in Nigeria: Evidence from Parametric Analysis RJOSAS, 2(75) :162-171

Danso-Abbeam, G., Dahamani, A. M., & Bawa, G. A.-S. (2015). Resource-use-efficiency among smallholder groundnut farmers in Northern Region, Ghana. *American Journal Experimental Agriculture*, 6(5), 290–304

Danso-Abbeam, G., Dahamani, A. M., & Bawa, G. A.-S. (2015). Resource-use-efficiency among smallholder groundnut farmers in Northern Region, Ghana. *American Journal of Experimental Agriculture*, 6(5), 290–304

Dominic T. K, Franklin N. M., and Hamdiyah, A. (2019). Technical and resource-use-efficiency among smallholder rice farmers in Northern Ghana**.**Cogent Food &Agriculture, 5(1); https://doi.org/10.1080/23311932.2019.1651473

FAO. (2020). FAOSTAT. Retrieved from http://www.fao.org/faostat/en/#home

Ishiaku, O. K., Haruna, U., Danwanka, H. A., & Suleiman, H. R. (2017). Resource use efficiency of fadama III small-scale rice farmers in Nasarawa State, Nigeria. *International Journal of Agricultural Economics and Extension*. 5 (4), 284–294, April, 2017

Mabe, F. N., Donkoh, S. A., & Al-hassan, S. (2018). *Accounting for rice productivity heterogeneity in Ghana:* The two-steps to chasticmeta frontier approach

Nwahia, O.C., Balogun, O.S., Balogun, O.L., Emeghara, U.U., Onwegbunam, N.E., Bala, U.J. (2020). Analysis of Technical, Allocative and Economic Efficiency of Rice Farmers in Ebonyi State, Nigeria RJOAS 10(106):135-143

Okello, D.M. Bonabana-Wabbi, J. & Mugonola, B. (2019). Farm Level Allocative Efficiency of Rice Production in Gulu and Amuru Districs Northern Uganda *Agriculture and Food Science* 7(9) :1-19

Parveen, K, Chauhan, R. S and Grover, R. K. (2016). Economics Analysis of Tomato Cultivation Under Poly House and Open Field Conditions in Haryana, India. *Journal of Applied and Natural Science*8 (2): 846 – 848.

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CLINICAL INVESTIGATION OF CANINE DISEASE AND DISORDERS IN KATHMANDU VALLEY OF NEPAL

Ayush Kumar Thakur*, Md. Shajedur Rahman, Begum Fatema Zohara, Mahesh Thakur[1]

Department of Medicine, Surgery and Obstetrics, Faculty of Veterinary and Animal Science
Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh
[1]City Veterinary Hospital Pvt. Ltd. Satdobato, Lalitpur, Nepal
***Corresponding author**: ayushaayan1@gmail.com

ABSTRACT

A case control study was conducted to ascertain the prevalence of clinical disease and clinical disorders of sick pet dogs presented to the City Veterinary Hospital Kathmandu Valley Nepal for a period of one year from July 2020 to June 2021. A total 1409 clinically ill pet dogs were examined and recorded the disease and disorders on the basis of age, season and breeds of dogs. Among diseases and disorders the highest prevalence (26.54%), was significantly (p <0.01) seen by viral disease followed by digestive disorders (10.14%), ear and eye disease (8.72%), respiratory disorders (7.73%), fungal disease (7.16%), protozoan disorders (6.52%), urinary disorders (5.53%), metabolic and nutritional disease (5.39%), genital disease (5.03%), skin disorders (4.54%), helminthiasis (3.97%), external parasite (3.12%), poisoning (3.12%), and lowest (2.41%) by edema. It is observed that the prevalence of diseases and disorders was significantly (p <0.01) higher above 36 months of age group and moderate in 7-36 months' age and lowest in 0 to 6-month age groups. According to season the highest prevalence (29.59%) was seen in winter season (December-February) followed by 25.90% in summer (March-May), 24.27% in autumn and lowest 20.22 % in rainy season and it was statistically significant (p <0.01). According to breed the prevalence was significantly higher 34.56% in local dogs followed by 14.05% in German shepherd dogs, 10.14% in Labrador breed, 7.94% in pug, 7.59% in Golden Retriever breed, 6.03 % in lhasa Apso breed, 5.89% in Doberman breed, 4.61% in Spitz breed, 3.97% in Boxer breed, 3.26% in Beagle breed and lowest 1.92% seen in Spaniel breed. The present study demonstrated the excellent efficacy of Amoxicillin @ 20mg/kg body weight against secondary bacterial infection of canine parvo virus infection reduced the clinical signs of CPVI within 6.0±0.32

days than Ceftriaxone @ 25 mg/kg body weight and Enrofloxacin @ 8mg/kg body weight that took recovery period of 7.4±0.25and 7.9±0.37 days respectively but it was not statistically significant and present study demonstrated the excellent efficacy of Doxycycline @ 10mg/kg body weight against Ehrlichiosis reduced the clinical signs within 5.0±0.32 days than Rifampicin @ 20 mg/kg body weight orally that took recovery period of 8.0±0.25 days In conclusion it was observed that the age, seasons and breed has effect on disease and disease conditions of pet dogs and commercial drug was found effective to control infections and healing of CPVI lesion.

Keywords: Canine Disease, Antibiotics, Age, Season, Breeds

INTRODUCTION

Dog, (*Canis lupus familiaris*),domestic mammal of the family Canidae (*order Carnivora*). It is a subspecies of the gray wolf (*Canis lupus*) and is related to foxes and jackals. The dog is one of the two most ubiquitous and most popular domestic animals in the world. For more than 12,000 years it has lived with humans as a hunting companion, protector, object of scorn or adoration, and friend. Dogs are the most thriving canids, adapted to human habitation worldwide including Bangladesh. They have contributed to refreshment by pet keeping, physical, social and emotional well-being for their owners (Robertson *et al.*, 2000; Dohoo *et al.*, 1998). Usually, pet keeping is associated with certain responsibilities like housing, disease management (William *et al.*, 2002). However, in spite of the beneficial effects, close bond between dogs and humans remain a major threat to public health, with dogs harboring a large number of infective stages of disease causative agents transmissible to man and other domestic animals (Robertson *et al.*, 2000; Molyneux, 2004). Since pets share the same environment with humans, they constitute an important reservoir of zoonotic diseases (Kornblatt and Schantz, 1980). Household pets have been found to play a direct role in transmitting zoonosis (Kornblatt and Schantz, 1980; Dada *et al.*, 1979).

A lot of diseases and disease conditions are frequently occurred in dogs. Among the viral diseases rabies, infectious canine hepatitis, canine distemper, canine parvo viral infections are very common in Indo-Bangladesh sub-continent (Biswas *et al.*, 1996). Rabies is the most important zoonotic disease in worldwide including Bangladesh (Biswas *et al.*, 1996) and approximately 90% of human cases result from dog bites. Almost all human deaths caused by rabies originating from Asia and Africa and there are an estimated 55,000 human deaths annually from rabies, with about 31000 in Asia and 24,000 in Africa (Samad, 2008).

Othersly, on bacterial conditions, dogs are usually affected with leptospirosis, brucellosis, kennel cough, clostridium etc.

Ectoparasites and intestinal helminth species are widely prevalent health problems in dogs. Parasites documented in dogs throughout the world including Nepal with a pronounced difference in prevalence and density among the regions. Considering the high prevalence of ectoparasites and intestinal helminth infections found in dogs, and the close bonds in which dogs live together with people, the risk of transmission of these parasites to humans seems to be obviously elevated. Higher prevalence rate of fleas, ticks, lice, mites have been reported by Rodriguez-Vivas *et al.,* 2003; where *Demodex canis* (23.0%) as a most frequent mite, followed by *Sarcoptesscabei var canis* (7.0%) and *Otodectes cynotis* (3.5%). Seasonal frequency of ectoparasites infestations has also been reported by Shoorijeh *et al.,* 2008. The higher rate of echinococcosis has been available in stray dogs in Bangladesh (Molan and Saida, 1989). In our country, dogs are generally infected with various diseases. A lot of cases are frequently observed in City Veterinary Hospital, kathamndu. Considering those important facts the present study is anticipated to following objectives:

To investigate the prevalence of disease and disorders in dogs in Kathmandu Valley, Nepal and to know the age, breed and season-wise prevalence of dog diseases and eventually to evaluate the efficacy of commercial drugs against canine parvo virus infection and canine *Ehrlichiosis*.

MATERIALS AND METHODS

Study area

This study was executed on dogs residing at different areas of Kathmandu valley, Nepal. All dog breeds come to "City Veterinary Hospital Kathmandu valley, Nepal were examined thoroughly.

Study Period

The study was conducted for a period of 1 year from July 2020 to June 2021.

Study population

The examined dogs mostly were exotic such as Spitz, German Shepherd, Golden Retriever, Labrador, some were street dogs and few were cross with exotic. A total 1409 clinically ill dogs of different age brought to the City Veterinary Hospital, Kathmandu valley, Nepal was under investigation.

Questionnaire design and data collection

In order to collect data, a structured questionnaire was carefully prepared on the basis of the objectives. It was a cross sectional study and the questionnaire was

designed to comprise mostly closed ended (categorical) questions to ease data processing, minimize variation and improve precision of responses (Thrusfield, 2005). The questionnaire was filled up by repeated questioning to the owner, personal observation of patient and taking records from register book. Important data recorded including owner's complaint, breed, age, sex, body condition, weakness, onset and duration of illness of the dog. Other information sought included history of birth, de-worming, vaccination, pregnancy status, parity, housing pattern, diet, environmental condition. Clinical examinations were performed according to questionnaire designed mentioning about temperature, respiration, pulse, hair coat, skin, general attitude of animal, posture, gait, lameness, fracture, depthness of wound etc.

(Source: https://www.researchgate.net/figure/Urbanizing-Nepal-showing-the-Kathmandu-Valley-in-the-set-map_fig1_332713605)

Figure 1. **Map of working area (City Veterinary Hospital Kathmandu Valley Nepal)**

Case identification

The sequential procedure of clinical diagnosis of the patient:

i. Owner's complaint
ii. Anamnesis: History was taken about weakness of patient, onset and duration of illness from owner. Identify the pre-disposing factors of diseases.
iii. Clinical examination of patient; It includes:

a. Inspection

***Distant Inspection*:** Firstly the general attitude of the patient (alertness/ dullness/ depression) was carefully inspected. Following this, the body condition of the animal (Cachectic/ poor/ fair/ good/ fat/ over fat) was observed as described by Radostitis *et al., (*2000). In addition, posture and gait (normal or defective) were examined according to the condition of the dog.

***Close Inspection*:** Following distant inspection, the patient was closely examined by visual examination, parting of hair/fleece, light palpation and close direct inspection to detect hair coat and skin abnormalities. Skin lesions, nature of lesions (foul odorous discharge, crusts, scale and dandruff), location/ distribution of those lesions were also studied. In addition, external parasites (eg. ticks, lice, flea, flies and larvae of flies) identified during examination were documented.

b. Clinical examination and determination

Wounds were identified by inspection and further examined for more precise diagnosis to categorize the nature of the wound whether it might be septic/ lacerated/ incised/ punctured/ perforating/ abrasions/ avulsion/ hematoma. Needle puncture was also performed if required. Temperature, pulse, respiration was taken through other scientifically clinical method. In case of fracture, extension and flexion were occurred in the dog.

c. Laboratory diagnosis

Samples considered significant for diagnostic purposes were taken. Fecal samples and skin scrapings were examined at City Veterinary Hospital Kathmandu Nepal. Blood and urine samples were collected for routine and specific examinations and were examined at Laboratory of City Veterinary Hospital. Owners were asked to perform X-ray to diagnose fracture. Dead pets were subjected to post mortem examination to find out the gross lesions and collect samples for pathological observation.

Among the infected dogs 30 were treated with different commercial drugs. The dogs were divided into 3 groups and treated as shown in Table 1. Among the infected dogs 20 were treated with different commercial drugs. The dogs were divided into 2 groups and treated as shown in Table 2.

Table 1. Grouping of dogs for antibacterial treatment against secondary bacterial infection in canine parvo virus infection

Name of the group	No. of dogs treated	Name of drugs	Dose & route of administration
Group-A	10	Amoxicillin	@ 20 mg/kg body wt. i/v daily for 7 days
Group-B	10	Ceftriaxone	@ 25 mg/kg body wt. i/v daily for 7 days
Group-C	10	Enrofloxacin	@ 8 mg/kg body wt. i/v daily for 7 days

Table 2. Grouping of dogs for evaluation efficacy of commercial drugs against Ehrlichiosis

Name of the group	No. of dogs treated	Name of drugs	Dose & route of administration
Group-D	10	Doxycycline	@ 10mg/kg body wt. i/v daily for 3 days followed by orally for 18 days
Group-E	10	Rifampicin	@ 20 mg/kg body wt. orally daily for 21 days

Data analysis

Results are reported as percentage and the differences between the case and control groups for age, gender, season and breed were compared with X^2 analysis. All analyses were performed with standard software (SPSS, version 20.0, SPSS Inc, Chicago, III); values of $p < 0.05$ were considered significant.

RESULTS AND DISCUSSION

Different clinical and laboratory methods were used to study the prevalence of clinical diseases and disorders of pet dogs in City Veterinary Hospital during July 2020 to June 2021. A total of 1409 pet dogs were examined for diseases and conditions.

Prevalence of clinical diseases and disorder of pet dogs:

Among all diseases and disorders the highest prevalence was seen by viral disease (26.54%), followed by digestive disorders (10.14%), Ear and eye disease (8.72%), respiratory disorders (7.73%), fungal disease (7.16%), protozoan disorders

(6.52%), Urinary disorders (5.53), Metabolic and nutritional disease (5.39%), genital disease (5.03%), skin disorders (4.54%), helminthiasis (3.97%), external parasite (3.12%), poisoning (3.12%), and lowest by edema (2.41%) shown in Table 3.

Table 3. Prevalence of clinical diseases and condition of pet dog

Diseases/ Disorders	No of affected dogs	Prevalence (%)	Level of significance
Digestive disorders	143	10.14	<0.001***
Respiratory disorders	109	7.73	
Genital	71	5.03	
Viral	374	26.54	
Helminthiasis	56	3.97	
Protozoan diseases	92	6.52	
External parasite	44	3.12	
Ear and eye diseases	123	8.72	
Urinary disorders	78	5.53	
Edema	34	2.41	
Metabolic and nutritional	76	5.39	
Poisoning	44	3.12	
Fungal (Dermatomycosis)	101	7.16	
Skin disorders	64	4.54	

***means statistically highly significant

Age-wise prevalence of clinical diseases and condition of pet dogs

It is observed that the prevalence of diseases and disorders was highest above 36 months of age group and moderate in 7-36 months' age and lowest in 0- 6months age groups shown in Figure 2.

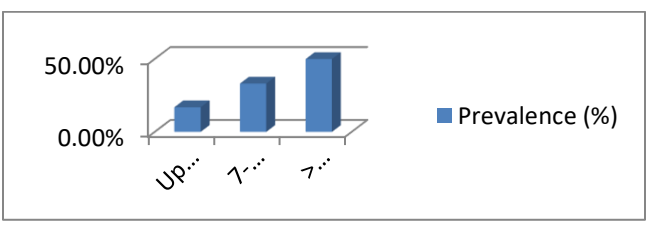

Figure 2. Age-wise prevalence of clinical diseases and condition of pet dogs
(P-value = 0.001***) ***means statistically highly significant

Season-wise prevalence of clinical diseases and disorders of pet dogs:
According to season the highest prevalence (29.59%) was seen in winter season (December-February) followed by 25.90% in summer (March-May), 24.27% in autumn and lowest 20.22 % in rainy season shown in Table 4.

Table 4. Season-wise prevalence of clinical diseases and disorders of pet dogs

Season	No. of affected dogs	Prevalence (%)	P Value
Summer (Mar-May)	365	25.90	<0.001***
Rainy (June-Aug)	285	20.22	
Autumn (Sep-Nov)	342	24.27	
Winter (Dec-Feb)	417	29.59	

**means statistically significant at 1% level of significance

Breed-wise prevalence of clinical diseases and disorders of pet dogs
According to breed the highest prevalence 34.56% of clinical disease and disorders were seen in local dogs followed by 14.05% in German shepherd dogs, 10.14% in Labrador breed, 7.94% in pug, 7.59% in Golden Retriever breed, 6.03 % in lhasa Apso breed, 5.89% in Doberman breed, 4.61% in Spitz breed, 3.97% in Boxer breed, 3.26% in Beagle breed and lowest 1.92% seen in Spaniel breed and shown in Table 5.

Table 5. Breed-wise prevalence of clinical diseases and disorders of pet dogs

Total no. of dogs	Name of the breed	No. of affected dogs	Prevalence (%)	P Value
1409	German Shepherd	198	14.05	<0.000***
	Local	487	34.56	
	Doberman	83	5.89	
	Golden Retriver	107	7.59	
	Lhasa-Apso	85	6.03	
	Labrador	143	10.14	
	Pug	112	7.94	
	Boxer	56	3.97	
	Spaniel	27	1.92	
	Beagle	46	3.26	
	Spitz	65	4.61	

***means statistically highly significant

Efficacy of antibacterial drugs against secondary bacterial infection in canine parvo virus infection

Among the canine parvo virus infected dog, 30 animals were selected for antibacterial treatment against secondary bacterial infection. The antibacterial efficacy of Amoxicillin (Clavam®, Alkem Ltd.), Ceftriaxone (Monocef®, Aristo Ltd.) and Enrofloxacin (K FLOX®, KAP Animal Health Ltd.) were determined on the basis of recovery of the disease showed in table 6. The present study demonstrated the excellent efficacy of Amoxicillin @ 20 mg/kg body weight against secondary bacterial infection of canine parvo virus infection that significantly ($P<0.05$) reduced the lesions of CPVI within 6.0±0.32 days than Ceftriaxone @ 25 mg/kg body weight and Enrofloxacin @ 8 mg/kg body weight that took recovery period of 7.4±0.25and 7.9±0.37 days respectively. Amoxicillin injection was found more effective to control the secondary bacterial infections and healing of CPVI lesion than the other Ceftriaxone and Enrofloxacin.

Efficacy of commercial drugs against Ehrlichiosis in dog:

Among the Ehrlichiosis infected dog, 20 animals were selected for treatment. The efficacy of drug Doxycycline (Docline®, Ear india overseas) and Rifampicin (R-Cin®, Lupin Ltd.) were determined on the basis of recovery of the disease showed in Table 7. The present study demonstrated the excellent efficacy of Doxycycline @ 10 mg/kg body weight against Ehrlichiosis reduced the clinical signs within 5.0±0.32 days than Rifampicin @ 20 mg/kg body weight orally that took recovery period of 8.0±0.25 days.

Table 6. Efficacy of antibacterial drugs against secondary bacterial infection in canine parvo virus infection

Name of the group	No. of animal treated	Name of antibiotic	Dose & route of administration	Average duration of complete recovery (days) (Mean±SE)
Group-A	10	Amoxicillin	@ 20mg/kg body wt. i/v daily for 7 days	6.0±0.32
Group-B	10	Ceftriaxone	@ 25 mg/kg body wt. i/v daily for 7 days	7.4±0.25
Group-C	10	Enrofloxacin	@ 8mg/kg body wt. i/v daily for 7 days	7.9±0.37
Level of significance				0.070 (NS)

NS = means not significant

Table 7. Efficacy of commercial drugs against Ehrlichiosis in dog

Name of the group	No. of animal treated	Name of antibiotic	Dose & route of administration	Average duration of complete recovery (days) (Mean±SE)
Group-D	10	Doxycycline	@ 10mg/kg body wt. i/v daily for 3 days followed by orally for 18 days	5.0±0.32
Group-E	10	Rifampicin	@ 20 mg/kg body wt. orally daily for 21 days	8.4±0.25
Level of significance				0.170 (NS)

NS = means not significant

DISCUSSION

The different clinical and laboratory methods were used to study the prevalence of clinical diseases and disorders of pet dogs in City Veterinary Hospital Kathmandu Nepal for a period of 1 year. A total of 1409 sick pet dogs were examined during the study.

Prevalence of clinical diseases and condition of pet dogs

In this study the prevalence of Viral Disease was (26.54%) and internal parasites was (3.97%) which were higher than the findings of Hossain *et al.*, (2017) and Tarafder and Samad (2010). The prevalence of digestive disorders was (10.14%) which is closely related with the findings of Rakha *et al.*, (2015). In this study the prevalence of skin diseases was 7.16% which were lower than the study of Runa *et al.*, (2016) who found 18.69% skin infection. The prevalence of protozoan disease 6.52% was Lower with the findings of Smith *et al.*, (2011) and higher than the study of Samad *et al.*, (2010). Fungal disease and viral diseases of our study was Higher than the findings of Hossain *et al.* (2017).

Age-wise prevalence of clinical diseases and condition of pet dogs

In my study the prevalence of clinical diseases and disorders was highest above 36 months of age group and moderate in 7-36 months' age and lowest in 0-6months age groups which is similar with the findings of Tarafder and Samad (2010).

Season-wise prevalence of clinical diseases and condition of pet dogs

In this study the prevalence (29.59%) was highest in winter season (December-February) followed by 25.90% in summer (March-May), 24.27% in autumn and lowest 20.22 % in rainy season which were lower than the findings of Ghada Tagorti (2019) and similar with the findings of Hossain *et al.* (2017).

Breed-wise prevalence of clinical diseases and condition of pet dogs

In my study the highest prevalence 34.56% of clinical disease and conditions were seen in local dogs followed by 14.05% in German shepherd dogs, 10.14% in Labrador breed, 7.94% in pug, 7.59% in Golden Retriever breed, 6.03 % in lhasa Apso breed, 5.89% in Doberman breed, 4.61% in Spitz breed, 3.97% in Boxer breed,3.26% in Beagle breed and lowest 1.92% seen in Spaniel breed, all the findings are nearly similar with the findings of Tarafder and Samad (2010).

Efficacy of antibacterial drugs against secondary bacterial infection in canine parvo virus infection

The antibacterial efficacy of Amoxicillin (Clavam®, Alkem Ltd.), Ceftriazone (Monocef®, Aristo Ltd.) and Enrofloxacine (Bacnil®, JJ Laboratories pvt.Ltd.) were determined on the basis of recovery of the disease. The present study demonstrated the excellent efficacy of Amoxicillin @ 20mg/kg body weight against secondary bacterial infection of canine parvo virus infection that significantly ($P<0.05$) reduced the lesions of CPVI within 6.0±0.32 days which was similar with the findings of Kataria and Agnihotri *et al.*, (2020).

Efficacy of commercial drugs against Ehrlichiosis in dog

The present study demonstrated the excellent efficacy of Doxycycline @ 10mg/kg body weight against Ehrlichiosis reduced the clinical signs within 5.0±0.32 days than Rifampicin @ 20 mg/kg body weight orally that took recovery period of 8.0±0.25 days was similar with the findings of Harrus *et al.*, (1998).

CONCLUSION

On the basis of present findings, conclusion were found that among the clinical disease and disorders in dogs the highest prevalence was seen by Viral (26.54%) and the lowest prevalence was by Edema (2.41%),according to age wise distribution of diseases old dogs were more prone to disease and disorders than younger dogs ,seasonal prevalence of clinical disease were found more in winter season ,according to breed wise prevalence pure breed were found less prone to disease than local disease ,according tochoice of antibiotic for reduction of secondary bacterial infection was Amoxicillin as it significantly reduces the secondary bacterial infection in canine parvo virus infection than other antibacterial drugs.

REFERENCES

Anene BM, Nnaji TO and Chime AB, (1996). Intestinal parasitic infections of dogs in the Nsukka area of Enugu, Nigeria. *Preventive Veterinary Medicine*,27: 89-94.

Awad RA, Martens B and Hassan SA, (2019). Successful Treatment of Canine Parvovirus Infection in Naturally Infected Puppies. *Asian Journal of Scientific Research*, 12: 308-315.

Belsare AV and Gompper ME, (2013). Assessing demographic and epidemiologic parameters of rural dog populations in India during mass vaccination campaigns. *Preventive Veterinary Medicine*.111(1-2):139-46.

Biswas HR, Hoque MM, Samad MA and Rahman A, (1996). Prevalence of in apparent rabies infection in street dogs. *Bangladesh Veterinarian*,13: 29-31.

Blixenkrone-Moeller M, Svansson V, Have P, Örvell C, Appel M, Pedersen IR, Dietz HH, Henriksen P, (1993). Studies on manifestations of canine distemper virus infection in an urban dog population. *Veterinary microbiology*.37(1-2):163-73.

Dada BJO, Adegboye DS and Mohammaed ANA, (1979). A survey of gastrointestinal parasites of stray dogs in Zaria Negeria. *Veterinary Record*,104: 145-146.

Dan GON, David BC, Paul DM, Peter CT and Dave CB, (2014). Prevalence of disorders recorded in dogs attending primary-care veterinary practices in England. *PLoS One*. 4;9(3):e90501. doi: 10.1371/journal.pone.0090501. PMID: 24594665; PMCID: PMC3942437.

Dohoo IR, McDonell WN, Rhodes CS and Elazhary YL, (1998). Veterinary research and human health. *Canadian Veterinary Journal*, 39: 549-556.

Gamage BGSS and Dissanayake DRA, (2020). Risk, prognosis and causality of parvo viral enteritis in dogs in Sri Lanka, Comparative Immunology, Microbiology and Infectious Diseases, Volume 72

Gberindyer FA, Abatan MO, Apaa TT and Tion TM 2017. Drugs Prescription Pattern in Dogs Diagnosed with Parvovirus Enteritis in Some Veterinary Clinics in Nigeria. *Nigerian Veterinary Journal* 38(3). 250-259.

Gelatt KN and MacKay EO, (2005). Prevalence of primary breed-related cataracts in the dog in North America. *Veterinary Ophthalmology*, 8: 101-111.

Harrus S, Waner T, Aizenberg I and Bark H, (1998). Therapeutic effect of doxycycline in experimental subclinical canine monocytic ehrlichiosis: evaluation of a 6-week course. *Journal of clinical microbiology*. 36(7):2140-2.

Hossain MA, Islam MR and Rahman MM, (2017). A retrospective study on dog diseases in Sylhet City of Bangladesh. *Inter J Vet Sci*, 6(3): 127-130.

Hossain SSMR and Kayesh MEH, (2014). Common diseases of pet animals in Dhaka city and their zoonotic importance, *International Journal of Natural and Social Sciences* 1 , 81-84

https://www.researchgate.net/figure/Urbanizing-Nepal-showing-the-Kathmandu-Valley-in-the-set-map_fig1_332713605

Irwin PJ and Jefferies R, (2004). Arthropod-transmitted diseases of companion animals in Southeast Asia. *Trends in Parasitology*, 20 (1): 27-34.

Kataria D and Agnihotri D, (2020). Molecular Occurrence and Therapeutic Management of Canine Parvovirus Infection in Dogs, *International Journal of Current Microbiology and Applied Sciences* ISSN: 2319-7706 Volume 9.

Katagiri S and Oliveira-Sequeira TC, (2008). Prevalence of dog intestinal parasites and risk perception of zoonotic infection by dog owners in São Paulo State, Brazil. *Zoonoses Public Health*.55(8-10):406-13. doi: 10.1111/j.1863-2378.2008.01163.x. PMID: 18811905

Kornblatt AN and Schantz PM, (1980). Veterinary and public health considerations in canine roundworm control. A survey of practicing veterinarians. *Journal of American Veterinary Medical Association*. 195: 1212-1215

Kongkaew W, Coleman P, Pfeiffer DU, Antarasena C and Thiptara A, (2004). Vaccination coverage and epidemiological parameters of the owned-dog population in Thungsong District, Thailand. *Preventive veterinary medicine*.65(1-2):105-15.

Lorusso V, Dantas- Torres F, Lia R P, Tarallo VD, Mencke N, Capelli G and Otranto D (2010). Seasonal dynamics of the brown dog tick, Rhipicephalus sanguineus, on a confined dog population in Italy. *Medical and Veterinary Entomology*, 24: 309-315.

Manzoor S and Jamil A (2013). Canine parvovirus associated with bloody diarrhea in Labrador retriever pup. *Res. j. vet. pract*. 1 (3): 34 – 35.

Menelaos LA and Smaragda KE, 2006. Prevalence of hookworm parasites in dog from the area of Thessaloniki and their zoonotic importance. Buttetin USAMV-CN63: 297 – 303.

Molan AL and Saida LA, (1989). Echinococcosis in Iraq: Prevalence of Echinococcus granulosus in stray dogs in Arbil Province. *Japanese Journal of Medical Sciences and Biology*, 42: 137 – 141.

Molyneux DH, (2004). Neglected diseases but unrecognized successes-challenges and opportunities for infectious disease control. *Lancet* .364: 380 – 283.

Parvez MA, Prodhan MAM, Das BC and Khatun R, (2014). Prevalence of Clinical Conditions in Dogs and Cats at Teaching Veterinary Hospital (TVH) in Chittagong Veterinary and Animal Sciences University, Bangladesh . *Research Journal for Veterinary Practitioners*, 2 (6): 99 – 104.

Rakha GMH, Abdl-Haleem MM, Farghali HAM and Abdel-Saeed H, (2015). Prevalence of common canine digestive problems compared with other health problems at teaching veterinary hospital, Faculty of Veterinary Medicine, Cairo University, Egypt, *Veterinary World* 8(3):403-411.

Rani PAMA, Irwin PJ, Gatne M, Coleman GT and Traub RJ. (2010). Canine vector-borne diseases in India: a review of the literature and identification of existing knowledge gaps. *Parasites & Vectors*, 3 (1). p. 28.

Reddy KB, Shobhamani B, Sreedevi B, Rani PD and Reddy BS, (2015). Prevalence of canine parvovirus in dogs in and around Tirupathi of India. *International Journal of Livestock Research*. 5: 93-98

Robertson ID, Irwin PJ, Lymbery AJ and Thompson RCA, (2000). The role of companion animals in the emergence of parasitic disease. *International Journal of Parasitology*. 30: 1369-1377.

Rodriguez-Vivas RI, Ortega-Pacheco A, Rosado-Aguilar JA and Bolio GM, (2003). Factors affecting the prevalence of mange-mite infestations in stray dogs of Yucatan, Mexico. *Veterinary Parasitology*.115: 61-65.

Runa NS, Uddin AS, Husna A, Runa NY, Yesmin S, Badruzzaman ATM, Islam MS, Noor M, Alam KJ and Rahman MM, (2016). Prevalence of diseases in pet animals at Dhaka city of Bangladesh. *Annals of Veterinary and Animal Science* ,3(3):88-92.

Samad MA, (2008). *Animal Husbandry and Veterinary Science.* Volume 2, LEP Pub. No. 11, BAU Campus, Mymensingh.

Sharma DK, Maldonado JE, Jhala YV and Fleischer RC, (2004). Ancient wolf lineages in India. Proceedings of the Royal Society of London. Series B: *Biological Sciences* ;271(suppl_3):S1-4.

Singla, Das and Lachhman Das, (2016). Critical analysis of vector-borne infections in dogs: Babesia vogeli, Babesia gibsoni, Ehrlichia canis and Hepatozoon canis in Punjab, India" *Acta Parasitologica*, vol. 61, no. 4, pp. 697-706.

Shoorijeh SJ, Ghasrodashti AR, Tamadon A, Moghaddar N and Behzadi MA, 2008. Seasonal frequency of ectoparasites infestation in dogs from Shiraz, Southern Iran. *Turkish Journal of Veterinary and Animal Science* 32: 309 – 313.

Smith FD, Ballantyne, Morgan ER and Wall R, (2011). Prevalence, distribution and risk associated with tick infestation of dogs in Great Britain. *Medical and Veterinary Entomology*;25(4):377-84. doi: 10.1111/j.1365-2915.2011.00954.x. Epub 2011 Mar 21. PMID: 21418263.

Tagorti G, (2019). Disease prevalence among young dogs in Grand Tunis, Tunisia: A retrospective study. *Veterinary World*, 12(4):489-495

Tarafder M and Samad MA, 2010. Prevalence of clinical diseases of pet dogs and risk perception of zoonotic infection by dog owners in Bangladesh. *Bangladesh Journal of Veterinary Medicine*, 8(2): 163 – 174.

Thrusfield MV (2005). Criteria for Success of Questionnaire. In: *Veterinary Epidemiology*.3rd edi., Oxford, UK: Blackwell Science. pp: 189-213.

Umar S, Ali AA, Younus M, Kashif M, Ali S, Khan WA and Irfan M, (2015). Prevalence of Canine Parvovirus Infection at Different Pet Clinics in Lahore, Pakistan. *Pakistan Journal of Zoology* 47(3):657-663 *Pakistan Journal of Zoology*, 47(3):657-663.

Weeks ENI, Allan SA, Gezan SA, (2020). Auto-dissemination of commercially available fungal pathogens in a laboratory assay for management of the brown dog tick Rhipicephalus sanguineus. *Med Vet Entomol*, 34: 184-191.

William A, Chaudharti SUR and Atsanda NN, (2002). Prevalence of some diseases of dogs and cats at the State Government Veterinary Clinic in Maiduguri-Nigeria. *International Journal of Agriculture and Biology*. 4: 568-569.

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COMPARATIVE ANALYSIS OF PACKAGING MATERIALS AND MODIFIED ATMOSPHERIC PACKAGING ON THE POSTHARVEST LIFE OF BROAD LEAF MUSTARD (*Brassica juncea var. rugosa)*

Aashish Ghimire[1*], Krish Rauniyar[1] & Ananta Pudasaini[1]
Himalayan College of Agricultural Sciences and Technology, Kathmandu
***Corresponding Author**: ghimireaashish233@gmail.com

ABSTRACT

In this study, titled "Comparative Analysis of Packaging Materials and Modified Atmospheric Packaging on the Postharvest Life of Broad Leaf Mustard (Brassica juncea var. rugosa)," conducted in HICAST, Kathmandu, Nepal, from June 13 to June 19, 2023, Investigation of the postharvest condition of 17 kg of freshly harvested broad leaf mustard. The experiment employed four distinct packaging materials—polythene, perforated polythene, muslin cloth, and MAP bags—in addition to a control group, following a Completely Randomized Design with four replications. Critical parameters such as shelf life, weight loss, moisture content, chlorophyll content, total soluble solids (TSS), pH, color, and pathological infection at 3-day intervals was monitored and evaluated. Remarkably, T2 (Polythene) and T3 (Perforated polythene) displayed a meager 3-day shelf life due to rapid decay and saturation, warranting early disposal. T5 (MAP Bag) emerged as the standout performer with a substantial average shelf life of 6 days. Moisture loss was most pronounced in the control group (T1), dropping from 96.76% to 91.2%, whereas T4 (Muslin Cloth) reached 94.82%, and T5 recorded 95.5%. MAP bags (T5) also excelled in preserving chlorophyll content and color stability. In conclusion, findings underscore the superiority of MAP bags, particularly T5, in preserving the postharvest quality and prolonging the shelf life of Brassica juncea var. rugosa, offering a promising solution for enhancing postharvest management in horticulture.

Key Words: Broad Leaf Mustard, MAP Bags, Packaging Materials, Post-harvest, Shelf life

INTRODUCTION

Broad Leaf Mustard (BLM), 2n=36, scientifically known as *Brassica juncea* var. *rugosa*, is a popular leafy vegetable in Nepal, cultivated widely for its affordability and nutritional value (Khatiwada, 2008). Commonly referred to as 'Rayo,' it belongs to the Brassicaceae family and is grown in diverse climates, displaying resilience to frost. BLM, with its short shelf life, requires careful handling to maintain quality (Bhattarai, 2018). Leafy vegetables, including BLM, are crucial for global nutrition, offering a cost-effective source of essential nutrients (Kennedy, 2011; Mohammed & Hussaini, 2023). However, addressing postharvest losses is essential for food security, especially in Nepal, where subsistence farming and high postharvest losses contribute to food insecurity (FAO, 2022; *Thapa et al.,* 2019). Innovative solutions like modified atmospheric packaging can extend shelf life and minimize wastage, contributing to sustainable food production (Lucia & Assennato, 1994).

Postharvest losses, a substantial component of food loss and waste, largely stem from biological deterioration after harvest. Fresh fruits and vegetables deteriorate due to factors like respiration, ethylene production, compositional changes, water loss, physiological disorders, and pathological breakdown (Kader, 2004). Mitigating these losses is essential for sustainable food production.

Post-harvest losses indicate quantifiable reductions in both quantity and quality following harvest (Mohammed & Hussaini, 2023). Countries like Nepal grapple with inadequate knowledge of proper practices and technologies, contributing to significant losses in vegetable quality and quantity (Parazuli, 2015). Biological and environmental factors, including transpiration water loss, significantly contribute to postharvest deterioration. Leafy vegetables are deemed unsalable if they lose over 3% of their water content (Ambuko *et al.,* 2017). Broad leaf mustard's cultivation spans 10,851 hectares, yielding 146,756 metric tonnes in Nepal (MoALD, 2022).

Modified Atmosphere Packaging (MAP) involves modifying the atmosphere within a package to enhance shelf life and preserve food quality, achieved either actively or passively (Robertson, 2019). While beneficial, MAP does not replace proper temperature management. Applying passive MAP at non-optimal storage temperatures necessitates finding films with appropriate Oxygen Transmission Rates that align with product respiration rates (Lange, 2000).

MATERIALS AND METHODS

A study conducted at the Himalayan College of Agricultural Sciences and Technology in Nepal examined the postharvest life of Broad Leaf Mustard. The experiment involved using different packaging materials and modified atmospheric packaging. The research utilized ZY No.2 Leaf Mustard and employed a completely randomized design with five treatments.

Treatments:

T1	Control	Broad Leaf Mustard were kept as it is without any treatments.
T2	Polythene Bag	High density polyethylene (HDPE) bags of thickness 40µ were used. No perforations were done.
T3	Perforated Polythene Bag	HDPE bags of thickness 40µ were used by making perforations. Overall, there were 12 perforations.
T4	Muslin Cloth	Muslin cloths were wrapped around the Broad Leaf Mustard.
T5	MAP Bags	Modified atmosphere packaging (MAP) bags which is biodegradable was used as packaging material.

Parameters Observed:

Physical Parameters:

Color: Evaluated using a standardized color chart. The color of the leaves was matched to the closest swatch on the Royal Horticulture Society's color chart to determine color intensity or shade (Royal Horticulture Society, 2019).

Moisture Content/Dry Matter Content: Measured using a precision balance.

$$\text{Moisture Content}(\%) = \frac{\text{Initial Weight Of Fresh Sample} - \text{Weight of Oven Dried Sample}}{\text{Initial Weight Of Fresh Sample}} \times 100\%$$

Biochemical Parameters:

Chlorophyll Content: The chlorophyll content was assessed using the Wellburn technique. Broadleaf mustard's samples weighing 0.2 g was extracted with 7 mL

of 80% acetone and the optical density of the solution was measured at 645 nm and 663 nm (Wellburn, 1994). The chlorophyll content was determined by using equation given below:

- Chlorophyll a (mg/g) = (12.70 × A663 - 2.690 × A645) × V / (1000 × W)
- Chlorophyll b (mg/g) = (22.90 × A645 - 4.680 × A663) × V / (1000 × W)
- Total chlorophyll content = chlorophyll a + chlorophyll b

Where, V= Volume of acetone used and W = weight of the fresh cucumber peels

Total Soluble Solid (TSS): Monitored using a digital refractometer.

pH: Measured using a digital pH meter.

Shelf-life Parameters:

Shelf Life: Assessed by monitoring pathological infestations and marketability.

Weight Loss: Measured using a digital weighing machine (Teixeira *et al.*, 2012).

$$\textbf{Weight Loss}(\%) = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100\%$$

Spoilage Ratio: Calculated based on the count of spoiled or damaged leaves.

$$\textbf{Spoilage Ratio}(\%) = \frac{\text{Initial Total Fresh Leaf} - \text{Fresh leaf}}{\text{Initial total Fresh Leaf}} \times 100\%$$

Pathological Infection: Evaluated by monitoring microbial growth through swabbing and incubation.

Experimental Design:

Replication: The experiment had four replications for each treatment.

Statistical Analysis: Data analysis was conducted using Excel and GENSTAT software, considering various observed parameters.

RESULTS AND DISCUSSION

The research study titled "Comparative Analysis of Packaging Materials and Modified Atmospheric Packaging on the Postharvest Life of Broad Leaf Mustard *(Brassica juncea* var. *rugosa*)" was carried out, on the 4th day of the experiment, treatments 2 and 3 were excluded from further analysis due to their nearly complete decay and saturation in their own liquid. However, the experiment continued with treatments 1, 4, and 5. Detailed findings from the experiment are presented below:

Physical Parameter

Effect of Packaging Materials on Color

Selected fresh and visually appealing leaves from each treatment group were compared. On the initial observation day, leaf color closely matched 140A on the color chart. The MAP bag notably maintained consistent color throughout storage, aligning with Yang *et al.* (2022) findings. Their study indicated that MAP not only preserved color but also increased vitamin C levels, maintained stable polyphenol content, reduced cell membrane damage, suppressed enzymes related to phenolic metabolism, and mitigated lignin deposition during storage.

Table 1. Effect of Packaging materials on Color of Broad Leaf Mustard

Treatment	Initial Color	Days of Storage	
		Color	
		3rd Day	6th Day
T1 (Control)	140A	140B	141C
T2(Normal Polythene (40µ))	140A	144A	N/A
T3 (Perforated Polythene (40µ))	140A	141C	N/A
T4 (Muslin Cloth)	140A	140A	141C
T5 (MAP bag (35µ))	140A	140A	140A

Effect of Packaging Materials on Moisture Content

Freshly harvested produce, with 65-95% water, is regulated by protective layers with small pores, primarily on leaves (Collalti *et al.*, 2020). The study found an initial moisture content of 96.76%. By the 3rd day, moisture varied significantly. T1 (control) had the lowest at 93.87%, T2 (polythene) decayed to 96.46%, T5 (MAP Bag) maintained freshness at 96.33%, T3 (perforated polythene) showed 95.99%, and T4 (wet muslin cloth) had 95.81%. Treatments 2 and 3 were discontinued on day three due to decay.

On the 6th day, T1 wilted to 91.2%, while T5 (MAP Bag) retained the highest moisture at 95.5%, and T4 recorded 94.83%, preserving freshness. The significant results align with Agüero *et al.,* (2011) on lettuce quality loss, emphasizing water

content changes in different storage conditions and variations between outer and inner leaves.

Table 2. Effect of Packaging materials on Moisture Content of Broad Leaf Mustard

Treatment	Initial Moisture Content (%)	Days of Storage	
		Moisture %	
		3rd Day	6th Day
T1 (Control)	96.76	93.87	91.2
T2(Normal Polythene (40µ))	96.76	96.46	N/A
T3 (Perforated Polythene (40µ))	96.76	95.99	N/A
T4 (Muslin Cloth)	96.76	95.81	94.82
T5 (MAP bag (35µ))	96.76	96.33	95.5
Mean		**95.69**	**93.84**
CV %		**0.5**	**1.1**
LSD		**0.71**	**1.76**

Biochemical Parameter

Effect of Packaging Materials on Chlorophyll Content

Chlorophyll is crucial for Broad Leaf Mustard quality, influencing color and freshness. Enzyme-induced degradation, detailed in Table 4 and Appendix 1, follows multi-pathway chlorophyll breakdown (Xiao *et al.,* 2014). Day one average chlorophyll was 0.96 mg/g. By day three, T2 and T3 decayed to 0.15 mg/g and 0.17 mg/g, while the MAP Bag maintained stability at 0.84 mg/g. T1 had 0.46 mg/g, and T4 had 0.55 mg/g. T2 and T3 were discontinued on day four. By day six, T1 and T4 averaged 0.22 mg/g and 0.35 mg/g, respectively, while the MAP Bag retained 0.47 mg/g, double that of T1. Statistical analysis supports the MAP Bag's superior chlorophyll preservation, aligning with Thapa *et al.* (2019).

Table 3. Effect of packaging materials on chlorophyll content of broad leaf mustard

Treatment	Initial Chlorophyll (mg/g)	Days of Storage	
		Chlorophyll Content (mg/g f.w)	
		3rd Day	6th Day
T1 (Control)	0.963	0.46	0.22
T2(Normal Polythene (40µ))	0.963	0.15	N/A
T3 (Perforated Polythene (40µ))	0.963	0.17	N/A
T4 (Muslin Cloth)	0.963	0.55	0.35
T5 (MAP bag (35µ))	0.963	0.84	0.47
Mean		**0.43**	**0.34**
CV %		**32.1**	**47.1**
LSD		**0.21**	**0.28**

Note: f.w = fresh weight

Effect of Packaging materials on TSS

Our research reveals that Broad Leaf Mustard's Total Soluble Solids (TSS) content increases during storage, following an initial steep incline that gradually levels off (Rajak *et al.,* 2014). At the experiment's start, TSS was 2 °Brix. By the 3rd day, T1 had the most significant change, reaching 3.75 °Brix, while T2, T3, T4, and T5 remained stable, indicating a subtle taste alteration. On the 6th day, the control group (T1) showed the highest increase to 5.75 °Brix, T4 reached 5 °Brix, and T5 had the smallest change at 4.25 °Brix, suggesting a relatively sweeter taste in the other treatments compared to the MAP bag. T5 exhibited a more consistent and natural taste. Notably, although T2 and T3 maintained constant TSS levels, they decayed and became unusable.

Effect of packaging materials on pH

Vegetables' pH levels decrease as nutrient constituents diminish (Fimbres-Acedo *et al.,* 2023). On day one, the pH was 5.24, gradually increasing. By day 3, T3 had the highest pH at 8.57, followed by T2 at 8.1 due to decay. T5 showed the least variation with a stable pH of 5.66. T4 increased to 5.98, while T1 reached 5.89.

Table 4. Effect of Packaging materials on TSS of Broad Leaf Mustard

Treatment	Initial TSS (° Brix)	Days of Storage (° Brix)	
		3rd Day	6th Day
T1 (Control)	2	3.75	5.75
T2(Normal Polythene (40µ))	2	2	N/A
T3 (Perforated Polythene (40µ))	2	2	N/A
T4 (Muslin Cloth)	2	3	5
T5 (MAP bag (35µ))	2	3	4.25
Mean		**2.75**	**5**
CV %		**8.1**	**18**
LSD		**0.35**	**1.55**

Treatments 2 and 3 were discontinued on day 4 due to decay. By then, T5's pH was 6.01, T1 and T4 reached 6.51 and 6.61, respectively. pH tends to increase with extended storage of green leafy vegetables, less pronounced in T5 (MAP bag). T4 and T1 also had relatively minor pH alterations.

Table 5. Effect of packaging materials on ph of broad leaf mustard

Treatment	Initial pH	Days of Storage pH	
		3rd Day	6th Day
T1 (Control)	5.24	5.89	6.51
T2(Normal Polythene (40µ))	5.24	8.1	N/A
T3 (Perforated Polythene (40µ))	5.24	8.57	N/A
T4 (Muslin Cloth)	5.24	5.98	6.61
T5 (MAP bag (35µ))	5.24	5.66	6.01
Mean		**6.84**	**6.38**
CV %		**3.9**	**2.7**
LSD		**0.41**	**0.30**

Shelf-Life parameters

Effect of Packaging Materials on Shelf Life

Research shows that T5 (MAP Bags) exhibited the longest average shelf life, approximately 6 days, followed closely by T4 (Wet Muslin Cloth) and T1 (Control) with 4.5 and 4 days, respectively. In contrast, T2 (Polythene) and T3 (Perforated Polythene) had the shortest average shelf life at 3 days. These findings align with Thapa *et al.* (2019), who observed extended shelf life for broadleaf mustard stored in Modified Atmosphere Packaging (MAP) bags.

Broad Leaf Mustard's shelf life is influenced by factors pre- and post-harvest, such as rootstock selection, cultivar choice, cultural practices, harvesting conditions, and maturity stage (Kader *et al.,* 1973). Post-harvest considerations include operational efficiency, pre-cooling methods, treatments like fungicides, and overall storage process efficiency.

Table 6. Effect of Packaging Materials on Shelf Life of Broad Leaf Mustard

Treatment	Average Shelf Life (Days)
T1 (Control)	4
T2(Normal Polythene (40µ))	3
T3 (Perforated Polythene (40µ))	3
T4 (Muslin Cloth)	4.5
T5 (MAP bag (35µ))	6.25
Mean	**4.05**
CV %	**17.3**
LSD	**1.08**

Effect of Packaging Materials on Weight loss

Broad Leaf Mustard faces weight loss after harvest due to factors like transpiration and respiration, causing shrinkage. Leafy greens, with over 90% water content, are particularly vulnerable to such issues. The choice of packaging is crucial to combat these challenges (Mohammed & Hussaini, 2023).

In a 7-day study, significant differences in weight loss were noted. By the 3rd day, losses ranged from 1.51% to 35.34%. The control group (T1) suffered the most, while T2 (Polythene) had the least due to its sealed packaging. T2 and T3 deteriorated quickly. By the 6th day, T4 (Wet Muslin Cloth) had the highest weight loss at 33.08%, and the MAP Bag (T5) had the lowest at 8.70%.

The MAP Bag (T5) maintained freshness, unlike T2, which, despite showing no weight loss, had decayed leaves stuck to the polythene by day 4. T5 persevered, keeping low weight loss and freshness. Statistical analysis validated results on the 3rd and 6th day, aligning with Thapa *et al.* (2019), emphasizing the packaging's crucial role in mitigating weight loss in Broad Leaf Mustard.

Table 7. Effect of Packaging materials on Weight Loss of Broad Leaf Mustard

Treatment	Initial Weight (g)	Days of Storage	
		Weight loss (%)	
		3rd Day	6th Day
T1 (Control)	2435	35.34	39.46
T2(Normal Polythene)	2445	1.51	N/A
T3(Perforated Polythene)	2446	12.88	N/A
T4 (Muslin Cloth)	2487	27.67	33.08
T5 (MAP Bag)	2424	6.07	8.7
Mean		**16.69**	**23.75**
CV		**12.9**	**19.9**
LSD		**3.31**	**8.19**

Effect of Packaging materials on Spoilage

Packaging is vital for preserving leaf lettuce quality, but polymeric films, while reducing deterioration, can introduce issues like moisture and decay. Spoilage in Broad Leaf Mustard was observed in different treatments. By day 3, T3 had the highest spoilage at 94.68%, while the MAP bag had the least at 33.74%. T1 had 65.31% spoilage, and T4 had 77.9%. Despite some wilted leaves in T1, most remained marketable. T2 had the second-highest spoilage. Treatments 2 and 3 decayed and were discontinued by day 4.

By day 6, spoilage was highest in T4 at 89%, followed by T1 at 74.95%, with the MAP bag having the least at 47.8%. MAP bags proved significantly better for long-term storage, reducing spoilage in Broad Leaf Mustard compared to T2, T3, and T4. These results align with Thapa et al. (2019), emphasizing the superiority of MAP bags in decreasing decay and extending shelf life by slowing respiration and reducing moisture loss.

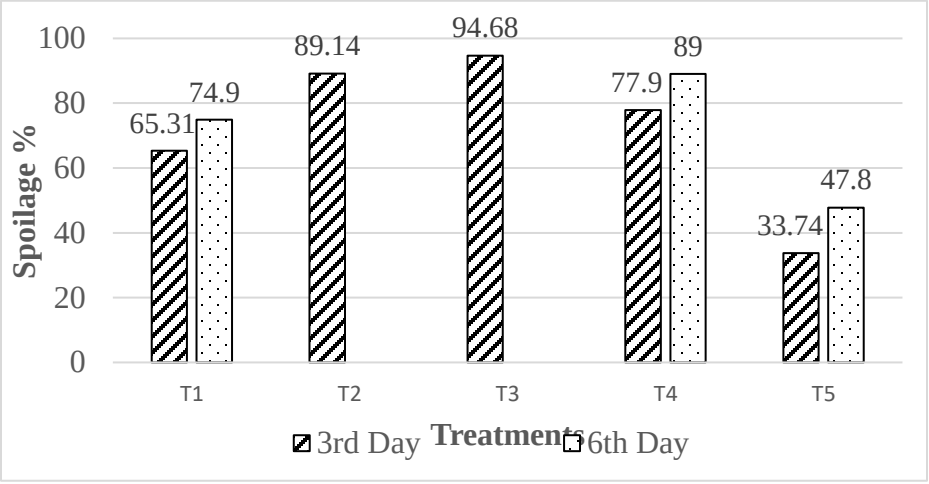

Figure 1. Effect of Packaging materials on Spoilage of Broad Leaf Mustard

Effect of Packaging Materials on Pathological Infection

Pathological diseases challenge Broad Leaf Mustard's postharvest handling, impacting marketability and shelf life. Research on microbial growth found no growth on the 1st and 3rd days. By the 6th day, microbial growth appeared in T1 and T4. T2 and T3 decayed rapidly, submerging in liquids by the 4th day. T4 showed some decay, possibly due to constant moisture. T5 had incipient decay at basal leaf ends, maintaining overall freshness. The control group (T1) had no decay but rapid wilting and yellowing from moisture loss.

In summary, T1 (Control) showed no decay but rapid wilting. T5 (MAP Bag) had minimal decay, maintaining overall freshness. These findings align with Khan (2020) and Thapa *et al.* (2019), emphasizing passive modified atmosphere packaging's efficacy in mitigating postharvest infestations and extending storage life, consistently upholding product quality.

CONCLUSION

In this research investigation, the impact of various packaging materials, particularly Modified Atmospheric Packaging (MAP) bags, on postharvest broadleaf mustard quality was assessed. The findings highlighted the remarkable performance of MAP bags, exemplified by T5, which extended shelf life to an impressive 6 days while minimizing weight loss. Notably, T2 (Polythene), despite indicating less weight loss, concealed complete decay due to its airtight condition.

In contrast, T2 and T3 treatments experienced swift and comprehensive deterioration, leading to early disposal. These results underscore the unparalleled effectiveness of MAP bags in preserving postharvest broadleaf mustard, consistently maintaining critical quality parameters such as color, chlorophyll content, and pH. As such, MAP bags emerge as the superior choice for extending the freshness and longevity of this vegetable during postharvest handling. To address moisture loss, exploring options like T4 & T5 (MAP Bag) which retained higher moisture levels compared to others, is recommended. In terms of superior parameters, MAP bags outperformed all other packaging materials in preserving postharvest Broad leaf mustard quality.

REFERENCES

Adhikari, B., & G.C., A. (2021). Post-harvest practices of horticultural crops in Nepal: Issues and management. *Archives of Agriculture and Environmental Science, 6*(2), 227-233. Retrieved July 3, 2023

Adhikari, S., Bhusal, Y., Paudel, S., Lohani, S., & Aryal, L. (2021). Performance Evaluation Of Broadleaf Mustard Varieties In The Mid-Hill Condition Of Kaski District, Nepal. Kaski.

Agüero, M., Ponce, A., Moreira, M., & Roura, S. (2011). Lettuce quality loss under conditions that favor the wilting phenomenon. . *Postharvest Biology and Technology*, 124–131.

Ambuko, J., Wanjiru, F., Chemining'wa, G. N., Owino, W., & Mwachoni, E. (2017). Preservation of Postharvest Quality of Leafy Amaranth(Amaranthus spp.) Vegetables Using Evaporative Cooling. *Journal of Food Quality*, 1-6.

Badia-Melis, R., Mc Carthy, U., Ruiz-Garcia, L., Garcia-Hierro, J., & Villalba, J. (2018). New trends in cold chain monitoring applications—A review. *Food Control, 86*, 170–182.

Batziakas, K., Singh, S., Ayub, K., Kang, Q., Brecht, J. K., Rivard, C. L., & & Pliakoni, E. D. (2020). Reducing Postharvest Losses of Spinach Stored at Non-optimum Temperatures with the Implementation of Passive Modified Atmosphere Packaging. *HortScience, 55*(3), 326–335.

Batziakas, K., Stanley, H., Batziakas, A., Brecht, J., C., R., & Pliakoni, E. (2020). Reducing postharvest food losses in organic spinach with the implementation of high tunnel production systems. *Agronomy for Sustainable Development, 42*.

Berba, K. J., & Uchanski, M. E. (2012). Postharvest physiology of microgreens. *Journal of Young*(24), 1-5.

Bhattarai, D. (2018). Postharvest horticulture in Nepal. *Horticulture International Journal, 2*(6), 458-460.

Bovi, G. Linke, M., Rauh, C., & Mahajan, P. (2016). Transpiration and moisture evolution in packaged fresh horticultural produce and the role of integrated mathematical models: A review. *Biosystems Engineering, 150*, 24-39.

Brandenburg, J. (2022, January). *International Fresh Produce Association.* Retrieved 07 2, 2023, from https://www.freshproduce.com/siteassets/files/sustainability/map-white-paper.pdf

Cantwell, M., & Kasmire, F. (2002). Postharves handling systems: flower, leafy and stem vegetables. *Postharvest Technology of horticulture crops*(3311), 423-433.

Cantwell, M., Rovelo, J., Nie, X., & Rubatzky, V. (1998). Specialty Salad Greens: Postharvest Physiology and Shelf-Life . *Postharvest physiology and shelf-life. Acta Horticulturae*(467), 371-377.

Carthy, M., Uysal, U., & Badia, M. (2018). Global food security–Issues, challenges. *Trends Food Science Technology*(77), 11-20.

Cheptoo, G., Owino, W., & Kenji, G. (2020). Effect of Different Packaging Materials on β-carotene and Vitamin C Content of Minimally Processed African Indigenous Leafy Vegetables. *Journal of Medicinally Active Plants, 9*(2), 98-110.

Collalti, A., Tjoelker, G., Hoch, G., Mäkelä, A., Guidolotti, G., Heskel, M., . . . Battipaglia, G. (2020). Plant respiration: Controlled by photosynthesis or biomass? *Global Change Biology, 26*(3), 1739-1753.

Dahal, K., Timilsena, J., & Gautam, M. (2021). Investigation on Probabilistic Model for Corrosion Failure Level of Buried Pipelines in Kirtipur Urban Areas (Nepal). *Journal of Failure Analysis and Prevention, 21*, 3. Retrieved 7 2, 2023

Dayarathna, N., Gama, N., Damunupola, J., Xiao, Z., Gamage, A., Merah, O., & Madhujith, T. (2023). Effect of Storage Temperature on Storage Life and Sensory Attributes of Packaged Mustard Microgreens. *Life, 13*(2), 393.

FAO. (1989). *Prevention of post-harvest food losses fruits, vegetables and root crops a training manual* (17 ed.). Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO. (2022). *FAO In Nepal*. Retrieved 06 01, 2023, from https://www.fao.org/nepal/fao-in-nepal/nepal-at-a-glance/en/

Fimbres-Acedo, Y., Traversari, S., Cacini, S., Costamagna, G., Ginepro, M., & Massa, D. (2023). Testing the Effect of High pH and Low Nutrient

Concentration on Four Leafy Vegetables in Hydroponics. *Agronomy, 3*(13).

Gago, P., Ghidelli, C., & Maria, B. (2016). Recent advances in modified atmosphere packaging and edible coatings to maintain quality of fresh-cut fruits and vegetables. Valencia, Spain: R & D Department, Advanced Technologies Inspiralia.

Garande, V., Raut, P., Shinde, U., Dhumal, S., Sonawane, P., & Sarvade, S. (2019). Studies on Storage Behavior of Primary Processed Leafy Vegetables under Different Storage Conditions. *Int.J.Curr.Microbiol.App.Sci*, 2249-2272.

Ghimire, D., Lamsal, G., Paudel, B., Khatri, S., & Bhusal, B. (2018). Analysis of Trend in Area, Production and Yield of Major Vegetables of Nepal. *Trends in Horticulture, 1*(2).

Gil, M., Tudela, J., Martínez, A., & MC, L. (2012). Harvest maturity indicators of leafy vegetables. *Stewart Postharvest Review, 1*(1).

Gillespie, D., Kubota, C., & Miller, S. A. (2020). Effects of Low pH of Hydroponic Nutrient Solution on Plant Growth, Nutrient Uptake, and Root Rot Disease Incidence of Basil (Ocimum basilicum L.). *HortScience horts, 55*(8), 1251-1258.

Graziele, G., Oluwafemi, J., Linke, M., Rauh, C., & Mahajan, P. V. (2016). Transpiration and moisture evolution in packaged fresh horticultural produce and the role of integrated mathematical models: A review. *Biosystems Engineering, 150*, 24-29.

Harker, F., Feng, J., Johnston, J., Gamble, J., Alavia, M., Halla, M., & Chheanga, S. (2019). Influence of postharvest water loss on apple quality: The use of a sensory panel to verify destructive and non-destructive instrumental measurements of texture. *Postharvest Biology and Technology, 148*, 32-37.

Imathiu, S. (2021). Neglected and Underutilized Cultivated Crops with Respect to Indigenous African Leafy Vegetables for Food and Nutrition Security. *Journal of Food Security, 9*(3), 115-125.

Jambhekar, H. (1992). Use of earthworm as potential source of decomposed organic wastes. *National Seminar on Organic farming* (pp. 52-53). Pune: Mahatma Phule Krishi Vidyapeeth.

Kader, A., & Rolle, R. (2004). The role of postharvest management in assuring the quality and safety of horticultural produce. *FAO Agricultural Services Bulletin, 152*.

Kader, A., Lipton, W., & Morris, L. (1973). Systems for scoring quality of harvested lettuce. *Horticulture Science, 8*, 408-410.

Kader, A., Zagory, D., Kerbel, E., & Wang, C. (1989). Modified atmosphere packaging of fruits and vegetables. *Critical Reviews in Food Science and Nutrition, 28*(1), 1-14.

Kawas, H. (2012). *Microbiology Practical Guide.* Retrieved 6 11, 2023, from https://www.researchgate.net/profile/Houda_Kawas/post/Does_anyone_know_how_to_extract_microorganism_from_soil/attachment/59d6467779197b80779a17e4/AS%3A458082133254144%401486226699094/download/PRACTICAL+GUIDE-2012-A.pdf

Kennedy, D. (2011). 21st Century Greens Leaf Vegetables in Nutrition and Sustainable Agriculture. In D. Kennedy, *21st Century Greens Leaf Vegetables in Nutrition and Sustainable Agriculture* (pp. 19-21). USA: Leaf for Life.

Khan, M. (2020). Modified Atmosphere Packaging Technique: An Overview. (pp. 11-16). Aligarh: ResearchGate.

Khatiwada, P. (2008). Broadleaf Mustard Production during Dry Season by Altering Husbandry Practices. *Nepalese Horticulture, 6*, 39-45.

Koca, N., Karadeniz, F., & Burdurlu, H. (2007). Effect of pH on chlorophyll degradation and colour loss in blanched green peas. *Food Chemistry, 100*(2), 609–615.

Lange, D. (2000). New Film Technologies for. *HortTechnology*, 487-490.

Lee, J., & Dulal, C. (2018). Effects of different packaging materials and methods on the physical, biochemical and sensory qualities of lettuce. *Joural of food Science and Technology, 55*, 1685–1694.

Lin, P., Hongmei, D., Wang, G., Zhiqing, L., Huanxiu, L., Zhang, F., & Sun, B. (2021). Modified Atmosphere Packaging Maintains the Sensory and Nutritional Qualities of Post-harvest Baby Mustard During Low-Temperature Storage. *Frontliners In Nutrition, 8*(730253).

Lucia, M., & Assennato, D. (1994). *Agricultural engineering in development* (93 ed.). Rome, Italy: Food and Agriculture Organization of the United Nations.

Lufu, R., Ambaw, A., & Opara, U. (2020). Water loss of fresh fruit: Influencing pre-harvest, harvest and postharvest factors. *Scientia Horticulturae, 272*.

Manolopoulou, T., & Varzakas, E. (2016). Effect of Temperature in Color Changes of Green Vegetables. *Current research in Nutrition and food science*(4).

Mgaya-Kilima, B., Remberg, S., Chove, B., & Wicklund, T. (2014). Influence of storage temperature and time on the physicochemical and bioactive properties of roselle-fruit juice blends in plastic bottle. *Food Science Nutrition*, 181-191.

MoALD. (2022). Statistical Information on Nepalese Agriculture (2020/21). 200.

Mohammed, A., & Hussaini, U. (2023). Assessment Of Post Harvest Losses Of Leafy Vegetables Among Rural Farmers In Kano And Jigawa State, Nigeria. *Bichi Journal of Education*, *17*(1), 26-32.

Opara, O., Caleb, J., Mahajan, P., Said, F., & Linus, U. (2013). Modified Atmosphere Packaging Technology of Fresh and Fresh-cut Produce and the Microbial Consequences - A Review. *Food Bioprocess Technol, 6*, 303-329.

Parazuli, A. (2015, 02 13). *Agrarian Blog*. Retrieved 05 28, 2023, from Wordpress: https://parajulianish.wordpress.com/2015/02/13/cultivation-and-management-practices-of-leafy-vegetables-in-nepal/

Paudel, M., Joshi, B., & Ghimire, K. (2016). Management Status of Agricultural Plant Genetic Resources in Nepal. *Agronomy Journal of Nepal, 4*, 75-91.

Porat, R., Lichter, A., Terry, L., Harker, R., & Buzby, J. (2018). Postharvest losses of fruit and vegetables during retail and in consumers' homes : Quantifications, causes, and means of prevention. *Postharvest Biol. Technology*(139), 135-149.

Prusky, D. (2011). Reduction of the incidence of postharvest quality losses, and future prospects. *Food Security, 3*, 463–474.

Rajak, D., Sharma, P., & Kumar, S. (2014). Effect of total soluble solid during storage of litchi fruits under different temperatures. *Advance Applied Science Ressearch*, 117-121.

Raseetha, S., & Nadirah, S. (2018). Effect of different packaging materials on quality of fresh-cut broccoli and cauliflower at chilled temperature. *International Food Research Journal, 25*(4), 1559-1565.

Reid, M. (2002). Maturation and maturity indices. *Postharvest technology of horticultural crops, 3311*, 55-62.

Robertson, G. (2019). Reference Module in Food Science. *History of Food Packaging*, 45.

Royal Horticulture Society. (2019). *International Lilac Society*. Retrieved 05 11, 2023, from https://www.internationallilacsociety.org/wp-content/uploads/2019/12/Lilac-Color-Groups-by-RHS-columns.pdf?fbclid=IwAR1gBAubnBe9DZE3ujoJUoMqGltOR_CMinQUra7JKjBZbztTlvywyCGHkZQ

Sanjay, K. (2020). Comparative study of acidity status in some wild vegetables. *International Journal of Food Science and Nutrition, 5*(4), 11-13.

Scetar, M., Kurek, M., & Galic, K. (2010). Trends in fruit and vegetable packaging–a review. *Croatian J Food TechnolBiotechnolNutri*, 69–86.

Sewed, A., Muhammed, A., Ahamed, E., & Thompson, A. (2006). Improvement of Banana quality in relation to storage humidity. *Horticulture Science*, 28-33.

Shimin, W., Feiya, S., & Danfeng, H. (2016). Effects of packaging materials and types on postharvest nutritional quality of mini Pakchoi Brassica chinensis. *Int J Agric & Biol Eng, 9*(6), 207－213.

Shivputra, S., Patil, C., Swamy, S., & Patil, P. (2004). Cumulative effect of VAM fungi and vermicompost on nitrogen, phosphorus and potassium and chlorophyll content of papaya leaf. *Mycorrhiza News*, 15-16.

Sowley, M., Elias, N., Dewey, F., & Shaw, M. (2010). Persistent, symptomless, systemic, and seed-borne infection of lettuce by Botrytis cinerea. *European Journal of Plant Pathology, 126*, 61-71.

Tano, K., Kamenan, A., & Arul, J. (2009, 2 9). *Respiration And Transpiration Characteristics Of Selected Fresh Fruits And Vegetables.* Retrieved 7 22, 2023, from https://www.ajol.info/index.php/aga/article/view/1662

Techavuthiporna, C., & Boonyaritthongchai, P. (2016). Effect of prestorage short-term Anoxia treatment and modified atmosphere packaging on the physical and chemical changes of green asparagus. *Postharvest Biology and Technology*(116), 64-70.

Teixeira, P., Silva, M., & Mata, J. (2012). Motivation, self-determination, and long-term weight control. *International Journal of Behavioral Nutrition and Physical Activity, 9*(22).

Thapa, N., Panta, R., & Khanal, A. (2019). Effect of modified atmosphere packaging on postharvest quality of broad leaf mustard (BLM) under different storage condition. *Horticulture International Journal, 3*(5), 12-18.

USDA. (2019, 4 1). *U.S. DEPARTMENT OF AGRICULTURE.* Retrieved from https://fdc.nal.usda.gov/fdc-app.html#/food-details/169256/nutrients

Wang, J., Zhiqiang, Z., Moga, L., Jinyou, H., & Zhang, X. (2019). A Holistic Packaging Efficiency Evaluation Method for Loss Prevention in Fresh Vegetable Cold Chain. *Sustainability, 11*(14), 3874.

Wellburn, A. (1994). The Spectral Determination of Chlorophylls a and b, as well Total Carotenoids, Using Various Solvents with Spectrophotometers of Different Resolution. *Journal of Plant Physiology, 144*(3), 307-313.

Xiao, Z., Luo, Y., Lester, G., Kou, L., Yang, T., & Wang, Q. (2014). Postharvest quality and shelf life of radish microgreens as impacted by storage temperature, packaging film, and chlorine wash treatment. *Food Science and Technology, 55*, 551-558.

Yang, T., Chen, Y., Zeng, F., Ming, Y., Wang, L., Luo, Z., . . . Chen, F. (2022). Effects of modified atmosphere packaging on the postharvest quality of mulberry leaf vegetable. *Scientific Reports, 12*(10893), 50-62.

Yokokawa, N., Kikuchi, E., Sugiyama, H., & Hirao, M. (2018). Framework for analyzing the effects of packaging on food loss reduction by considering consumer behavior. *Clean Production, 174*, 26–34.

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MODIFIED ATMOSPHERIC PACKAGING AS ALTERNATIVE TO THE CONVENTIONAL PACKAGING FOR POSTHARVEST QUALITY AND SHELF LIFE OF CUCUMBER

Ananta Pudasaini, Aashish Ghimire, Karishma Awasthi &
***Bidur Prasad Chaulagain**
[1]Himalayan College of Agricultural Sciences and Technology, Kathmandu
***Corresponding Author**: *bidur@hicast.edu.np*

ABSTRACT

A comparative impact analysis about conventional packaging materials and modified atmosphere packaging (MAP) on the postharvest life of cucumber was conducted in the post-harvest lab of HICAST on mid June 2023. The experiment was conducted under ambient condition of 28-32℃ and 70-80% relative humidity. Five different treatments consisting of one control and 4 different packaging materials which included polythene bag, perforated polythene, muslin cloth and MAP bag were applied to access the effect on post-harvest life and different quality parameters of cucumber. The experimental setup was based upon completely randomized design with each treatment being replicated four times. The physiological loss of weight (PLW) across treatments ranged from 0.35% to 9.37% (days 1-4) and 1.13% to 9.55% (days 4-8) with cucumbers in non-perforated polythene bags recording lowest PLW at 0.35% and 1.13% in both cases. The firmness of cucumber initially which was at 2.856 kg/cm^2 decreased to a range of 1.410 to 2.410 kg/cm^2 by day8 with biodegradable MAP bags retaining the maximum firmness while the control group had lowest. MAP also ensured stable TSS, delayed chlorophyll degradation, and maintained cucumber freshness throughout storage. During the experiment MAP demonstrated superior performance in preserving various quality parameters and also significantly enhanced cucumber marketability over extended storage period. While polythene can reduce weight loss, it raises problems with firmness, marketability of the packaged material along with its pertinent environmental issues. The MAP stands superior over conventional polythene packaging by preserving the overall quality of cucumbers for longer period.

Key words: MAP, Post-harvest, Cucumber, Packaging Materials, shelf life

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an economically important crop which is used for pickling and eaten fresh. At immature stage cucumbers are widely consumed as salad (Jat *et al.,* 2021). Globally, cucumber is the third most cultivated vegetable after tomatoes and onions with China being the largest producer of cucumber. China accounts to 80% of total production of cucumber in the world followed by turkey in second position. The total area under cucumber production in the year 2021 was 2,172,193 ha with total production being 93,528,796 mt and the yield was 430,573 kg/ha (FAO, 2021). In Nepal it is cultivated from terai to mid hills with altitude ranging from 100-1800masl. The area, production, productivity of cucumber in Nepal is 9,978 hectare (ha), 152,862 ton (t), and 15.32 t/ha respectively (MoALD, 2022).

Cucumber fruits are a good source of antioxidants, magnesium, and vitamin C and are rich in dietary fiber (Shi *et al*., 2015). Fresh consumption of this crop provides a variety of health benefits including valuable antioxidant, anti-inflammatory, and anti-cancer benefits (Mukherjee *et al*., 2013). Despite being high-value cash crops, Nepalese farmers continue to experience low return from cucumber cultivation and one of the major reasons for it is the perishable nature of cucumber and improper way of storing and packaging after harvest and insufficient knowledge of proper post-harvest technology (Khanal *et al.,* 2020). Cucumber fruits have short storage duration, limited to less than 14 days due to loss of weight and firmness, discoloration, and fungal infections (Kahramanoğlu & Usanmaz, 2019). Cucumbers are classified as perishable fruits due to their high moisture content and delicate nature. As with many other fruits and vegetables, cucumbers have a limited shelf life and can spoil relatively quickly if not stored properly.

The post-harvest loss of cucumber fruit is around 27.1% (Kitinoja *et al*., 2018). It has been estimated that postharvest losses range from 20% to 30% for fresh fruits and vegetables, and in adverse conditions, these losses can exceed 50%. These losses in vegetables occur due to various factors such as harvesting at an inappropriate stage of maturity, direct packing, and shipping without removing field heat, inadequate packaging and sorting, subpar transportation and handling practices, and insufficient storage facilities (Bhattarai, 2021). However, the most significant losses occur during transportation, starting from the field to the collection center, and further on to the wholesale market and retail outlets (Adhikari & G.C., Post-harvest practices of horticultural crops in Nepal: Issues and management, 2021).

Modified atmosphere packaging (MAP) is a technology that has revolutionized the way we store and transport perishable food products. MAP works by modifying the composition of the air surrounding the food product, creating an environment that slows down spoilage and extends the shelf life of the product. MAP is an active or passive dynamic process of altering gaseous composition within a package. It relies on the interaction between the respiration rate of the produce, and the transfer of gases through the packaging material, with no further control exerted over the initial gas composition (Farber *et al*., 2003). Passive MAP can be generated inside a package by relying on the natural process of produce respiration and film permeability to attain the desired gas composition over time (Farber *et al.*, 2003). While, active MAP is a rapid process of gas replacement or displacement, or the use of gas scavengers or absorbers to establish a desired gas mixture within a package (Charles *et al*., 2006). This involves the addition of active agents into packaged food product, such as O_2, CO_2 and ethylene scavengers (Sandhya, 2009). This study aims to explore the potential of MAP as a packaging alternative for cucumbers, with broader applicability in commercial and household packaging for various fruits and vegetables in the future.

MATERIALS AND METHODS

The study was carried out on mid June 2023 in the post-harvest laboratory of HICAST College located at Kirtipur, Kathmandu. The research Centre lies at 27.6◦N latitude receiving annual rainfall of about 1025 mm with. Brishma hybrid F1 variety of cucumber was selected for research purpose because it seemed to be one of the most popular varieties which is being cultivated by local farmers in and around Kathmandu valley. The experiment was carried in ambient environmental condition with temperature ranging from 28 to 32℃ and 70-80% relative humidity (RH). The experiment was designed in completely randomized design (CRD) with 5 treatments and each treatment was replicated 3 times. The layout of the experiment was done based on lottery method and treatment was randomized to each experimental plot in such a way that each experimental plot has equal chance of getting a treatment. Overall, there was 20 experimental units and within each treatment there was 3 cucumber fruits. Experimental units were properly labeled for identification of the treatment applied.

Table 8. Outline of treatments

T1	Control	Cucumbers were kept as it is without any treatments
T2	Polythene Bag	High density polyethylene (HDPE) bags of thickness 40µ were used. No perforations were done.
T3	Perforated Polythene Bag	HDPE bags of thickness 40µ were used by making perforations. Overall, there were 12 perforations.
T4	Muslin Cloth	Muslin cloths were wrapped around the cucumbers.
T5	MAP Bags	Modified atmosphere packaging (MAP) bags which is biodegradable was used as packaging material.

Physiological loss in weight (PLW)

PLW was recorded by calculating the loss in weight of the fruit during storage over initial values.

$$\text{PLW}(\%) = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100\%$$

Chlorophyll content

The chlorophyll content was determined using the Wellburn's technique. Cucumber's outer peel samples weighing 0.2 g was extracted with 7 mL of 80% acetone and the optical density of the solution was measured at 645 nm and 663 nm (Wellburn, 1994). The chlorophyll content was determined by using equation given below:

- Chlorophyll a (mg/g) = (12.70 × A663 - 2.690 × A645) × V / (1000 × W)
- Chlorophyll b (mg/g) = (22.90 × A645 - 4.680 × A663) × V / (1000 × W)
- Total chlorophyll content = chlorophyll a + chlorophyll b

Where, V= Volume of acetone used and W = weight of the fresh cucumber peels

Total soluble solids (TSS)

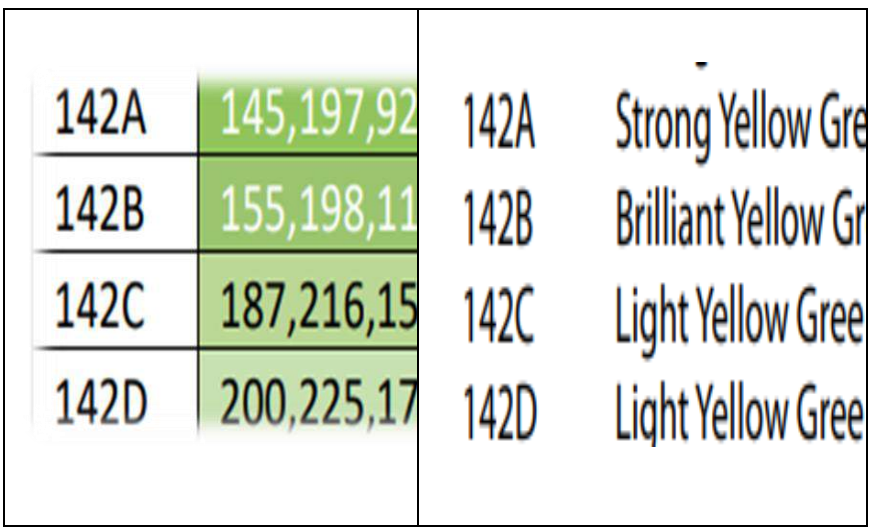
TSS was measured using refractometer and expressed in °Brix.

Firmness

The firmness of cucumber under different treatments was measured using fruit penetrometer and expressed in kg/cm^2.

Color of cucumbers

The color of cucumber was compared against a color chart with standardized color swatches and the color of the cucumber sample to the closest swatch on the chart of Royal Horticulture Society was matched to determine the color intensity or shade (Royal Horticulture Society, 2019). Every colour code specified a certain colour name and category whereas the alphabet A, B, C and D indicated the colour intensity within the category (Royal Horticulture Society, 2015).



Source : Royal Horticulture Society, (2019) , Royal Horticulture Society , (2015)

Statistical analysis

The data were systematically arranged and tabulated using MS-Excel program whereas statistical analysis was done using GENSTAT software.

RESULTS AND DISCUSSION

Physiological loss in weight (PLW)

The result showed that the different treatment had significant impact on the physiological loss in weight (PLW) of cucumber over the course of storage. During the first 4 days of storage all treatments namely T2, T3, T4, T5 had shown significantly lesser PLW than that of control. The PLW was maximum in control (T1) followed by muslin cloth (T4). The PLW of cucumber in control from Day

1 to Day 4 of the storage period was 9.366% whereas cucumber stored by wrapping in muslin cloth (T4) lost 5.568% of its initial weight during first 4 days of storage. The PLW was minimum in polythene bag without perforation (T2) in which the stored fruit lost only 0.355% of its initial weight during first 4 days of storage. Likewise, cucumbers stored in MAP bag (T5) and perforated plastic bag (T3) lost significantly less weight than both control and muslin cloth. Cucumbers in MAP bag lost 1.676% of its initial weight for 4 days storage period meanwhile cucumbers in perforated plastic bag (T3) lost 1.727% of its initial weight in the same period.

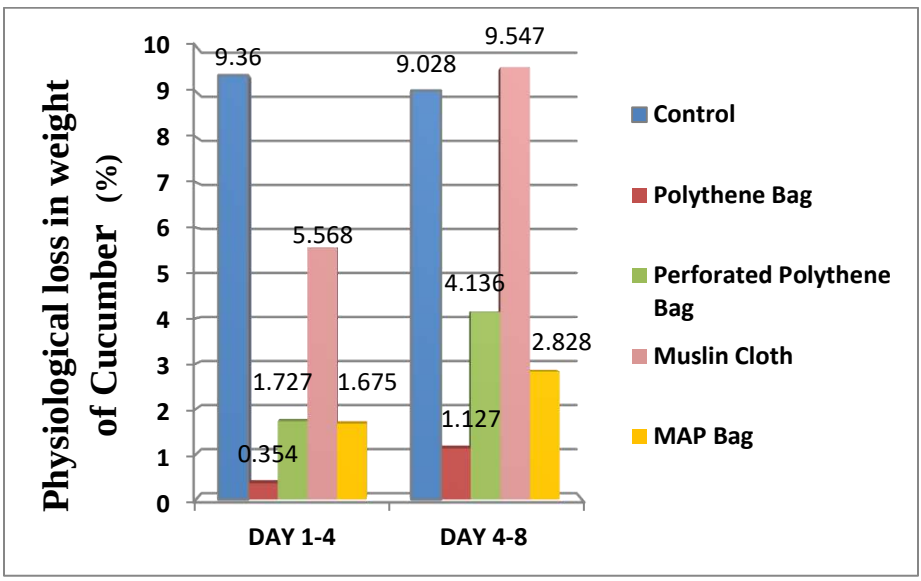


Figure 4. Effect of different packaging materials on PLW of cucumber

Meanwhile, during the next 4 days the trend of weight loss was slightly different which is evident on figure 1. The maximum PLW was recorded in cucumber wrapped in muslin cloth (T4). Cucumbers wrapped in muslin cloth (T4) lost 9.546% of its initial day 4 weights between Days 4-8 whereas PLW for cucumbers kept in control (T1) was about 9.029% which is slightly lower as compared to T4. Use of perforated polythene bag (T3) lowered the PLW to 4.136% but the most impressive result was observed with cucumbers stored in simple plastic bags (T2), where PLW was notably minimal at just 1.128%. Normal polythene bag (T2) showed considerable success in maintaining cucumber's weight loss. Additionally, the use of MAP bags made from biodegradable material (T5) also presented convincing result, resulting in PLW of 2.828% from day 4-8. Overall,

the outcome of this study demonstrated that there is significant impact on the PLW of cucumber due to different packaging materials used. The outcome is consistent with the findings of Poudel *et al*., (2022) who found that the PLW in cucumber is minimum when kept in polythene bag with no perforations. Suchitra *et al*., (2023), Dhall *et al*., (2011) , Owoyemi *et al*.,(2021) also came up with the same conclusions that adjustment or improvement of packaging material slows down the PLW of cucumber.

Impact on firmness of cucumber

Analyzing the firmness of cucumbers stored under diverse packaging materials at ambient condition of 28-32°C and 70-80% RH, we observed a gradual decline in firmness over the storage period from day 1 to day 8 as shown in Figure 2. Among the different treatments, the control group (T1) exhibited a reduction in firmness from an initial value of 2.856 kg/cm² to 1.410 kg/cm² by day 8. Cucumbers stored in polythene bags (T2) demonstrated a moderate decline, measuring 2.183 kg/cm² on day 4 and 1.958 kg/cm² on day 8. Similarly, cucumbers in perforated polythene bags (T3) showed a relatively modest decrease in firmness, reaching 2.144 kg/cm² on day 4 and 1.802 kg/cm² on day 8. The use of muslin cloth (T4) yielded a comparable firmness pattern, with values of 1.811 kg/cm² on day 4 and 1.520 kg/cm² on day 8. Notably, cucumbers stored in MAP bags (T5) displayed a distinct trend, with firmness values of 2.757 kg/cm² on day 4 and 2.410 kg/cm² on day 8. These results suggest that while all treatments led to a decline in firmness over time, variations exist in the degree and rate of decline, with the MAP bag treatment showing promising potential in maintaining cucumber firmness during storage.

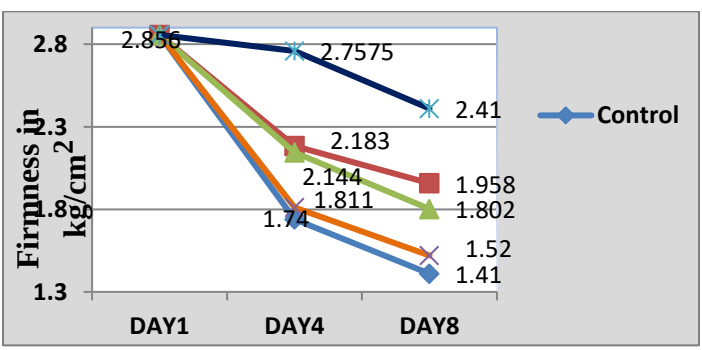


Figure 5. Effect of different packaging materials on firmness of cucumber

Decline of firmness is a natural outcome due to water loss and other physiological changes in the cucumber tissues. MAP (T5) appears to have the highest firmness

values on both day 4 and day 8 compared to the other treatments. The cucumbers stored in MAP bags showed the least decline in firmness over the storage period compared to other treatments. This suggests that the MAP is the most effective packaging material in preserving cucumber firmness. MAP involves modifying the atmosphere within the packaging to slow down spoilage and maintain product quality. This controlled atmosphere helped in reducing the rate of moisture loss and other physiological process thus contributing to better firmness retention. The result of this experiment is consistent with that of Dhall *et al*., (2011) , Suchitra *et al*., (2023), Manjunatha & Anurag, (2014) and Kahramanoğlu & Usanmaz, (2019). The statistical analysis indicates that there is significant difference in the firmness of cucumber as a result of different packaging materials used.

Total soluble solids (TSS) analyis

The study revealed that the TSS were considerably stable in the samples kept under MAP bags (T5) in comparison to samples under other treatments. The TSS content at the beginning of the experiment was measured around 3 brix showed increasing trend over the course of storage. Among the treatments, Treatment 5, involving MAP bags made from biodegradable materials, demonstrated the most favorable performance, with a minimal 0.050 Brix increase from the initial TSS value to 3.050 Brix on day 8. Among the treatments, the most notable increase in TSS values by Day 8 was observed in Treatment 4 (muslin cloth), where it increased by 0.750 Brix to reach 3.750, followed closely by Treatment 1 (control group), with an increase of 0.625 Brix to 3.625. In contrast, Treatment 2 (polythene bags) exhibited a moderate increase to 3.225 Brix. Likewise, the TSS of cucumbers in Treatment 3 (T3) increased to 3.375 by Day 8. The variations in TSS values among cucumbers subjected to various storage treatments did not show statistical significance until Day 4, but by Day 8, the differences became statistically significant at 0.05% level of significance as indicated by p-value on Table 2.

The more stable TSS in cucumbers stored in (MAP) bags compared to other treatments can be attributed to the controlled atmosphere within the bags which slowed down the metabolic processes in cucumbers, including respiration and ethylene production, which are known to increase agitation leading to suspension of solids particles that were previously settled. The present result is consistent with the findings of Miano *et al*., (2016) who concluded that TSS of cucumber stored by using polyethylene bag shows minimal fluctuations in comparison to other treatment. Likewise, Kahramanoğlu & Usanmaz, (2019) also highlighted the efficiency of MAP combined with propolis to maintain stable TSS of cucumber .MAP maintained stable TSS which indicated that taste of cucumbers

packed in MAP remained fairly constant and balanced which is neither overly sweet nor too mild.

Table 9 Effect of different packaging materials on TSS of cucumbers

Treatment	D4	D8
1	3.500	3.625
2	3.175	3.225
3	3.175	3.375
4	3.425	3.750
5	3.000	3.050
LSD (0.05)	0.2970	0.3442
S.E.M	0.0985	0.1142
p-value	0.016	0.004
C.V (%)	6.1	6.7
Grand Mean	3.255	3.405

Chlorophyll content of cucumbers under different treatments

Chlorophyll degradation of cucumber's peel is apparent during storage irrespective of the type of packaging materials used which is indicated in Figure 3. Despite the use of different packaging materials, the cucumbers stored underwent a noticeable decline in green coloration over the storage period. Although cucumbers in every packaging material experienced chlorophyll degradation the intensity with which the chlorophyll degradation occurred in different treatment varied significantly. The chlorophyll content which was determined by spectrophotometric analysis was 0.1mg/g at the beginning of the analysis.

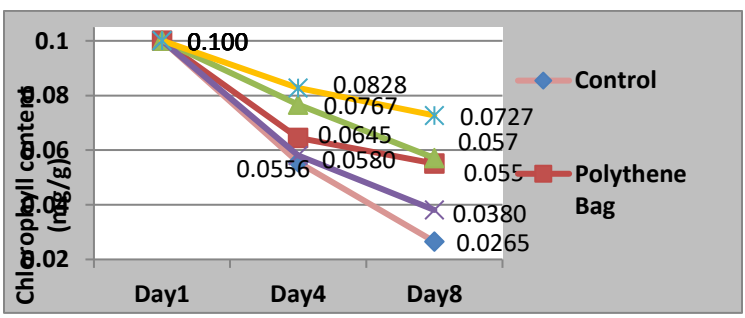


Figure 6. Effect of different packaging materials on chlorophyll content of cucumber

The degradation of chlorophyll was most prominent in cucumbers kept in control reaching 0.02652 mg/g by day 8. Similarly, Muslin cloth (T4) also displayed diminishing levels, recording chlorophyll content at 0.03809mg/g by day 8. The intensity of chlorophyll breakdown was slightly slower in polythene bag where the green pigment was retained better. Chlorophyll content of cucumbers stored in non-perforated and perforated polythene bag was 0.05509 and 0.05711 mg/g respectively on day 8. MAP exhibited slower degradation where chlorophyll content was measured around 0.7271 mg/g on day 8. Intensity of chlorophyll breakdown in MAP bags was slower which indicated that cucumber in MAP bag retained green color better in comparison with other packaging materials. Cucumber in control and muslin cloth lost chlorophyll faster than cucumbers kept in polythene bag due to increased exposure to oxygen that promoted chlorophyll degradation and polythene wrapping created a barrier that slowed down the process of chlorophyll degradation. However, polythene wrapped cucumbers lost chlorophyll faster than MAP (T5) made up of biodegradable materials because regular plastic is not designed to regulate the atmosphere because of which gas exchange is limited and moisture accumulation is also higher and favorable environment for enzymatic reactions is created that contributed to breakdown of chlorophyll. MAP limited airflow which impacted atmosphere inside the package by regulating moisture and gases and reduced enzymatic activity responsible for chlorophyll breakdown. The outcome of this experiment aligns with (Suchitra *et al*., 2023) who observed that shrink-wrapped cucumbers retained their green color for a longer duration compared to the control group, indicating the effectiveness of passive modified atmosphere packaging in retaining greenness.

Color changes of cucumbers under different treatments

The cucumber samples were monitored on a regular basis for any change of color, we observed distinct color changes in cucumbers under different treatments over the course of the experiment. The control group (T1) experienced a gradual degradation in color quality, transitioning from strong yellow-green (142A) on Day 1 to light yellow-green (142C) by Day 4, which further faded out to even lighter colour by Day 8. T4 employing muslin cloth showed similar trend by displaying less effective color preservation, transitioning from strong yellow-green (142A) on Day 1 to light yellow-green (142C) on Day 4 which faded further more towards 142D by Day 8. T2 involving polythene bags and T3 involving perforated polythene bag displayed similar trend of colour change and exhibited slower color degradation, transitioning from strong yellow-green (142A) on Day 1 to brilliant yellow-green (142B) by Day 4, which turned into light yellow green (142C) by Day 8.

MAP (T5) proved to be the most efficient packaging material in color retention. Cucumbers maintained strong yellow-green (142A) on Day 1 and Day 4, transitioning to brilliant yellow-green (142B) by Day 8, showcasing minimal color degradation. Passive MAP bags emerged as the suitable choice for enhancing cucumber shelf life and color quality during postharvest storage. Similar results regarding color changes in cucumbers under different packaging materials were demonstrated by previous studies conducted by Dhall, et al., (2011) , Manjunatha & Anurag, (2014) and Owoyemi, et al.,(2021).

CONCLUSION

In summary, MAP appeared to be the most efficient packaging alternative for cucumber as it preserved the valuable quality and extended the period of time over which cucumbers remained marketable. MAP slowed down chlorophyll degradation by creating a controlled environment that inhibited enzymatic processes responsible for chlorophyll breakdown, resulting in better retention of green colour. Cucumbers stored in MAP experienced minimal quality deterioration compared to other treatments. The MAP bags effectively retained cucumber freshness, firmness, and moisture levels throughout the storage period. Consequently, cucumbers in MAP bags didn't show any signs of shriveling or wilting even at the end of day 8. Furthermore, the use of MAP also contributed to maintaining a consistent TSS level in cucumbers, indicating a uniform and desirable taste throughout the storage period. Future research could be done to explore the optimization of MAP materials and storage conditions to further enhance postharvest quality and shelf life of other fruits and vegetables.

REFERENCES

Adhikari, B. & G.C., A., (2021). Post-harvest practices of horticultural crops in Nepal: Issues and management. *Archives of Agriculture and Environmental Science*, 6(2), 227-233.

Bhattarai, D. R., (2021). Postharvest horticulture in Nepal. *Horticult Intl J.*, 458-460.

Charles, F., Sanchez, J. & Gontard, N., (2006). Active modified atmosphere packaging of fresh fruits and vegetables: modeling with tomatoes and oxygen absorber. *Journal of Food Science*, 68(5), 1736-1742.

Dhall, R. K., Sharma, S. R. & Mahajan, B., (2011). Effect of shrink wrap packaging for maintaining quality of cucumber during storage. *Journal of Food Science and Technology*, 49(4), 495-499.

FAO. (2021). *Faostat.* Retrieved 2023, from https://www.fao.org/faostat/en/#compare.

Farber, J.N., Harris, L.J., Parish, M.E., Beuchat, L.R., Suslow, T.V., Gorney, J.R., Garrett, E.H. and Busta, F.F., (2003). Microbiological safety of controlled and modified atmosphere packaging of fresh and fresh-cut produce. *Comprehensive reviews in food science and food safety*, *2*, 142-160.

Jat, G. S., Behera, T. K., Lata, S. & Kumar, S., (2021). Classical Genetics and Traditional Breeding in Cucumber (Cucumis sativus L.). In *Cucumber Economic Values and Its Cultivation and Breeding*, Rijeka, Croatia: IntechOpen.

Kahramanoğlu, İ. & Usanmaz, S., (2019). Improving postharvest storage quality of cucumber fruit by modified atmosphere packaging and biomaterials. *HortScience*, 54(11), 2005-2014.

Khanal, S., Shrestha, J. & Lamichhane, J., (2020). Economics of production and marketing of Cucumber in Nawalpur district of Nepal. *Azarian journal of agriculture*, 7(3), 93-101.

Kitinoja, L., Yadav Tokala, V. & Brondy, A., (2018). A review of global postharvest loss assessments. *Journal of Postharvest Technology*, 6(4), 1-15.

Manjunatha, M. & Anurag, R. K., (2014). Effect of modified atmosphere packaging and storage conditions on quality characteristics of cucumber. *Journal of Food Science and Technology*, 51(11), 3470-3475.

Miano, T. F., Khaskheli, A. A., Miano, T. F. & Miano, F. N., (2016). Influence of Packaging Material on PhysicoChemical and Sensory Quality of Cucumber under. *European academic research*, 4(5), 4562-4585.

MoALD, (2022). Statistical Information on Nepalese Agriculture 2077/78 (2020/21).
Available at: https://moald.gov.np/wp-content/uploads/2022/07/statistical-information-on-nepalese-agriculture-2077-78.pdf

Mukherjee, P. K., Nema, N. K., Maity, N. & Sarkar, B. K., (2013). Phytochemical and therapeutic potential of cucumber. *Filoterapia*, 227-236.

Owoyemi, A., Porat, R. & Rodov, V., (2021). Effects of compostable packaging and perforation rates on cucumber quality during extended shelf life and simulated farm-to-fork supply-chain conditions. *Foods*, 10(2), 471.

Poudel, S. P., Upadhyay, K. P., Timilsina, C. & Basnet, R. B., (2022). Effect of thin paper polythene wrapping and chlorine water treatments in post harvest life of cucumber at Gandaki Province , Nepal. Kirtipur , Nepal Horticulture Society and National Centre For Fruit Development, 56-64.

Royal Horticulture Society, (2015). RHS colour chart - neue auflage 2015. Available at: https://www.torso.de/media/products/RHS_Colour_Chart_Farbliste.pdf

Royal Horticulture Society, (2019). Lilac-color-groups-by-RHS-columns. Available at: https://www.internationallilacsociety.org/wp-content/uploads/2019/12/Lilac-Color-Groups-by-RHS-columns.pdf?fbclid=IwAR1gBAubnBe9DZE3ujoJUoMqGltOR_CMinQUra7JKjBZbztTlvywyCGHkZQ

Sandhya, (2009). Modified atmosphere packaging of fresh produce: Current status and future needs. *LWT - Food Science and Technology*, 43(3), 381-392.

Shi, J., Wang, J., Li, R., Li, D., Xu, F., Sun, Q., Zhao, B., Mao, A.J. and Guo, Y.D., (2015). Expression patterns of genes encoding plasma membrane aquaporins during fruit development in cucumber (Cucumis sativus L.). *Plant Physiology and Biochemistry*, *96*, 329-336.

Suchitra, V., A, C., Dhurve, L. & Flora, N., (2023). Post-harvest treatments for extending the shelf of European Slicing Cucumber. *The Pharma Innovation Journal*, 12(2), 3004-3006.

Wellburn, A. R., (1994). The Spectral Determination of Chlorophylls a and b, as well Total Carotenoids, Using Various Solvents with Spectrophotometers of Different Resolution. *Journal of Plant Physiology*, 144(3), 307-313.

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IMPACT OF TURMERIC POWDER DIETARY SUPPLEMENTATION ON THE PERFORMANCE OF COMMERCIAL BROILER CHICKENS

Aakash Subedi[1*], Ishwor Dhakal[2] and Sunil Sapkota[1]
1Himalayan College of Agricultural Sciences and Technology (HICAST)
[2]Military Canine Breeding Center, Bhaktapur
***Corresponding Author**: aakash3subedi@gmail.com

ABSTRACT

A study was undertaken to investigate the effect of dietary supplementation of turmeric (Curcuma longa) powder on the performance of commercial broiler chicken. This experiment was conducted at the Instructional Livestock Farm Complex, HICAST, Kirtipur, Nepal for 42 days from 20th May 2023 to 30th June 2023. A total of 200 day-old commercial broiler chicks comprising 50 chicks in each group with uniform body weight were randomly divided into four groups viz. T0 (diet with 0% Turmeric powder as control), T1 (diet with 0.5% Turmeric powder), T2 (diet with 0.75% Turmeric powder), and T3 (diet with 1% Turmeric powder). Experimental birds were provided adlib starter feed for first 21 days and continued with the finisher feed for another 21 days and had easy access to drinking water. Feed intake was recorded daily and body weight gain was measured at 7-day intervals. The final body weight was significantly higher ($p<0.05$) in the T1 group (2046.89 g) followed by T0 (1807.2 g), T2 (1773.55 g), and T3 (1742.323 g) respectively. With respect to overall FCR, the T1 group showed the best FCR value of 1.58 followed by T2 (1.74), T3 (1.86), and T0 (1.91). This study revealed that increased body weight improved FCR and highest BEPI in chicks fed with 0.50 % Turmeric powder. Thus, it can be recommended that Turmeric powder can be used as a natural feed additive in feed at the level of 0.50% to improve the overall performance of broiler chicken.

Keywords: Cobb 500, Feed Intake, FCR, Turmeric, Weight Gain

INTRODUCTION

Poultry business being one of the major agricultural practices (Osti *et al.*, 2017) is an important occupation of the people in Nepal. Easy rearing, less manpower, and less investment are possible causes for people's attraction to this field. In the world, Nepal stands at 112th in the chicken meat production ranking and 92nd in

the egg production ranking (Shrestha *et al.*, 2014). There is tremendous growth in poultry farming in the last six decades and it creates income generation in urban and periurban areas (Bhattarai, 2005). Poultry farming is extensively increasing in Nepal and has a greater contribution to the National GDP (Gross Domestic Production). Poultry production contributes 4% of the national GDP alone. The poultry population of Nepal is estimated to be 82,598,879 (Statistical-Information-On-Nep… 2023). Typical broilers have white feathers and yellowish skin. Most commercial broilers reach slaughter weight at between five and seven weeks of age, although slower-growing breeds reach slaughter weight at approximately 14 weeks of age (Kruchten, 2002).

Turmeric (*Curcuma longa*) is one of such perennial herbs that contains an active component named curcumin (Mashhadani, 2015) and it ranges from 2 to 5% of the Turmeric (Bagchi, 2012). The therapeutic properties of curcumin included antibacterial, anticoccidial, antioxidant, hypocholesterolemic, hypolipidaemic, immunomodulatory, and hepatoprotective properties (Hussein, 2013, and Qasem *et al.*, 2015). It also possesses anti-inflammatory (Holt *et al.*, 2005). Considering the above facts, the present study was undertaken to determine the dietary supplementation of Turmeric powder on the performance of broiler chicken fed at different levels with feeds.

The general objective of this study is to assess the effects of dietary supplementation of Turmeric powder on the growth performance of broiler chicken. Other specific objectives are to evaluate the body weight gain; feed intake of boiler chicken in different treatment groups; find out the feed conversion ratio (FCR) and Broiler Performance Efficiency Index (BPEI).

As Turmeric is locally available, this study may help to reduce cost production in poultry farming and to uplift their economic status which will be beneficial to the farmer. Thus, the rationale for this thesis lies in addressing the need to explore the potential benefits of Turmeric as a feed additive and consider the economic implications of such supplementation.

MATERIALS AND METHODS

The study was conducted in the Instructional Livestock Farm Complex, HICAST, Kirtipur, Nepal with Cobb 500 broiler chicken from 20th May 2023 to 30th June 2023 for 42 days (6 weeks). Chickens were kept in a deep-litter system of rearing. Two hundred experimental day-old chickens were procured from the Hatchery

and kept in four treatment groups with two replications having 25 birds in each replication by using Complete Randomized Design (CRD). The control treatment group (T0) was fed with basal diet without any turmeric powder supplementation and the treatment group T1, T2 and T3 were supplemented with different levels of Turmeric powder variety of turmeric powder at the rate of 0.5gm/kg, 0.75gm/kg, and 1gm/kg feed respectively. A concentrated mixture was given on a group basis and was provided to the experimental birds twice a day (morning and evening) in adlib amounts for both periods (starter-21 days and finisher-21 days) of the experiment. Drinking water was provided in adequate amounts. The quantity of concentrate mixture was weighed and given to the birds in the group and refusal was weighed the next morning. The body weight gain was measured on a group basis (replication-wise) in seven-day intervals in the morning before feeding. The recorded data were analyzed using Microsoft Excel's One-way Analysis of Variance (ANOVA) in a randomized block design. All statistical analysis was performed using Microsoft Excel. The level of statistical analysis was defined at (5%) level of significance.

RESULTS AND DISCUSSION

Weekly Feed Intake and Total Feed Consumption

The mean weekly feed intake of the present study indicated that during the 1st week of age, the feed intake was higher in the T0 group, and T1, T2, and T3 groups were comparatively slightly lower.

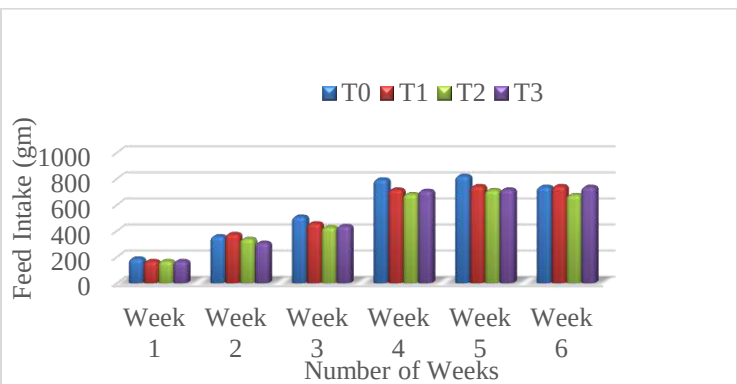

Figure 1. Feed intake gm per chicken

During the 2nd week of age, the highest feed intake was found in the T1 group (1850g) and the lowest in the T3 group (1550 g). During the 6th week of age, similar feed intake was found in the T0, T1, and T3 groups and lowest in the T2 group. Thus, it is proved that, among all weeks, except in the 2nd where T1 is better and 6th where T3 is better T0 revealed higher feed intake compared to other treatment groups. The total feed consumption per broiler for different experimental groups was found to be highest in the T0 group (3418.62 g) and lowest in the T2 group (3015.04 g).

Similar findings with respect to feed intake were observed by several reserchers (Sharma *et al.,* 2015; and Shah, *et. al.,* 2023) where the addition of Turmeric powder does not show improvement in feed intake as compared to control(T0). These findings were supported by Nouzarian *et al*. (2011). Contrary to the present observation, (Ahlawat *et al.,* 2018) reported improved feed efficiency in the treatment group; this might be due to differences in agro-climatic conditions (Mehala and Moorthy, 2008).

Weekly Body Weight and Body Weight Gain

The (Mean± S.E.) weekly body weight of different experimental groups did not differ significantly during the 1st week of age. In the 2nd week, body weight differed significantly ($p<0.05$) among different treatment groups. The T1 group achieved significantly ($p<0.01$) higher body weight (422.40 g) as compared to T0, T2, and T3 groups (395.60, 365.60, and 321.40 g), respectively.

Table 1. (Mean ± S.E.) weekly body weight (g) of broilers under different treatments

Week	Group			
	T0 (Control)	**T1 (TP-0.5%)**	**T2 (TP-0.75%)**	**T3 (TP-1%)**
1st	165.5^{a} ±23.75	156.83^{a} ±7.24	156.16^{a} ±10.22	144.83^{a} ±13.74
2nd	395.6^{ab} ±51.33	422.4^{a} ±44.11	365.6^{b} ±25.35	321.4^{c} ±35.82
3rd	735^{a} ±87.18	748^{a} ±69.24	625^{b} ±101.14	600.5^{b} ±89.83
4th	1148.8^{a} ±82.53	1161.4^{a} ±90.94	1041^{b} ±126.42	1043^{c} ±104.41
5th	1538^{ab} ±99.68	1655.7^{a} ±147.88	1489.2^{b} ±92.89	1484.5^{b} ±122.99
6th	1807.2^{a} ±131.62	2046.89^{b} ±146.33	1773.55^{a} ±161.42	1742.323^{a} ±120.07

Means bearing the same superscripts in a row do not differ significantly

In the 3rd and 4th weeks, body weight differed significantly ($p<0.05$) among the different treatment groups. The T0 and T1 groups achieved significantly ($p<0.01$) higher body weight as compared to T2 and T3 groups. During the 5th and 6th week of age, the body weight of broiler chickens differed significantly ($p<0.01$) among the different experimental groups. The T1 gained significantly ($p<0.01$) higher body weights as compared to the T0, T2, and T3 groups during the 5th and 6th week of age.

The initial body weight of day-old broiler chicks fed on different dietary treatments were similar that is 45.5 g. The mean weekly weight gain of the present study indicates that 1st week weight gain is almost similar in all groups.

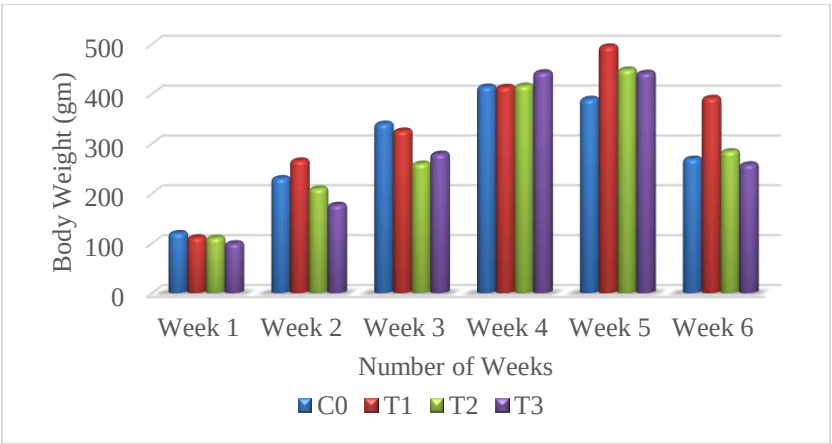

Figure 2. Weekly body weight gain (g/bird) of broilers under different treatment groups

The control group grew the most body weight (120 and 339.4 g) during the 1st and 3rd weeks of age, and the T3 group gained the most (442.50 g) during the 4th week of age. The T1 group experienced the largest body weight gain at the 2nd, 5th, and 6th weeks of age (265.57, 494.3, and 391.19 g). The experimental birds' average mean body weight ranged from 45.5 g at the start to 1842.5 g at the conclusion. The T1 group (2046.89 g) saw the largest increase in total body weight, followed by the T0 (1807.2 g), T2 (1773.55 g), and T3 (1742.32 g) groups, in that order.

The improvement in body weight and body weight gain of the broiler chickens due to supplementation of Turmeric powder in the diets might be due to the increased length of the intestinal villi as well as decreased pH in the intestine (Sieo

et al., 2005). Turmeric decreased the intestinal microbes, population and selectively increased the Lactobacillus count (Sieo *et al.,* 2005; and Namagirilakshmi *et al.,* 2010). This reduction in the microbial load of broiler chickens could be due to the antibacterial effect of Turmeric on intestinal microbiota (Faghani *et al.,* 2014). Turmeric also enhanced the secretion of digestive enzymes and hence improved nutrient absorption, ultimately resulting in improved growth performance (Arslan *et al*., 2017). These findings corroborated well with the reports of Sharma *et al.* (2015).

Feed Conversion Ratio

Among the different experimental groups, the mean weekly feed conversion ratio of the T1 group showed the best FCR values during the 1st (1.523), 2nd (1.422), and 3rd (1.41) weeks of age. In the 4th week, the T3 group showed the best values (1.601) as compared to other groups. In the 5th and 6th weeks, the mean FCR value of the T1 group (1.507 and 1.904)) was the best among all the experimental groups. In the 6th week of age, the T1 group (1.904) showed the best FCR followed by the T2 (2.381), T0 (2.747), and T3 (2.867) groups, respectively.

The overall FCR of the entire period of the experiment was best in the T1 group (1.584) followed by T2 (1.7392), T3 (1.856), and T0 (1.905867) groups, respectively.

Table 1. Mean weekly feed conversion ratio of broilers under different treatment groups

Week	Group			
	T0 (Control)	**T1 (TP-0.5%)**	**T2 (TP-0.75%)**	**T3 (TP-1%)**
1st	1.58	1.52	1.54	1.71
2nd	1.57	1.42	1.62	1.76
3rd	1.50	1.41	1.66	1.57
4th	1.92	1.74	1.64	1.60
5th	2.12	1.51	1.59	1.63
6th	2.75	1.90	2.38	2.87
Overall	1.91	1.58	1.74	1.86

The better feed conversion ratio can be attributed to the antimicrobial properties of Turmeric powder which resulted in better absorption of the nutrients in the gut and finally led to improvement in feed conversion ratio (Ong-ard *et al.,* 2010).

Turmeric could control and limit the growth and colonization of numerous pathogenic and non-pathogenic species of bacteria in chicken's gut resulting in a balanced gut microbial ecosystem that leads to better feed utilization reflected by improved feed conversion ratio (Hussein, 2013). Similar observations were reported by several researchers (Naderi *et al.*, 2014; and Arslan *et al.*, 2017). On the other hand, the addition of Turmeric powder in the broiler ration did not show significant differences in feed conversion ratio according to the findings of Mehala and Moorthy, (2008); and Fallah and Mirzaei, (2016).

Broiler Performance Efficiency Index (BPEI)

Among the different treatment groups**,** the T2 group showed the highest BPEI (129.55) followed by T2 (101.93), T0 (94.62), and T3 (93.67) group.

Table 2. Broiler Performance Efficiency Index (BPEI) of broiler birds in different treatment groups of broiler chicken

Group	**BPEI**
T0	94.62
T1	129.55
T2	101.93
T3	93.67

Similar findings with respect to improvement in efficiency index were observed in previous findings, Attia *et al.* (2017) in broiler chicken. The higher value of BPEI in the T2 group was due to higher average body weight and better feed conversion ratio in broiler chicken during the entire experimental trial. Contrary to the present observation, Choudhury *et al.* (2018) found T3 had the highest efficiency index while T0 had the lowest efficiency index.

CONCLUSION

Based on the results of the present study, it may be concluded that Turmeric powder supplemented at a level of 0.5% Turmeric powder has a significant effect on body weight gain, and FCR, though there were no differences in feed intake. This suggests that the supplementation of Turmeric (*Curcuma longa)* powder at 0.5% level in diets has a high potential for commercial applications for the

production performance of broilers. However, further study should be conducted to validate this finding in the farmer's field for wider dissemination.

REFERENCES

Arslan, M., Ul Haq, A., Ashraf, M., Iqbal, J. and Mund, M.D. (2017). Effect of Turmeric (*Curcuma longa*) supplementation on growth performance, Immune response, Carcass characteristics and Cholesterol Profile in broilers. *Veterinaria*, 66(1): 16-20.

Attia, Youssef, A., Al-Harthi, Mohammed, A. and Hassan, S.S. (2017). Turmeric (*Curcuma longa Linn*.) as a phytogenic growth promoter alternative for antibiotic and comparable to mannan oligosaccharides for broiler chickens. *Revista Mexicana de Ciencias Pecuarias*, 8(1): 11-21.

Bagchi, A. (2012). Extraction of Curcumin. *Journal of Environmental Science Toxicology and Food Technology*, 1(3): 15-23.

Bhattrai, T.C. 2005. Nepalese poultry industries and sustainable development. *National Poultry* Expo-2005, Nepal, pp 166-171

Choudhury, D., Mahanta, J., Sapcota, D., Saikia, B., and Islam, R. (2018). Effect of Dietary Supplementation of Turmeric (curcuma longa) Powder on the Performance of Commercial Broiler Chicken. *International Journal of Livestock Research*, *8*(5), 182. https://doi.org/10.5455/ijlr.20171129032810 (Accessed: 7th August 2023)

Faghani, M., Rafiee, A., Namjoo, A.R. and Rahimian, Y. (2014). Performance, cholesterol profile and intestinal microbial population in broilers fed Turmeric extract. *Research Opinion of Animal and Veterinary Science*, 4(9): 500-503.

Fallah, R. and Mirzaei, E. (2016). Effect of dietary inclusion of Turmeric and thyme powders on performance, blood parameters and immune system of broiler chickens. *Journal of Livestock Sci*ence, 7: 180-186.

Holt, M.D.P.P., Seymour Katz, M.D. and Kirshoff, R. (2005). Curcumin Therapy in Inflammatory Bowel Disease: *A Pilot Study. Digestive Disease Science*, 50(11): 2191–2193.

Hussein, S.N. (2013). Effect of Turmeric (*Curcuma longa*) powder on growth performance, carcass traits, meat quality, and serum biochemical parameters in broilers. *Journal of Advanced Biomedical and Pathological Research*, 3(2): 25-32.

Kruchten, T. (2002). U.S Broiler Industry Structure. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture. Retrieved June 23, 2012

Mashhadani, H.E. (2015). Effect of different levels of Turmeric (Curcuma longa) supplementation on broiler performance, carcass characteristic and bacterial count. *Egyptian Poultry Science Journal*, 35(1): 25-39.

Mehala, C. and Moorthy, M. (2008). Production Performance of Broilers Fed with *Aloe vera* and *Curcuma longa* (Turmeric). *International Journal of Poultry Science*, 7 (9): 852-856.

Naderi, M., Akbari, M.R., Asadi-Khoshoei, E., Khaksar, K. and Khajali, F. (2014). Effects of Dietary Inclusion of Turmeric (*Curcuma longa*) and Cinnamon (*Cinnamomum verum*) Powders on Performance, Organs Relative Weight and Some Immune System Parameters in Broiler Chickens. *Poultry Science Journal*, 2 (2): 153-163.

Namagirilakshmi, S., Selvaraj, P., Nanjappan, K., Jayachandran, S. and Visha, P. (2010). Turmeric *(Curcuma longa)* as an alternative to in-feed antibiotic on the gut health of broiler chickens. *Tamilnadu Journal of Veterinary and Animal Science*, 6 (3): 148-150.

Nouzarian, R., Tabeidian, S.A., Toghyani, M., Ghalamkari , G. and Toghyani, M. (*2011).* Effect of Turmeric powder on performance, carcass traits, humoral immune responses, and serum metabolites in broiler chickens. *Journal of Animal and Feed Science, 20: 389-400.*

Ong-ard, L., Ngampong, K. and Boonsong, K. (2010). Antimicrobial activity of curcuminoids from Curcuma longa L. on pathogenic bacteria of shrimp and chicken. *Kasetsart Journal of Natural. Sci*ence, 44: 364-371.

Qasem, M.A.A., Alhajj, M.S., El Nabi, A.R.G. and Al-Mufarrej, S.I. (2015). Effect of Turmeric powder as a dietary supplement on performance indicators and immune responses in broiler chickens. *Journal of Animal and Veterinary Advances*, 14(2): 30-35.

Rajani Osti, D. B. (2017). Poultry Production in Nepal: Characteristics, Productivity and Constraints*. Int. J. Appl. Sci. Biotechnol*, Vol 5(2): 222-226

Sharma, A., Ranjan, S. and Krishna , V. (2015). Evaluation of Growth Promoter-Boon and Its Effect on Growth Performance of Broilers. *International Journal of Advanced Biotechnology and Research*, 6(3): 366-371

Shrestha, D. K. (2014). Poultry Sector Nepal. Rome: FAO Animal Production and Health Livestock Country Reviews.

Sieo, C.C., Abdullah, N., Tan, W.S. and H.O., Y.W. (2005). Influence of beta-glucanase producing Lactobacillus strains on intestinal characteristics and feed passage rate of broiler chickens. *Poultry Science.* 84: 734-741.

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MANAGEMENT OF CHINESE CITRUS FLY, *Bactrocera minax*, (ENDERLEIN) (DIPTERA: TEPHRITIDAE) IN KATHMANDU, NEPAL

Ashmit Thapa*[1], Debraj Adhikari[2], Lalit Sah[3], Sagar Pandey[4], and Diwas Dhital[1]

[1]Himalayan College of Agricultural Science and Technology (HICAST), Kritipur

[2]Plant Quarantine and Pesticide Management Centre, Hariharbhawan, Lalitpur

[3]iDE Nepal, Dhobighat, Lalitpur[3]

[4]Muktinath Krishi Company, Kathmandu[4]

***Corresponding Author's email**: ashmitthapa07@gmail.com

ABSTRACT

The research on management of Chinese citrus fly (*Bactrocera minax*) was conducted at a citrus orchard. The average pupal length and breadth was recorded 7.98±0.22 mm and 3.81±0.13 mm respectively. The average length and breadth of adult fly was recorded 8.20±1.00mm and 4.5±0.00mm respectively. The average citrus fruit loss (%) due to Chinese citrus fly in 2021 at Chhahari Retreat, Kathmandu was 86.80%. It revels this is one of the serious pest in citrus fruits there. So, this action research was performed to manage the problem. AWCP (Area-wide control program) is practiced for the management of Chinese citrus fly by using spot application of protein bait. Lethal protein bait having 25% protein hydrolysate and 0.1% abamectin (Great Fruit Fly Bait) was used in spot application (one spot among 3 productive citrus trees) in weekly interval for 12 weeks. Following the AWCP, fruit loss was reduced to 27.68% in 2022 harvest. The overall fruit loss (%) was reduced by 59.12 % compared to year 2021 ($p<0.001$) by the spot application of protein bait.

Key words: *Bractrocera minax*, protein bait, sweet orange, spot application

INTRODUCTION

Citrus has a big impact on how people get their nutrients and how much money producers in Nepal make. Citrus fruit cultivation, in particular the SUNTALA (Mandarin) and JUNAR (Sweet Oranges) varieties, has been practiced in Nepal for generations. Citrus is one of Nepal's major fruit products in terms of area covered, output, and export potential. In fact, Nepal is one of the centers for citrus diversity, and many different species of citrus are grown here (Adhikari and GC,

2020). It is grown in more than 50 districts in Nepal (Adhikari and GC, 2020). In recent years, the Chinese Citrus Fly (CCF), *Bactroceraminax*(Enderlein) (Diptera: Tephritidae), has emerged as a significant threat to the production of the citrus fruits with tight skin, such as sweet Oranges, lemon, and lime as well as loose skinned mandarin fruit. Originating in China, it appears that this invasive species migrated into north-eastern Nepal through India and Bhutan (Adhikari et al., 2020).

Chinese citrus fly is one of the major pests of citrus in Nepal. The pest is more problematic in the eastern part of the country, Nepal. Because of its bigger size and univoltine life cycle, as well as its oligophagous feeding behavior and exclusive feeding on citrus fruits, this pest is unlike any other. It is not attracted by para-pheromone lures, cue lures, or methyl lures (Chen and Xie, 1955). Because of the difficulties associated with the control of this pest by chemical insecticides, farmers had experienced great losses in Sweet Oranges (Wang et al., 2018).Chinese citrus fruit fly is one of the major pests of citrus and is a big threat to commercial citrus farming. This fruit fly can cause (30-100%) reduction in yield of citrus (Sharma et al., 2015). The fly prefers to swoop down on its prey. Insects attack practically all citrus fruits, including sweet Oranges (Xia et al., 2018). Sex pheromones and parapheromones can be used to track most fruit flies; however, *Bactrocera minax* is not known to be attracted to any male lure (Drew et al., 2006, Zhou et al., 2012). Climate conditions have a significant impact on fruit fly species' biology, behavior, and morphological features (Dominiak et al., 2006). Identifying the pest and learning about its habitat and behavior before implementing any pest management strategies is the most fundamental necessity for successful pest management. The males of this species of *Bactrocera* are not drawn to any known chemical lures, in contrast to the majority of pest species. Protein bait traps (either protein hydrolysate or protein autolysate) can be used to monitor both sexes, however they also catch a lot of unrelated insects. The recurrent high infestation levels of *B. minax* in China highlight the need for a deeper comprehension of its biology and ecology in order to create and use more effective management techniques. Through open field surveys and video recordings, we investigated the eating and mating behaviors of *B. minax* in situ (Citrus orchards and surrounding ecosystems) as part of the development of a sterile insect method program against this pest (Dong et al., 2014).

From May to July 2018, the AWCP was implemented in Nepal by Junar Super-zone, Sindhuli under the Prime Minister Agriculture Modernization Project (PMAMP). The main components of the AWCP were the use of protein bait called Great fruit fly bait (Protein hydrolysate 25+0.1 percent Abamectin) as spot

applications underside of the 0.5 to 1 m^2 leaf for 10 times at a weekly interval, in accordance with the protocol developed by Ecoman Biotech, China. It's interesting to note that from 56.7 percent in 2017, the average fruit loss attributable to the fly dropped to 10.90 percent in 2018. While 6 percent of the infestation in the 10.90 percent of the population was brought on by causes other than the CCF, water stress, nutritional problems, and bug infestations (Adhikari et al., 2020). Unsuitable orchard management techniques enhance the likelihood of a fruit fly; as a result, routine training/pruning operations and a balanced fertilizer dose are advised. A balanced fertilizer DOSE SERVES TO REVITALIZE THE ORCHARD WHILE TRAINING AND PRUNING REMOVE THE INSECT'S HABITAT (GAUTAM et al., 2019). Maintaining field sanitation lowers the fly incidence from 50% to 100% to 1% (Xia et al., 2018). After pollination and the development of little fruits, fruit can be bagged with wax-coated or oil-soaked paper to assist prevent fly assault and spread. According to reports, the brown paper bag worked well to keep fruit flies under control (Sarker et al., 2009). Another approach to stop future spread is proper disposal of contaminated fruits. To prevent the spread of the pest, it can be buried deeply, tightly packaged in polythene plastic, submerged in water, burned, and fed into the hooper of a gas plant powered by FYM. Fruits that are contaminated (fallen fruit) must be collected and buried at least 30 cm below the surface, in a trench that is between 1 and 1.5 meters deep.The general objective of the study is to know the morphology and management of Chinese citrus fly. To measure the diameter of fruit, know the morphological characters of Chinese citrus fly, assess the damage in 2021 and 2022 after protein bait application are other specific objectives.

MATERIALS AND METHODS

Site selection

The site was selected on the basis of the availability of a problematic citrus orchard in Kathmandu. The problematic citrus orchard was purposefully selected for the study. Compatibility with the field owners was taken into account as well. The cost of the total project was considered and the distance to the field was taken into consideration as well. The study area was confined to the Kathmandu district at Chhahari Retreat, Budanilkantha. The orchard is situated at 1485.17-meter masl and thelatitude and longitude was 27.7863210 degree N, 85.3542847 degree E respectively. The research was done from3rd May, 2022 till 19th July, 2022.

Record of citrus fruits in the orchard and measurement of morphological characteristics of pupae and adults

Manual Vernier Caliper was used to measure the breadth of the fruit for research. This measurement was taken so that the spraying could be started at the optimum time i.e. when the average fruit size of the orchard is 10-15 mm. Manual Vernier Caliper was used to measure body length, breadth, wingspan of the fruit fly, the length and breadth of pupae. The breadth of the adult fly was recorded by measuring the mesothorax portion. Apical tip-to-tip of forewings including the thorax was measured to compute wingspan. In addition to the aforementioned variables, information on body type and color was gathered. Puape (n=23) was collected from the site (Chhahari resort) on 1st May, 2022. The pupae were carefully placed in a transparent plastic container covered with thin muslin cloth for ventilation purposes. From the pupae collected, 2 adult flies emerged which were used to measure major morphometrics parameters like length and breadth of adult flies, and wingspan at Chhahari Retreat, Kathmandu.

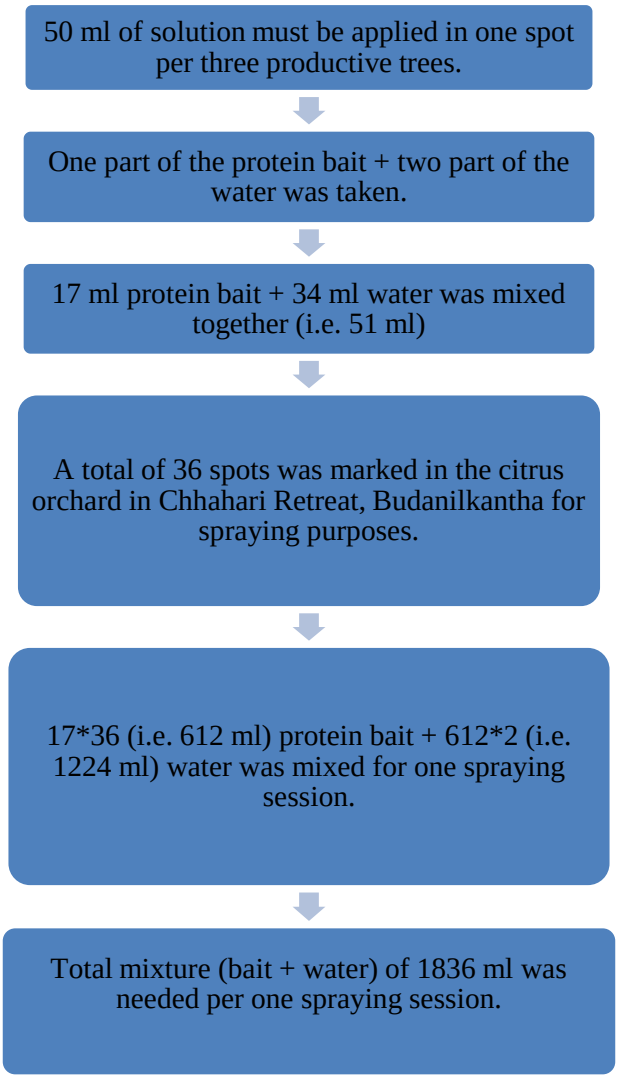
Damage assessment of citrus fruit in 2021 and protein bait application and damage assessment on 2022

The damage assessment of the citrus fruit in 2021 was done by questioning the owner of the orchard about the loss of each specific tree that we had marked. Pieces of colorful ribbons were used to mark the trees. Protein bait and water were combined in a ratio of one part protein bait to two parts water to create an aqueous bait solution for treatment. Thus, the prepared aqueous bait solution was sprayed @ 50 ml solution over 0.5 to 1 m^2 area under the leaves in one among three productive Sweet Oranges trees at the location in the weekly intervals, which was repeated 10-12 times (Ecoman-Biotech, 2018). A total of 12 spraying sessions was performed for research purposes at Chhahari Retreat, Budanilkantha at weekly interval. Application of protein bait during rainfall was avoided as the solution could be washed away by the rain. Proper precautions were taken during the application of protein bait solution in the citrus orchard and sanitation was maintained as well. The application of the solution was done through Knapsack sprayer. For preparing the solution, we used mixture of water and bait in the ratio of 2:1. The protein bait used (Great Fruit Fly Bait) contained 25% protein hydrolysate and 0.1% abamectin.

Data Analysis

The diameter of the fruits recorded was used to analyze the minimum, maximum, S.D., S.E., with the help of Ms. Excel to get the optimum time to start the spot

application of protein bait spray. The varieties of citrus trees and the number of productive and non-productive trees recorded were sorted in the form of pie-chart and bar graph respectively. The mean and range of the adult fly (length and breadth) as well as the wing span was analyzed from Ms. Excel.



Photograph 1. Protein bait spot

Photograph 2: Spot application of protein bait

RESULTS AND DISCUSSION

Record of citrus fruits in the orchard

Citrus fruit diameter measurement in Chhahari Retreat, Budanilkantha

We measured citrus fruits in the orchard on 15/01/2079 B.S. This measurement helped us to spray the protein bait at the optimum time. The average fruit size was 9.78 mm from the total of 30 fruits that we measured. Figure 1 is a pie-chart showing the percentage of different citrus trees present in the orchard at Chhahari Retreat, Budanilkantha. This pie-chart helps us know varieties and percentage of citrus trees avaliable in orchard as well.

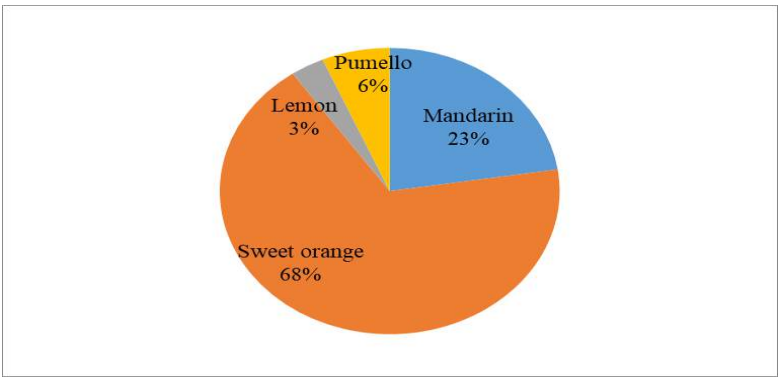


Figure 1. Types of citrus fruit in percentage

Figure 2 tells us the number of productive and non-productive citrus tree varieties present in the orchard at Chhahari Retreat, Budanilkantha. The non-productiveness of citrus tress was confirmed when it was not producing any fruit for more than a year.

Body size of *B. minax*:
The adult body ranged from 9.2 mm to 7.2 mm in length with a mean of 8.20±1.00 mm and 4.5mm in breadth with a mean of 4.50±0.00 mm. However, the average body length (12.52 ± 0.26 mm and 14.29 ± 0.20 mm), breadth (3.39 ± 0.05 mm and 3.90 ± 0.06 mm) and wingspan (22.80 ± 0.19 mm and 23.51 ± 0.23 mm), male and female respectively was measured in the morphological study of adult

Chinese citrus fly, Nepal (Adhikari 2022). Only two adults was taken for measurement due to the high mortality rate of pupa.

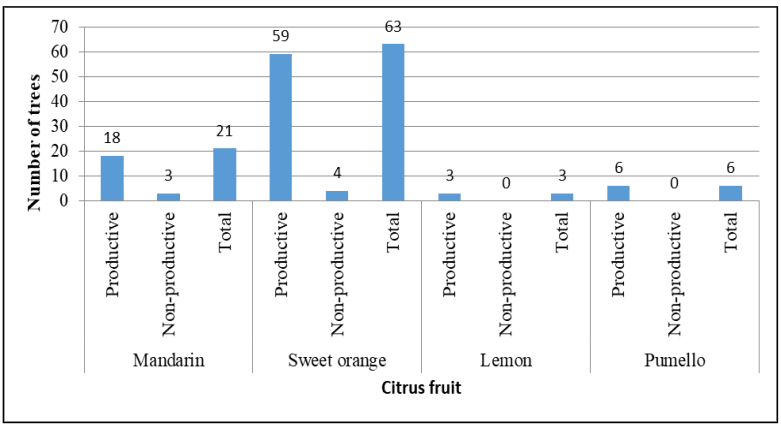


Figure 2- Citrus orchard detail in graph

Wing span of *B. minax*:

The pupae ranged from 9.9 to 5.4 mm in length with a mean of 7.98±0.22mm and the breadth of pupae ranged from 5.3-2.4 mm with a mean of 3.81±0.13 mm. The actual wingspan ranged from 11.7-11.5 mm with a mean of 11.60±0.10 mm.

Fruit damage assessment

In a non-AWCP condition, the highest CCF mean sweet orange fruit damage % in 2021 was 86.80 % in Chahari Retreat, Budanilkantha. Hence, with AWCP in 2022, the mean fruit damage receded remarkably in comparison to without AWCP in 2021. The recession in mean fruit damage in 2022 is obviously an impact of AWCP with applications of the Great Fruit Fly Bait in the citrus orchard. The clearly declining mean fruit damage percentages in 2022 by virtue of AWCP's handling of B. minax in citrus orchards was statistically confirmed using the Student's "t-test" to determine the effectiveness of the AWCP management against CCF in the citrus orchard of Chahhari Retreat, Budanilkantha. The mean fruit damage (MFD) 86.80% in 2021 was reduced to 27.68% (very highly significant; $p \leq 0.0000$). Chinese citrus fly management strategies can vary in their efficacy depending on the location of the orchards, the vegetation in the area, the sprayers' ability to apply spot treatments, and other managerial factors. Van Schoubroeck (1999) emphasized the necessity of management and monitoring methods for the growth of successful IPM practice.

Table 1. Student's t-test for fruit damage assessment

Particulars	Variable 1 (2021)	Variable 2 (2022)
Mean fruit damage percentage (%)	27.680000	86.800000
Variance	16.310000	34.083333
Observations	25.000000	25.000000
Pearson Correlation	0.110628	
Hypothesized Mean Difference		
df	24.000000	
t Stat	39.639483)	
t-test for mean fruit damage % P(T<=t) one-tail	0.000000	
t Critical one-tail	1.710882	
t-test for mean fruit damage % P(T<=t) two-tail	0.000000	
t Critical two-tail	2.063899	

RESULTS AND DISCUSSION

Chinese Citrus Fly (CCF), *Bactroceraminax* (Enderlein) (Diptera: Tephritidae), has emerged as a significant threat to the production of the citrus fruits with tight skin, such as sweet oranges, lemon, and lime as well as loose skinned mandarin fruit. Originating in China, it appears that this invasive species migrated into north-eastern Nepal through India and Bhutan (Adhikari et al., 2020). This study helps us know about citrus fruits, fruit flies, Chinese citrus fly in detail. We learn about mapping and labelling of an orchard, measuring the diameter of fruits through this research. Morphological study of the Chinese citrus fly and its management by spot application of protein bait is done during this study. The detailing of the citrus orchard by recording the varieties of citrus trees along with the number of productive or non-productive (each variety) is done. Rearing of pupae is done during the study where the length, breadth, and range of pupae (n=23) is recorded. Similarly, adults (n=2) are taken to measure their length, breadth, range as well as their wing span. The shape, size, and color of the adult is studied in detail. The loss of citrus fruit in the past year is recorded along with their average, minimum, and maximum. Lethal protein bait having 25% protein hydrolysate and 0.1% abamectin is used in spot application (one spot among 3 productive citrus trees) in weekly intervals for 12 weeks (Ecoman-Biotech, 2018). As abamectin is registered to manage ornamental insect pests, spinosad would have been a better killing agent for Chinese citrus flies but due to the unavailability of protein bait consisting of spinosad at that time abamectin was

used. The average citrus fruit loss (%) due to Chinese citrus fly in 2021 at Chhahari Retreat, Kathmandu is minimized as a result of protein bait application in 2022. AWCP (Area-wide control program) is used in the management of Chinese citrus fly by maintaining sanitation and spot application of Protein bait.

CONCLUSION

This study helps us in the identification of the Chinese citrus fly from its pupal stage to its adult stage. We got to know that precautions are very necessary for the management of *Bractrocera minax* and field sanitation to control maggots along with spot application of protein bait are major management strategies in controlling them and starting the treatment process early is highly recommended to have any chance of controlling its damage. As we already know the losses caused by Chinese citrus flies at Chhahari Retreat, Kathmandu in 2021 by questioning the owner about losses in all 25 citrus trees that we had marked. In order to know the impact we have made on preventing citrus production loss, in 2022 similar questioning was done to the farmers from which we got to know that the overall fruit loss (%) was reduced by 59.12 % compared to year 2021 by the spot application of Great fruit fly bait (25 % Protein hydrolysate + 0.1 % Abamectin).

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REFERENCES

Adhikari, D. and GC, Y.D., (2020). Opportunity to export citrus fruit from Nepal to China: Activities accomplished on plant quarantine concerned. *International Journal of Agriculture, Innovations and Research*, 8(5), pp.2319-1473.

Adhikari, D., Thapa, R. B., Joshi, S. L., Du., J. J., & Acharya, U. K. (2020b). Receded Sweet Orange Losses from Chinese Citrus Fly, Bactrocera minax (Enderlein) in Sindhuli Citrus Orchards: Lesson from Area Wide Control Program. *Proceeding of National Horticulture Seminar*, Kirtipur, and Kathmandu. February 6-7, 2020.

Adhikari, D., Thapa, R. B., Joshi, S. L., & Du, J. J. (2021). Area-Wide Control Program in management of Chinese citrus fly, Bactrocera minax (Enderlein) (Diptera: Tephritidae), in citrus orchards, Sindhuli, Nepal. *The Journal of Agriculture and Environment*, vol.: 22. pp.41-50.

Adhikari, D., Thapa, R. B., Joshi, S. L., Du. J. J., & Tiwari, S. (2022). Biology and

Management of Chinese Citrus Fly, Bactrocera minax. *Journal of Agriculture and Forestry University*, 5,1-13.

Adhikari, D., Thapa, R. B., Joshi, S. L., Liang, X. H., & Du, J. J. (2020a). Area-Wide Control Program of Chinese Citrus Fly Bactrocera minax (Enderlein) in Sindhuli, Nepal. *American Journal of Agricultural and Biological Sciences*, vol.: 15. pp. 1-7. DOI: 10.3844/ajabssp.2020.1.7

Chen, S.X. and Y.Z. Xie., (1955). Taxonomic notes on the Chinese citrus fly Tetradacuscitri Chen. *Acta Entomologica Sinica* 5: 123-126.

Dominiak, B.C., H.S. Mavi, H.I Nicol., (2006). Effect of town microclimate on the Queensland fruit fly Bactroceratryoni. *Australian Journal of Experimental Agriculture*. 46: 12391249

Dong, Y., Wan, L., Pereira, R., Desneux, N. and Niu, C. Sliva (2014). Feeding and mating behaviour of chinese fruit fly Bactroceraminax (Diptera, tephritidae) in the field. *Journal of Pest Science*, 87(4): 647-657, https://doi.org/10.1007/s10340 -014-0605-3

Drew, R.A., Dorji, C., Roming, M.C. and Loday, P., (2006). Attractiveness of various combinations of colors and shapes to females and male Bactroceraminax (Diptera: Tephritidae) in commercial mandarin grove in Bhutan. Journal of economic entomology, 99(5): 1651-5-1656, https://doi.org/10.1093/jee/99.5.1651

Ecoman-Biotech., (2018). *Area wide control program for fruit fly control*. Ecoman Biotech Co., Ltd. Beijing, China. Accessed from https://en.ecomanbiotech.com/

Gautam, E., Srivastava, A., Singh, L. K., Karki, S., Adhikari, D., & Acharya, U. K. (2020). Survey and Monitoring of Chinese citrus fly (BactroceraminaxEnderlein) in Sweet orange orchards of Sindhuli, Nepal. *Nepalese Horticulture*, 14 (1), 56-62.

Sarker, D., Rahman, M.M. and Barman, J.C., (2009). Efficacy of different bagging materials for the control of mango fruit fly. *Bangladesh Journal of Agricultural Research*, 34(1): 165-168.

Sharma, D.R., D. Adhikari and D.B. Tiwari., (2015). Fruit fly surveillance in Nepal. *Agricultural and Biological Sciences Journal* (USA). 1(3): 121-125. http://www.publicscience

Van Schoubroeck, F. (1999). *Learning to fight a fly: Developing citrus IPM in Bhutan. Wageningen, Netherlands*: PhD thesis, Wageningen University and Research Centre.
Retrieved from https://library.wur.nl/WebQuery/wurpubs/63028

Wang, F., Chambi, C., Li, Z., Huang, C., Ma, Y., Li, C., Tian, X., Sangija, F., Ntambo, M.S., Kankonda, O.M. and Hafeez, S., (2018). Influence of supplemental protein on the life expectancy and reproduction of the Chinese citrus fruit fly, Bactroceraminax (Enderlein) (Tetradacusminax) (Diptera: Tephritidae). *Journal of Insect Science*, 18(2), p.25

Xia, Y., Ma, X., Hou, B. and Ouyang, G., (2018). A review on Batroceraminax (Diptera: Tephritidae) in China for the purpose of safeguarding. *Advances in Entomology*, 6: 35-61, https://doi.org/10.4236/ae.2018.62005

Zhou, X.W., Niu, C.Y., Han, P. and Desneux, N., (2012). Field evaluation of attractive lures for the fruit fly Bactroceraminax (Diptera: Tephritidae) and their potential use in spot sprays in Hubei Province (China). *Journal of economic entomology*, 105(4): 1277-1284, https://doi.org/10.1603/EC12020

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ECONOMIC ANALYSIS OF POTATO PRODUCTION IN SINDHUPALCHOK DISTRICT

Bhim Prasad Acharya* and Arun GC
Himalayan College of Agricultural Sciences and Technology (HICAST), Kirtipur
Corresponding author: creativebhimsamir@gmail.com

ABSTRACT

Potato (Solanum tuberosum L.) is a major food crop which has a high contribution on food security as well as acts as a major source of income of Nepali farmers. It is also a major cash crop of Sindhupalchok district. To assess and analyze the economics of potato production in Sindhupalchok district, this study was conducted in two municipalities (Chautarasangachokgadi and Balephi RM) of Sindhupalchok, Nepal, where most of the farmers were involved in potato farming. Total 150 potato farmers were selected using simple random sampling technique. A semi-structured questionnaire was administered to collect the primary data. The result shows that the average production per household was 3,951Kg and 7,738.3Kg of Balephi and Chautarasangachokgadi Municipality, respectively. Moreover, the average productivity of potato was found to be 13,546.96 Kg/Ha with a statically significant yield gap between Chautarasangachokgadi (19,355.62 Kg/Ha) and Balephi Rural municipality (7,738.30 Kg/Ha). The average gross margin of potato was NRs. 12,737.8/ropani and the average benefit cost ratio was 1.68. The highest farm gate price was reported to be NRs. 23/Kg and highest selling price of retailer was reported to be NRs.35/Kg, where the average marketing margin was NRs.11/Kg. The study showed a statistical significant difference in variable costs between municipalities because of different level of input usage, particularly in the utilization of labor and fertilizer. According to the Cobb Douglas model, the coefficient of labor was negative while the coefficients for tractors, tubers, fertilizers, and manures were positive. The return to the scale was found to be 1.03, which means there was growing returns to scale. Findings revealed that timely unavailability of fertilizer, lack of irrigation facilities, pest problems and fragmented land holding were the major problems for the production of potato and access to national market , variation in climatic condition, fertile land and improving infrastructure were the major strength for potato production in study area.

Key words: Potato production, Productivity, BC ratio, Gross margin

INTRODUCTION

Potato is one of the important vegetable crops which is considered as major food crop in more than 100 countries and grown in more than 125 countries in the world (IYP,2008). The potato is native to the Peruvian-Bolivian Andes and is one of the world's main food crops. Potatoes are frequently served whole or mashed as a cooked vegetable and are also ground into potato flour, used in baking and as a thickener for sauces. The tubers are highly digestible and supply vitamin C, protein, thiamin, and niacin. After major cereals having global average per capita consumption of 33 kilograms per year; China and India being leading producer and consumer (IYP, 2008). In Nepal potato has been cultivated since 18th century (Ojha, Hidalgo, & Lama, 2001). The potato remained a relatively minor and unrecognized crop in Nepal for over 150 years, until the first official attempt to improve potato production in Nepal occurred in 1962 under a program sponsored jointly by Nepal and India. It is a noticeable food security and cash crop of high hills in Nepal, currently fourth to rice, wheat and Maize in importance as the largest consumed staple in the country (Timsina,Kafle & Sapkota, 2011). Though potato productivity has increased rapidly (by 43%) over the past 35 years in Nepal, it is still among the lowest in the world (ABPSD, 2008/2009).Potato cultivation is popular among smallholder farmers due to its wider adaptability, high yield potential and high demand and act as major source of food, income and employment to Nepalese and contributes about 6.57 and 2.17% in AGDP and GDP, respectively (MoALD, 2015).

Over the past few decades, potato has become the fastest growing staple crop in Nepal. It is considered as the major staple food crops and source of income for smallholder farmers in high mountain regions of Nepal (Timsina et al., 2011). Climatic diversity of the country permits year-round cropping of potato from plains (60 masl) to the mountains (4400 masl) (Timsina et al., 2011). By agro ecological region, out of the total area under potato crop, around 19% lies in the high hills/mountains, 43% in the mid-hills and remaining 38% in the Terai and Bhabar, occupies the fifth position in area coverage, second in total production and first in productivity among the food crops grown in the country (ABSPD, 2014). The larger share of its production is traded and consumed in major market centers in the cities such as Kathmandu, Chitwan, Biratnagar and Pokhara. Hills has fairly large share in total potato production (Timsina et al., 2011). According to (MoALD, 2019), important potato cultivation areas are Dolakha, Jhapa, Bara, Kavre, Morang, Ilam, and Jhapa districts and which were responsible for 40% of the total output.

In Nepal, potato production was ranked fifth in area (198788 Ha), second in production (3325231 Mt) and first in productivity (16.73 Mt/Ha) among the food crops grown in Nepal (MoALD, 2020). And according to latest data the average national productivity of potato of 2021 is (17.20 Mt/Ha) which is increased by 0.5 Mt/Ha (MoALD, 2021). In Sindhupalchok, the amount of potato production in 2020 was 55980 Mt in an area of 3,345 Ha with the productivity of 16.74 Mt/Ha (MoALD, 2021) and in 2021 the potato production was increased to 58,055 Mt in 3,415 Ha of land with the productivity of 17Mt/Ha which is less than the national average productivity. This study was conducted to assess the existing production practices, production, productivity, cost, income and benefit of potato production Sindhupalchok district.

METHODOLOGY

The study was carried out in the two municipalities of Sindhupalchok (Chautarasangachokgadi and Balephi RM) which were purposively selected. A total 150 potato farming households listed in Agriculture Knowledge Center were selected by sample random sampling method. The pre-tested interview schedule was administered to the respondent to collect the primary data on socio-demographic information, prevailing production practices, cost and return of production and others by carrying out the household survey. Similarly, to get the more information regarding the various aspects of potato production face to face interviews and Key Informant's Interviews (KII) with AKC officers, traders, input suppliers, consumers and financial service providers were conducted.

Two comprehensive Focus Group Discussions (FGDs) were conducted at each municipality/RM of the study area after completing the field survey with help of the checklist to verify the results obtained from household surveys. The secondary data were collected from various books, national reports, publications, reports of different INGOs, web, published articles, etc. The statistical packages for social science (SPSS) and Microsoft Excel were used for necessary qualitative and quantitative data analysis.

The benefit cost ratio, production, productivity, gross margin were calculated and analyzed. Similarly, Cobb-Douglas Production Function regression was carried out to find out the technological relationship between the factors used and gross revenue generated from potato production of study area. Gross margin of the producer for a particular enterprise is the difference between the gross revenue

earned and the total variable cost incurred (Gujrati, 2003). The gross margin was calculated by using following formula:

$$GM = \Sigma P_i Q_i - \Sigma C_j X_j$$

Where,

GM = Gross Margin, P_i = Unit price of product i, Q_i =Quantity produced of product i, C_j = per unit variable cost of input j, X_j = quantity of input used, $\Sigma P_i Q_i$ = Gross Return, $\Sigma C_j X_j$ = Variable cost

BCR ratio is the ratio of the benefits of a project or proposal, relative to its costs, both expressed in monetary terms (Hayes, 2020). Total variable cost of production and gross return from potato was used for benefit cost analysis as below:

$$B/C = \frac{Grossreturn}{Totalvariablecost}$$

The Cobb-Douglas production function is used for analyzing the resource used efficiency on potato cultivation. It is the most widely used model for fitting agricultural production data, because of its mathematical properties, ease of interpretation and computational simplicity (Heady and Dillon, 1969). It is a homogeneous function that provides a scale factor enabling one to measure the return to scale and to interpret the elasticity coefficients with relative ease (Beattie et al., 1985).The production function to be used is presented as:

$$Y = \alpha X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} X_5^{\beta 5} X_6^{\beta 6} X_7^{\beta 7} X_8^{\beta 8} X_9^{\beta 9} e^{\mu}$$

The production function was converted to logarithmic form so that it could be solved by Ordinary Least Square (OLS) method i.e.

$$\ln Y = \ln \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \mu$$

Where,

Y = production ofpotato (Rs/Ha), X_1 = cost of seed tuber used (Rs/Ha), X_2 = Cost of land (Rs/Ha), X_3 = FYM cost (Rs/Ha), X_4 = NPK cost (Rs/Ha), X_5 = Pesticides cost (Rs/Ha), X_6 = Labour cost (Rs/Ha), μ = error term, α and β_1,…….β_6 = parameter to be estimated

For identifying major problems of production index was prepared based on response frequencies. Indexing is a technique to analyze respondent's perceptions

by using the scaling technique (Subedi et al., 2019). Production problems were ranked by using five point level of influence comprising most serious,serious, moderate, low and very low or no problem at all using scores of 1.00, 0.80, 0.60, 0.40 and 0.20 respectively. The formula given below was used to find the index for intesity of production problems faced by the producers. The priority index for ech variable was calculated by weighted average mean in order to draw valid conclusion and making responsible decision.

Index of influence is calculated by using following formula:

$$I_{inf} = \sum \frac{s_i f_i}{N}$$

Where,

I_{inf} = index of influence, Σ = summation, s_i =scale value, f_i = frequency of influence given by respondents, N = total number of respondent

Return to scale indicates the response of output for the proportional change in inputs of any production activity. It was obtained by summing up the regression coefficients of respective inputs from CPDF regression analysis.

1 Decision rule:

2 Return to scale >1: Increasing return to scale

3 Return to scale =1: Constant return to scale

4 Return to scale<1: Decreasing return to scale

RESULTS AND DISCUSSSION

Socio-demographic characteristics of the respondents

The study depicted the average age of respondents was 37.65 yrs. and among them 54.7 % were male and 45.3 % were female. Agriculture activity was the respondents' primary source of income of both municipalities' people. Among 150 respondents 47.3 % respondents have joint family and 52.7 % respondents were living in nuclear family. Most of the respondents 73.4 % of both municipalities have cemented house and 21.5 % of respondents have mud house. Among total respondents 68.7 % were literate and remaining 31.3 % were illiterate, which was less than the national literacy 71.14 % of Nepal (CBS, 2021). Majority of the

respondents were from Brahmin/Chhetri caste which is 61.3 % followed by Janajati 34 % and remaining 4.7 % were from Dalit community. In both municipalities household head were male headed 80.7 % and 19.3 % household were female headed. The average family size of each family was 5.59 in which 3.09 were active population and 2.33 people of family were involved in agriculture.

Social Capital

Majority of the respondent family income was from agriculture; 84 percent, 5.3 percent family income from government service, 4 percent family income from business, 2.7 percent family income from foreign income and remaining 4 percent family income was from labour work or other occupations.

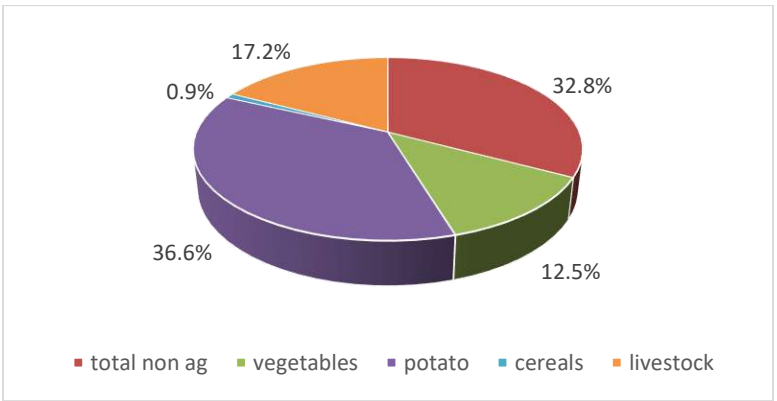

Figure 1. Distribution of household income of the study area

The average land holding of each family was 7.54 ropani (0.37 Ha.) and average area of land under potato cultivation was 4.93 ropani (0.25 Ha). The experience of growing potato of farmers on an average was 12.37 years. In study area most of the people were engaged in cooperatives/groups. During the study it was found that on average 70.7 % people were involve in cooperatives/groups in which from Balephi 44 % farmers were involve and from Chautarasangachokgadi 62 % farmers were involve. Among 150 farmers on an average 27 % borrow loan for potato cultivation in which 21% of Balephi and 33 % of Chautarasangachokgadi borrow loan. Overall the interest rate from institutional organization was 15.25% and non-institutional rate was 19.87 % in average in both municipalities.

Economics of Potato

Seed tubers, FYM, manure, chemical fertilizers, pesticides and labour were the major inputs used in potato production by the potato growers in study area. The quantity of different inputs used is significantly different between two municipalities. The result revealed that the average total cost of potato production was NRs. 329,637.27 /Ha. The average total cost of potato production in Balephi was significantly lower than in Chautarasangachokgadi and mean difference for average total cost between two municipalities were highly significant at 1% level of significance. Also, it was evident that the seed tuber cost was NRs. 83,379.60 in case of Chautarasangachokgadi and it was NRs. 74,538.17/Ha in case of Balephi. The cost for seed tubers was assigned as per the market price of potato as the farmers retained their own seed tubers for next season of cultivation while in case of Chautarasangachokgadi some farmers usually bought tubers from market. The mean difference of cost incurred in seed tuber was also highly significant between two municipalities. From the table it can be concluded that the major cost was incurred in labour wage in both municipalities. The labour cost was followed by manure cost, transportation cost, chemical fertilizers cost and land preparation respectively in Balephi while in Chautarasangachokgadi labour cost was followed by pesticides cost, FYM cost, NPK cost, transportation cost, land preparation and seed tubers respectively. Also, the mean differences of all categories of costs were highly significant between two municipalities. Due more amount of investment in Chaurasangachokgadi the cost was increased highly in comparison to Balephi. Hence the cost of inputs used was more in Chautarasangachokgadi. The comparative cost of potato production with location is shown below in Table 1.

The relative contribution of eight categories of cost incurred in potato cultivation was shown diagrammatically and it was found that labour cost have highest share in total cost accounting 29% of total average cost. This means huge amount of money was spent in labour. Similarly, about 24% cost was incurred for seed tuber, 13% in FYM, 11% in transportation of inputs and sold potatoes, 10% in pesticides, 9 % in NPK (chemical fertilizers), 3% in land preparation, and remaining 1% in other purpose. It was revealed that overall average production of potato was found to be 5,767.75 Kg/household. The average yield of potato was 951 Kg/ household of for Balephi which was significantly lower (at 1%) than that of Chautarasangachokgadi which was 6,384.5 Kg per household.Similarly, the yield (Kg potato tuber per Ha) was found 13546.96 Kg/Ha which was lower than national average productivity (17,204 Kg/Ha) of potato (MoALD, 2023).

Table 1. Cost components of potato production with location (NRs. per hectare) (2021)

Cost Components	Location			Mean Difference	t value	P value
	Overall	Chautara	Balephi			
Seed tuber	78958.89 (19332.3)	83379.60	74538.17	-8841.43***	-3.31	.001
Land preparation	10149.9 (9527.04)	15984.94	4314.86	11670.07***	10.95	.00
FYM	43915.41 (22429.74)	55874.68	31956.15	23918.53***	8.90	.00
Chemical fertilizer	27685.67 (23240.58)	45842.4	9528.93	36313.46***	17.73	.00
Pesticides	33436.98 (38629.37)	66873.97	0.00	66873.97***	24.57	.00
Labour	94408.40 (38749.59)	127296.19	61520.61	65775.58***	22.79	.00
Transportation	36973.69 (22818.02)	42361.6	31585.78	10775.82***	3.43	.00
Others	4108.33 (15385.31)	8016.67	200.00	7816.67***	3.71	.00
Total cost excluding HH labour	278383.37 (114040.82)	379142.45	177624.29	201518.15***	26.85	.00
Total cost including HH labour	329637.27 (120040.2)	436788.6	222485.94	214302.66***	28.21	.00

Note: Figures in parentheses indicates standard deviation. *** indicates the significant at 1% level.

The yield of potato in Balephi was 7,738.30Kg/Ha which is 44.97 percent less than national average while in Chautarasangachokgadi the yield was 19,355.62 Kg/Ha, 1.12 percent higher than national productivity. The mean difference of productivity between two municipalities was highly significant at 1% level.

Table 2. Production and yield of potato with location (2021)

Particulars	Location			Mean difference	t value	P value
	overall	Chautara	Balephi			
Production at HH level (Kg)	5167.75 (4082.16)	6384.50	3951	2433.50***	4.40	.00
Yield (kg/ha)	13546.96 (7141.52)	19355.62	7738.3	11617.32***	19.82	.00

The estimated values of coefficient and related statistics of Cobb-Douglas production function have been presented in table 3.The coefficient of NPK cost and pesticide cost were positive and significant at 1% level. The co-efficient tuber cost was negative and significant at 10% level and the coefficient of labour cost was also negative and significant at 1% level. Cost of manure application and land preparation had positive impact on the income of potato but the effects were not significant at desired level of significance.

The study revealed that an increase in 10% cost of NPK and chemical pesticides remaining other factors constant would increase the gross return of potato by 0.45% and 0.83% respectively (Haque, Miah, Hossain, & Rahman, 2012) also found positive and significant effect (1%) of NPK used in gross return of potato where the result showed that 10% increase in cost of NPK used increase the gross return of potato by 3.86%. Similarly, an increase in 10% cost of seed tuber and hired labour would decrease the gross return of potato by 1.4% and 0.28% respectively. The value of the co-efficient of multiple determination (R^2) of the model was 0.82 indicating about 82.1 percent of the variation in gross return of potato production were explained by the explanatory variables included in the model. The overall F value was 143.82 and it was statistically highly significant at 1% level of significant. This indicates that the explanatory variable included in the model were important for the explanation of variations in gross returns of potato. Similarly, on an average benefit cost ratio (B: C) from the potato was 1.68. The B:C ratio of potato obtained from this research was slightly lower than the B:C ratio (2.9) obtained by Timsina, Kafle and Sapkota (2011) in Taplejung district while the result was higher than the B:C ratio (1.44) obtained by Bajracharya and Sapkota (2017) in Baglung district. B: C ratio was found highest in Chautarasangachokgadi (1.89) followed by Balephi (1.46). The high B:C ratio in Chautarasanghachokgadi was accounted to high fertilizers, periodic pesticide application for pest control and proper crop management leading to high production per unit area in low cost.

Table 3. Estimated coefficients and their related statistics of production function for potato (2021)

Variables	Coefficients	Std. Error	T	P>|t|	Collinearity Statistics	
					Tolerance	VIF
LN cost of land preparation	0.08	0.05	1.64	0.10	0.34	2.96
LN tuber cost	-0.14*	0.08	-1.83	0.07	0.87	1.14
LN FYM cost	0.01	0.01	0.03	0.73	0.92	1.09
LN NPK cost	0.05***	0.01	5.3	0.00	0.66	1.52
LN pesticide cost	0.08***	0.01	12.37	0.00	0.25	4.05
LN labour cost	-0.03***	0.01	-4.91	0.00	0.72	1.39
(Constant)	13.31***	1.13	11.77	0.00		

Number of observations = 150
F (6, 188) = 143.82
Prob> F = 0.00
R- Squared = 0.82
Adj R- Squared = 0.82
Root MSE = 0.26
Return to scale: 1.03

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.
From the above table we can develop the cobb Douglas model for potatoes as:

$$\ln Y = 13.34 + 0.084 \ln \text{cost of land preparation} - 0.148 \ln \textit{tuber cost} + 0.005 \ln \text{FYM} + 0.045 \ln \text{NPK cost} + 0.083 \ln \text{Pesticides} - 0.028 \ln \text{labour cost} + \mu$$

The return to scale of potato cultivation in study area was found to be 1.032 which signifies the increasing return to scale in production of potato in the study area. It means with increase in variables such as fertilizers, irrigation and human labor can increase the production and can get more return by utilizing optimum resources. The return to scale of potato in Saptari district of Nepal was found 1.85 (Mahatha, 2012), 0.82 in Baglung district (Bajracharya & Sapkota, 2017) and 0.32 in Nuwakot district (Dahal and Rijal , 2019).

In this study the average marketing margin and producer share of potato was calculated. Produce's share in consumer price was found higher that is 66.67 percent. And the average marketing margin was found Rs.11/Kg. In study area**,** the lack of chemical fertilizer was the main problems in the production of potato in study area and ranked I whereas the least problems among was problems of disease and insect pests. Altogether, five marketing channels were operated for marketing of potato throughout the study area had been identified. Those channels

have been presented hereunder which are found during the survey of the study area and market. Multiple handling up to five different handlers were found from the farm to the final consumers which affected the prices and quality of potatoes of study area. Most of the farmers in study area used Channel IV (Producers⇒Collectors⇒Wholesalers⇒ Retailers⇒Consumers) (70.2%) which was more costly and lengthy.

CONCLUSION

Economically, potato cultivation was found to be a profitable business to undertaken in Sindhupalchok. From the obtained benefit cost ratio, it can be concluded that it is more profitable to cultivate potato in large scale as compared to small scale. Gross margin showed that potato cultivation was profitable and best option for potato growing farmers. During the course of survey, it was observed that the farmers were facing many constraints which ultimately affected the cultivation of the potato production. Expensive labor has drastically increased the cost of production of potato in the Sindhupalchok district. Similarly, unavailability of fertilizers in timely, the insects like Potato tuber moth, red ant, white grub and the disease like late blight were prominent and caused huge loss in production. Due to the difficult land topography along with fragmented and small land holding of farmers had caused higher production cost. Mechanization in potato farming could help bring down the associated costs and increase benefits. Apart from this, ensure year-round irrigation, developing higher yielding varieties, supply farm inputs and quality seeds at required times can dramatically boost up the profits from potato farming in the district. It is concluded from the result of this study that potato is still a most profitable crop, which is helpful in income and employment generation and offering the food and nutritional security to the country. The constraints prevailing in the study area needs to be managed by Government, Department of Agriculture, local government and farming community itself, in order to offer a prominent place to the crop in the cropping pattern.

REFERENCES

ABPSD, (2008/2009). *Statistical Information On Nepalese Agriculture*, Singha Durbar, Kathmandu: Agribusiness Promotion and Statistics Division, Ministry of Agricultural Development.

Beattie, B.R., Taylor, C.R. and Watts, M.J., (1985). *The economics of production*.

CBS, (2021).*National Census of Agriculture*, Kathmandu: Central Bureau of Statistics, Government of Nepal.

Dahal, B.R. and Rijal, S., (2019).*Production economics and determinants of*

potato production in Nuwakot, Nepal. International Journal of Applied Sciences and Biotechnology, *7*(1), pp.62-68.

Gujrati, D., (2003). *Basic Econometrics*. 4th edition. Singapore: Tata McGrawHill.

Haque, M.A., Miah, M.M., Hossain, S. and Rahman, M.M., (2012). Profitability of BARI released potato (Solanum tuberosum L.) varieties in some selected locations of Bangladesh. *Bangladesh Journal of Agricultural Research*, *37*(1), pp.149-158.

Hayes, A., (2020). Benefit-Cost Ratio (BCR). *Retrieved from Investopedia: https://www. investopedia.com/terms/b/bcr. asp*.

IYP, (2008). *Global Potato Economyl.* [Online] Available at: http://www.fao.org/potato-2008/en/potato/economy.html [Accessed 23 sseptember 2020].

MoALD, (2015).*Statistical Information on Nepalese Agriculture,* Kathmandu: Agri-Business Promotion and Statistics Division,MOAD.

MoALD, (2019).*Statistical Information on Nepalese Agriculture,* Kathmandu: Agri-Business Promotion and Statistics Division,MOAD.

MoALD, (2020).*Statistical Information on Nepalese Agriculture,* Kathmandu: Agri-Business Promotion and Statistics Division,MOAD.

MoALD, (2021).*Statistical Information on Nepalese Agriculture,* Kathmandu: Agri-Business Promotion and Statistics Division,MOAD.

MoALD, (2021).*Statistical Information on Nepalese Agriculture,* Kathmandu: Agri-Business Promotion and Statistics Division,MOAD.

Ojha, D., Hidalgo, O. A. & Lama, T. G., (2001).*A Report on informal high quality seed-potato production and marketing by seed producer groups in Nepal.*From the lab to the land, research for the 21st century, International Potato Center.

Subedi, S. et al., (2019). Economics of potato (Solanumtuberosum) production in Terai Region of Nepal. *Archives of Agriculture and Environmental Science*, 4(1).pp. 57-62.

Timsina, K. P., Kafle, K. &Sapkota, (2013).Economics of Potato Production in Taplejung District of Nepal.*Agronomy Journal of Nepa*l, pp. 173-181.

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ECONOMIC EFFICIENCY OF RICE MILLING INDUSTRY AMONG VALUE CHAIN PROCESSORS IN NORTH WEST OF NIGERIA.

***Olugbenga Omotayo,[1]ALABI., Paul Akinwumi, [2]ATTEH., Adeniyi Clement, [1]ABILORO., Jeremiah Samuel, [3]ALUWONG., Abduraman, [4]IBRAHIM., Hassan, [5]ISAH., Aisha Ozioma, [1]ALIYU, and Ojuh Ezekiel, [6]HARUNA**

[1]Department of Agricultural-Economics, Faculty of Agriculture, University of Abuja, PMB 117, Gwagwalada-Abuja, Federal Capital Territory, NIGERIA.

[2]Department of Agricultural Economics and Extension, Faculty of Agriculture, Federal University of Lafia, PMB 146 Lafia, Nasarawa State, NIGERIA.

[3]Department of Agricultural-Extension and Management, School of Agricultural Technology, Nuhu Bamali Polytechnic, Zaria, Samaru Kataf Campus, Kaduna State, NIGERIA.

[4]Department of Agricultural Technology, School of Applied Science, Federal Polytechnic Nasarawa, Nasarawa State, NIGERIA.

[5]Agricultural Research Council of Nigeria (ARCN), Agricultural Research House Plot 223D Cadastral Zone B6, Mabushi, PMB 5026, Wuse-Abuja, NIGERIA.

[6]Department of Agricultural-Economics and Extension, Faculty of Agriculture, Prince Abubakar Audu University, Anyigba, Kogi State, NIGERIA

***Corresponding Author:** omotayoalabi@yahoo.com

ABSTRACT

This study evaluated economic efficiency (EE) of the rice milling industry among value chain processors in North West of Nigeria. A purposive sampling technique was employed. A total sample size of 80 rice processors was selected. About 41 (51.25%) of rice processors were from Kano State, while 39 (48.75%) of rice processors were from Kaduna State. Primary data were obtained using a well-designed and a well-structured questionnaire. Data were analyzed using descriptive statistics, gross margin analysis, financial analysis, stochastic frontier efficiency model, Tobit dichotomous regression model, and principal component analysis. The results showed that the mean age of rice millers was 46 years. Averagely, about 289,906 Kg of rice paddy were purchased by the rice millers and 217, 216 Kg (75% of paddy rice purchased) of milled rice were processed per annum. Rice processing was profitable in the area with a net income of 13,

522, 068 Naira per annum. The mean allocative, economic and technical efficiency scores of rice millers were 0.6320, 0.6220 and 0.5795, respectively. The significant socio-economic factors influencing EE of rice processing activities included: age of processor (P < 0.05), educational level (P < 0.05), membership of cooperatives (P < 0.05), access to credit facilities (P < 0.05), and experience in processing (P < 0.05). The major constraints faced by rice millers included: lack of credit, high cost of processing equipment, lack of storage facilities, bad road infrastructures, high cost of inputs, poor price information, lack of training, and lack of extension services. The study recommends that rice paddy production should be improved through research and extension, and improved seeds variety, fertilizers inputs, chemical inputs and credit facilities should be adequately provided to the farmers.

Keywords: Economic Efficiency, Rice Processors, Value Chain, North West, Nigeria.

INTRODUCTION

Rice (*Oryza sativa*) is an important and staple food crop in Nigeria, majority of Nigerians rely on rice for their daily diet. Rice milling or processing is an essential and significant part of Nigeria' agricultural sector. Rice processing or milling has become an important agro-processing sector employing thousands of millers, traders, and parboilers as demand for rice has grown over the years (Johnson and Masias, 2016). Nigeria consume 7 million tonnes of milled rice as against 2.5 million tonnes of milled rice produced by farmers (which equals to 4 million tonnes of paddy produces by farmers) in 2017, leaving a huge supply gap (Foyeku, 2017).About 4.4million tonnes of paddy and 2.8 million tonnes of milled rice (100Kg of paddy rice equals 63Kg of milled rice) was produced in Nigeria with an estimated national consumption of about 6 million tonnes of milled rice leaving a gap of about 3.2million tonnes in 2013 (GAIN Report, 2014).In 2022,not all 8 million metric tonnes of milled rice consumed was produced in Nigeria, the quantity of milled rice produces in 2022 was estimated at 5.4 million metric tonnes (Danbaba, 2023). In 2008, about 2 million metric tonnes of milled rice was produced in Nigeria (USAID, 2009). Rice processing can reduce post-harvest losses and add value to the grain. Rice processing promotes local consumption and production. Rice milling or processing is a combination of activities or operation that turn paddy into high quality white rice, the operation is highly dependent on the management capabilities of the processors (Obianefo et al., 2023). Rice milling will help reduce poverty, has the potentials to create jobs, and can generate additional income, and improve overall standard of living for

farmers. Rice milling improve processors livelihood and promote Nigeria's economic stability. About 95% of rice processors are smallscale and they use low capacity and outdated mills and this result to poor quality of rice than imported rice, however, there is still an overall acknowledgement of higher organoleptic properties of local rice (Olaniyi, 2011; Bamidele et al., 2010; Lancon et al., 2003). Johnson and Ajibola (2016) reported that the average paddy production costs, including rice processing and marketing costs in Nigeria tends to be higher than those in Thailand. The higher milling costs in Nigeria were primarily due to the high costs of procuring paddy which involve high search cost and a premium for the scarce superior paddy varieties sought by large mill operators. The trade and marketing costs also are high because of the distance to urban markets throughout the country. The poor performance of the entire Nigerian rice value chain compared to that of Asian countries leaves significant room for improvement. Actors in the rice value chain have different skills and degree of access to improved technology, information, services, and thereby rarely upgrade to better paddy varieties and processing technology. The final milled rice from processors is therefore broken, discolored, contains foreign debris and stones, the consumers view the rice as inferior and non-substitutable with the higher quality premium rice obtained from modern mills. Small-scale rice milling operators serve a large number of people including rural traders, paddy farmers, retailers, wholesalers, final consumers and supply almost 70% of the domestic rice consumed in Nigeria. The small-scale processors make up the most significant sub-sector of the domestic rice milling industry in Nigeria. The various activities involved in rice processing from paddy stage include: cleaning, hulling, milling, polishing, grading, sorting, and packaging (Ibitoye et al., 2014). Agricultural productivity is determined by crop yield, marketing and efficiency of post-harvest processing (Sakurai et al., 2006). The processing efficiency of rice millers is very important for decision makers and has policy implications towards rice value addition. Rice processing form the major part of rice value chain has been identified as one of the ways of preventing post-harvest losses (Appaiah et al., 2011). Efficiency can be defined as the possibility of firms producing a certain level of output at minimum cost or a certain optimum level of product from a given bundle of inputs. Efficiency is a significant factor that can raise productivity growth, without developing a new technology or increasing the resource base (Adeyemi et al., 2017). A technical efficient firm is the one that produces the maximum output for a given amount of inputs given the level of production technology available. Allocative efficiency produces the optimal mix of outputs using the optimal amount of inputs given the production technology and the prices it faces. Economic efficiency is achieved when both allocative and technical efficiencies

have been attained. Economic efficiency is the product of technical and allocative efficiencies.

METHODOLOGY

This research study was conducted in Kano and Kaduna States, North West of Nigeria. Kaduna State occupies between Longitudes 06° 15| and 08° 50| East and Latitudes 09° 02| and 09° 02|North of the equator. The State has a total land area of 4.5 million hectares. The state vegetation is divided into 2, the Southern guinea savanna and the Northern guinea savanna. There are 2 seasons, they are: the wet and the dry seasons, the dry season is between October to March, and the wet season starts from April to October and in between the wet and dry seasons is the brief harmattan period which span from November to February. The mean rainfall is about 1,482mm, the temperature of the State ranges from 35°C - 36°C, which can be as low as 10°C to 23°C during the harmattan period. The population of the State in 2021 stood at 8.9 million people. They are involved in farming. Crops grown include: okra, maize, pepper, rice, sorghum, ginger, millet, yam, tomatoes and cassava. Animal reared include: sheep, cattle, rabbit, goats, and poultry. Purposive method of sampling was used. About 80 rice processors were selected. Data obtained from rice processors were of primary sources and were collected using a well-structured and also a well-designed questionnaire. The questionnaire was administered to rice processors using well trained enumerators.

Kano State occupies between Longitudes 08° 35| 31‖East and Latitudes 12° 0| 8‖North of the equator. The state is bordered by the states of Jigawa to the North and East Bauchi to the South-East, Kaduna to the South-West, and Katsina to the North-West. The total area of the state is 20, 280 Sq Km, with an annual temperature of 26°C - 30°C. Kano is very hot for most of the year peaking in April with 39.1°C, from December through February, the city is less hot, with morning temperatures during the months of December, January, February averaging 14°C - 16°C. Kano has an average of about 109.0 mm of rainfall per year. Kano is a tropical savanna climate, which consists of wooden savanna in the South, and scrub vegetation in the North. The population of Kano is about 13,852,238 in 2018 and 14, 253,549 as at 2019. They are involved in farming. Crops grown include: groundnut, millet, tomatoes, cowpeas, sorghum, maize, rice and cotton. Animal reared include: goats, cattle, sheep, rabbit, and poultry.

Research Design

A descriptive and cross-sectional research design was employed with the aim of describing the socio-economic characteristics of rice processors, and to evaluate

factors influencing economic efficiency (EE) of rice processing activities among value chain processors.

Sampling Techniques and Sample Size

A purposive sampling technique was adopted. A reconnaissance survey was conducted to identify the rice milling enterprises in Kaduna and Kano States, Nigeria. A total sample size of 80 rice processors comprising of 41 (51.25%) smallscale rice processors from Kano State, and 39 (48.75%) smallscale rice processors from Kaduna State) was identified and they were purposively selected for this study.

Methods of Data Collection

Primary data were used for this research study. The data were collected through the use of a well-designed and well-structured questionnaire. The questionnaire was administered to rice processors through well-trained enumerators. Data were analyzed through the use of descriptive and inferential statistics:

Descriptive Statistics: This involves the use of mean, frequency distributions, and percentages, to present the summary statistics of the rice processors and the rice milling enterprises. This was to achieve specific objectives 1 (i) and 2 (ii).

Gross Margin Analysis: Gross margin (GM) and net farm income analysis of rice milling enterprises was estimated using the following models:

$$GM = TR - TVC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$NFI = TR - TC \ldots\ldots\ldots\ldots\ldots (2)$$

Where

$TR =$ Total Revenue obtained from Rice Milling Activities (₦),

GM = Gross Margin (Naira)

$TVC =$ Total Variable Cost (₦),

$NFI =$ Net Farm Income (Naira)

The gross margin analysis was used to specifically achieve objective 3 (iii).

Financial Analysis: According to Alabi et al. (2020), gross margin ratio (GMR) is defined as:

$$GMR = \frac{Gross\ Margin}{Total\ Revenue} \ldots\ldots\ldots\ldots (3)$$

According to Olukosi and Erhabor (2015), operating ratio (OR) is defined as:

$$OR = \frac{TVC}{GI} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where,

TVC = Total Variable Cost (Naira),

GI = Gross Income (Naira),

The rate of return per naira invested (RORI) in rice processing is defined as:

$$RORI = \frac{NI}{TC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

$RORI =$ Rate of Return per Naira Invested (Unit),

$NI =$ Net Income (Naira),

$TC = Total\ Cost\ (Naira)$.

The financial analysis was used to analyze the profitability of rice processing as stated specifically in objective 3 (iii).

Stochastic Production Efficiency Frontier Model

According to Alabi et al. (2022), the stochastic production frontier model is stated thus:

$$Y_i = f(X_i, \beta_i)e^{v_{i-}u_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where,

$Y_i =$ Output of Rice Processing Facilities (Kg)

X_i = Vectors of Factor Inputs

β_i = Vectors of Parameters

V_i = Random Variations in Rice Milling Output

U_i= Error Term due to Technical Inefficiency

The stochastic frontier model, according to Obianefo et al. (2023) is defined as:

$$LnY_i = \sum_{j=1}^{6} \beta_j LnX_{ji} + (V_i - U_i) \ldots\ldots\ldots\ldots (7)$$

Ln = Natural Log

Y_i = Milled Rice Produced (Kg)

X_1 = Paddy Rice (Kg)

$X_2 =$ Labour Input (Manhour)

$X_3 =$ Diesel (Litres)

$X_4 =$ Water for Parboiling (Litres)

$X_5 =$ Amount Spent on Firewood (Naira)

X_6 = Depreciation of Assets (Naira)

$V_i =$ Random Noise

$U_i =$ Error due to Inefficiency

$$U_i \sim N^{+}(V_j(Z_j)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

They are individual variables which include: age (years), level of education (years), processing experience (years), and household size (numbers)

This was used to achieve specifically objective 4 (iv).

Economic Efficiency (EE)

Economic efficiency was derived from the product of TE and AE for individual rice processors. The EE of rice processing activities among processors is therefore specified as:

$$EE_i = TE_i \text{ X } AE_i \ldots\ldots\ldots\ldots\ldots (9)$$

Where,
EE_i= Economic Efficiency (Number)
TE_i = Technical Efficiency (Number)
AE_i= Allocative Efficiency(Number)
This was used to achieve specifically objectives 4(iv) which is to determine the AE, TE, and EE scores of rice processors, and 5 (v) which is to evaluate socio-economic factors influencing EE of rice processing activities.

Tobit Dichotomous Regression Model: The dichotomous Tobit response model following Gujarati (2004) is defined as follows:

$$Y_i^* = X_i\beta + \varepsilon_i$$

$$Y_i^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon_i \ldots\ldots (10)$$

$$Y_i = \begin{cases} 1 \; if \; Y_i^* \geq 1 \\ Y_i^* \; if \;\; 0 < Y_i^* < 1 \\ 0 \; if \; Y_i^* \leq 0 \end{cases}$$

$Y_i^* = \text{Latent or Unobserved Variable}$
Y_i = Efficiency Score Representing EE (Number)
$X_1 =$ Age of Processors (Years)
$X_2 =$ Sex of Processors (1, Male; 0, Otherwise)
$X_3 =$ Marital Status (1, Married; 0, Otherwise)
$X_4 =$ Household Size (Number)
$X_5 =$ Educational Level (Years)
$X_6 =$ Membership of Cooperative Society (1, Member; 0, Otherwise)
$X_7 =$ Access to Credit Facilities (1, Access; 0, Otherwise)
$X_8 =$ Experience in Processing (Years)
$\varepsilon_i = \text{Disturbance Term},$
$\beta_1 - \beta_8 = \text{Regression Coefficients},$
$\beta_0 = \text{Constant Term},$

This was used to achieve specifically objective 5 (v) which is to evaluate socio-economic factors influencing economic efficiency of rice processing activities.

Principal Component Analysis: The constraints facing rice processors and militating against rice milling activities were subjected to principal component analysis. This was used to achieve specifically objective 6 (vi).

RESULTS AND DISCUSSION

Summary Statistics of Rice Millers, Rice Milling Capacity, and Processing Activities

Table 1 presented the summary of data of rice millers and processing activities in Kano and Kaduna States, North West, Nigeria. The average rice paddy supplied to the milling machine was 289, 906.0 Kg, after milling activities that helped to convert the grain to milled rice, an average output of 217, 216 Kg milled rice was recorded. This shows that 25.07% of the initial paddy weight was lost along the rice value chain. This is in line with Obianefo et al. (2023) who reported that 25% of the initial paddy weight was lost along the rice value chain. The result is also in consonance with Sadiya and Hassan (2018) who reported that 21% of rice is lost at the processing stage. The mean age of rice processors was 46 years, this shows that they are in their active and productive age, age of rice processors had an impact on the managerial capability of the rice millers. This is consistent with the results of Adeyemi et al. (2017) who reported the mean age of 48 years among rice milers in southwest Nigeria. The mean household size of rice millers was 9 members. This is in consonance with findings of Ugwanyi et al. (2008) who reported an average household size of 6 members for rice millers in Enugu State, Nigeria. This is also in line with findings of Ojumu and Adeyelu (2014) who reported an average household size of 6 members for rice millers in Cross Rive State, Nigeria. The mean processing experience of rice millers was 12 years', this mean they could have acquired the good experience required in paddy rice processing. This is similar to findings of Adeyemi et al. (2017) who obtained the mean experience of 15 years for rice millers in Southwest, Nigeria. Education is an important socio-economic factor that influence rice millers' decision because of its influence on rice processors perception, awareness, adoption and reception of innovations the can bring about increase in profit margin. Averagely, rice processors spent 13 years in formal learning institutions, this means they are literate and can read and write.

This is consistent with the results of Bime et al. (2014) who reported that 58% of rice processors had primary education. About 88% of rice processors were male, this is in consistent with the findings of Ugwuanyi et al. (2008) who reported that male dominated the rice processing activities due to the physical labour required in handling the milling activities. The milled rice activities and trade involves travelling from villages to villages in search of paddy rice, bagging, measurements, loading, and parboiling which are too cumbersome for females.

About 8% of rice processors had access to credit facilities, and the average land owned by rice millers was 1.52 hectares.

Table 1. Summary statistics of rice processors and processing activities

S/N	Variables	S.I. Units	Mean	SD
1	Average Output of Milled Rice	Kg	217,216.0	616,213.1
2	Average Rice Paddy	Kg	289,906.0	757,113.4
3	Age	Years	46	10.30
4	Household Size	Number	9	3.70
5	Processing Experience	Years	12	5.90
6	Level of Education	Years	13	6.21
7	Sex	Dummy(1=Male)	0.88	0.32
8	Access to Credit Facilities	Dummy(1=Access)	0.08	0.27
9	Total Land Own	Ha	1.52	1.27

Source: Field Survey (2022) SD-Standard Deviation

Analysis of Average Costs and Returns of Rice Milling per Annum

The cost and return analysis of rice processing activities was presented in Table 2. The cost incurred and revenue obtained was based on the prevailing prices as at the time of this survey. The revenue obtained and TC of milling 217, 216 Kg of paddy rice per annum was 139, 018, 240 Naira and 125, 496, 172 Naira respectively. This was due to the fact that most rice mills operate on different levels. The analysis of the cost structure revealed that rice paddy cost account for 97.02% of the TC, this implies that rice paddy supply is low hence the high cost of purchase. This is followed by energy cost (Diesel) which accounted for 0.78%, milling machine which accounted for 0.684%, and labour which accounted for 0.44% of the total cost respectively. This result is similar to the findings of Adeyemi et al. (2017) who reported that rice paddy cost accounts for about 88%, energy accounts for 8.5%, transport accounts for 3.2% and labour accounts for 1.6% of the TC among rice millers in Southwest, Nigeria. The TVC (124, 261, 238 Naira) and TFC (1, 234, 914 Naira) accounted for 99.01% and 0.99% of the TC respectively. The FC consists of milling machine, depreciation of assets, and electricity bills/taxes. The GM and net income of rice processing per annum was 14, 757,002 Naira and 13, 522, 068 Naira respectively. This shows that rice processing was profitable in the area. The GMR and rate of return on investment was 0.106 and 0.107 respectively. The rate of return of 0.11 implies that for every one Naira invested in rice paddy processing, 11 kobo was realized. This result is in line with Ojumu and Adeyelu (2014) who reported an average rate of return of

0.35 for locally milled rice at micro scale in Ogoja local Government Area of Cross River State, Nigeria.

Table 2. Average Costs and Returns Analysis of Rice Milling per Annum

Variables	Naira	Percentage
Milled Rice ₦ per Kg	640	
Revenue (@ 217,216.0Kg)	139,018,240	
Gross Income	168,211,135	
Variable Cost		
Paddy Rice (420 ₦/Kg @ 289,906.0 Kg)	121,760,520	97.02
Firewood	141,225	0.11
Water	25,005	0.01
Parboiling/Drying	22,750	0.02
Hulling	247, 120	0.196
Milling	256, 565	0.20
Grading	27,247	0.02
Sorting	23,984	0.02
Parking	17,892	0.014
Labour	555,790	0.44
Loading and Offloading	22, 400	0.02
Transportation	140,750	0.11
Bagging	16, 570	0.01
Sewing	11, 270	0.008
Cost of Bags, Needle, Thread	12,670	0.01
Diesel	979,500	0.78
Total Variable Cost (TVC)	124,261, 238	99.01
Fixed Cost (FC)		
Milling Machine and other Assets	859,250	0.684
Depreciation of Mills	26,751	0.02
Electricity Bill/Taxes	221, 370	0.176
Deprecation of other Assets	127, 543	0.10
Total Fixed Cost (TFC)	1,234,914	0.99
Total Cost (TC)	125, 496,172	
Gross Margin (GM)	14,757,002	
Net Income (NI)	13,522,068	
Rate of Return on Investment	0.107	
Operating Ratio (OR)	0.738	
Gross Margin Ratio(GMR)	0.106	

Source: Field Survey (2022) 1 USD = 710 Naira

The summary statistics of AE, EE and TE scores of rice processors are presented in Table 3. It was observed that there are variations among the rice miller's allocative, economic and technical efficiencies. All the rice processors were

technically, allocativelly, and economically inefficient in the processing of rice paddy. This means that their levels of efficiency were less than 100%. The highest frequencies of occurrences of the AE, EE, and TE were between 0.61 (61 percent) and 0.80 (80 percent). This represent 36.25%, 46.25% and 26.25% of the AE, EE and TE scores for the sampled rice millers respectively. The mean AE, EE, and TE of the rice millers based on their milling capacities were 0.6320 (standard deviation=0.2022) ,0.6220 (standard deviation=0.2132) and 0.5795 (standard deviation = 0.2561), respectively.

The Allocative (AE), Economic(EE) and Technical Efficiency(TE) Scores of Rice Millers

These results showed that processors can increase their rice paddy processing by 42.05%. It also shows that they can reduce their cost of processing by 37.80% to achieve the potential minimum cost of processing relative to the efficient processors given the current output level.

The mean TE score of 0.5795 (maximum = 0.951) for the rice millers implies that they are operating at 42.05% below their optimal capacity (full capacity). The results imply that there are opportunities for processors in the industry to increase their milling capacities by engaging in activities such as entrepreneurship training, and participate in capacity program to improve their managerial skills. This result is in consistent with the findings of Obianefo et al. (2023) who recorded TE of 0.506 for smallscale rice processors in Anambra State, Nigeria.

Table 3. Summary statistics of technical, economic and allocative efficiency scores

Efficiency Score	Allocative efficiency		Economic Efficiency		Technical Efficiency	
	Frequency	%	Frequency	%	Frequency	%
0.00 – 0.20	02	02.50	03	3.75	07	08.75
0.21 – 0.40	08	10.00	12	15.00	15	18.75
0.41 – 0.60	24	30.00	14	17.50	18	22.50
0.61 – 0.80	29	36.25	37	46.25	21	26.25
0.81 – 1.00	17	21.25	14	17.50	19	23.75
Mean	0.6320		0.6220		0.5795	
St. Deviation	0.2022		0.2132		0.2561	
Minimum	0.161		0.157		0.126	
Maximum	0.927		0.873		0.951	

Source: Field Survey (2022)

Socio-Economic Factors Influencing Economic Efficiency (EE) among Rice Millers

Table 4 presents the Tobit dichotomous regression model used to analyze the socio-economic factors influencing EE of rice processing activities among rice millers. Economic efficiency measures which is the product of technical efficiency(TE) and allocative efficiency (AE) are regressed on age of processors, dummy variable for sex of the processors (male = 1, and 0 if otherwise), dummy variable for marital status (married =1, and 0 if otherwise), household size, educational level, dummy variable for membership of cooperative (membership = 1, and 0 if otherwise), dummy variable for access to credit (access = 1, and 0 if otherwise), and experience in paddy processing. The result of the model shows that four (4) out of the eight (8) variables were found to have a significant influence on the EE of rice millers. These variables included age of processors, educational level, membership of cooperatives, access to credit facilities, and experience in paddy processing. The coefficient of age of processors was negative (-0.00106) and significant at ($P < 0.05$), this implies that older processors are less economically efficient than younger processors who are more receptive to technological changes in processing that influence efficiency. As rice processors advanced in age, the probability of rice millers being economic efficient decreases by 37.16%. The coefficient associated with the educational level was positive (0.00287) and significant at ($P < 0.05$). This signifies that the level of education of processors contributes to the reduction in inefficiency in paddy rice processing. As education increase by one year, the probability of rice processors being economic efficient increase by 16.23%. Similar results were obtained in the works of Degefa et al. (2020), Tesema (2021) and Moges (2018). The coefficient of membership of cooperatives was positive (0.00348) and significant at ($P < 0.05$). Membership of cooperatives enables the rice processors have access to credit facilities, purchase their inputs in bulk and also jointly sell their products at affordable prices. As rice processors become member of cooperative group, the probability of being economic efficient increase by 8.78%. The result also indicated that access to credit facilities had a positive sign (0.05924) and statistically significant effect on EE level at 5% level of significance. This also indicated that rice processors who use credit facilities tend to unveil higher levels of efficiency. A change in the dummy variable representing the uses of credit facilities by the rice processors from 0 to 1 would increase the probability of the rice processors being economically efficient by about 27.67%. A significant positive influence was also reported by Awudu and Wallace (2016), Assefa et al. (2019), and Tesema (2021). The coefficient of experience in rice processing was positive (0.00272) and significant at 5% level of significance. An increase in

experience in rice processing will lead to probability of the rice processors being economic efficient by 6.58%. The Tobit dichotomous regression model carried out and evaluate socio-economic factors influencing EE of rice processing activities in North West of Nigeria was significant at one percent (1%) level of significant (P = 0.000). The Pseudo-R^2 obtained is equal to 0. 6471.This result signifies that the variables included in the regression model explained the EE of rice processing activities in the study area at 64.71%.

Table 4. Maximum likelihood results of the tobit dichotomous regression model

Variables	Parameters	Coefficient	Standard Error	t-Value	ME
Constant	β_0	1.2302	0.5419	2.27	0.0548
Age of Processors	β_1	-0.00106**	0.00047	-2.25	0.3716
Sex of Processors	β_2	0.03205	0.03724	0.860	0.2619
Marital Status	β_3	0.00407	0.00538	1.322	0.4131
Household Size	β_4	0.00807	0.00967	0.845	0.0176
Educational Level	β_5	0.00287**	0.00786	2.74	0.1623
Membership of Cooperatives	β_6	0.00348**	0.00866	2.49	0.0878
Access to Credit Facilities	β_7	0.05924**	0.02743	2.15	0.2767
Experience in Processing	β_8	0.00272**	0.00097	2.80	0.0658
Diagnostic Statistics					
Sigma	0.09724				
LR Chi^2 (8)	82.85***				
Pseudo R^2	0.6471				
Log Likelihood	57.2512				
Prob > Chi^2	0.00000***				

Source: Data Analysis (2022), ME=Marginal Effect
*Significant at ($P < 0.10$)., **Significant at ($P < 0.05$), ***Significant at ($P < 0.01$).

This implies that the model has good explanatory power on the changes in socio-economic factors influencing EE of rice processing activities among the respondents with 99% level of confidence. The Likelihood ratio obtained is relatively high. This shows that considering the variables included in the model rice processing has 82.85% chance of being economically efficient in the study area.

Constraints Faced by Rice Processors in the Study Area

The constraints facing rice processors were subjected to principal component analysis (Table 5). The constraints with Eigen-values greater than one were retained by the model. Those constraints with Eigen-values less than one were

discarded by the model. Lack of credit facilities with Eigen-value of 2.5740 was ranked 1st based on the perceptions of the rice processors. This explained 10.37% of all the constraints retained by the model. High cost of processing equipment's with Eigen-value of 2.2567 was ranked 2nd based on the perceptions of the rice processors and this explained 10.42% of all the constrained retained by the model. Lack of storage facilities with Eigen value of 2.0176 was ranked 3rd based on the perceptions of the rice processors and this explained 10.67% of all constraints retained by the model. This result is in consonance with the findings of Alabi and Anekwe (2023), Alabi and Chiogor (2023). All constraints retained by the principal component model explained 81.43% of all constrained included in the model. These challenges are in agreement with issues raised by Sennuga et al. (2021) who reported that rice processors in developing countries lack access to reliable market information, additionally, poor road network makes it difficult for processors to transport their products to access wider market option and that the smallscale processors lack the needed knowledge and skills necessary to maximize their production process. These findings are consistent with the study of Akinnira and Faleye (2020) who express concerns about poor access to storage facilities which leads to spoilage and pest infestations, and inadequate finance which will limit the processors ability to take advantage of new market opportunities.

Table 5. Principal component analysis of constraints encountered by rice processors

Constraints	Eigen-Value	Difference	Proportion	Cumulative	Rank
Lack of Credit Facilities	2.5740	0.3173	0.1037	0.1037	1st
High Cost of Processing Equipment	2.2567	0.2391	0.1042	0.2079	2nd
Lack of Storage Facilities	2.0176	0.1231	0.1067	0.3146	3rd
Bad Road Infrastructures	1.8945	0.1989	0.1178	0.4324	4th
High Cost of Input	1.6956	0.1324	0.1074	0.5398	5th
Poor Price Information	1.5632	0.1035	0.1302	0.6700	6th
Inadequate Capacity Building	1.4597	0.3318	0.0967	0.7667	7th
Lack of Extension Services	1.1279	0.1292	0.0476	0.8143	8th
Bartlett Test of Sphericity					
Chi Square	204.26				
KMO	0.7601				
Rho	1.0000				

CONCLUSION

This study was conducted to evaluate EE of rice processing industry among rice millers in Northwest, Nigeria. To this end, information on the socio-economic characteristic of rice millers, the costs and returns data, TE, AE and EE of rice processing activities were collected. The findings have demonstrated that the rice millers were mostly male, young, energetic, resourceful and well educated. They have large household size with 9 members and had considerable experience in rice processing with 12 years processing experience. Averagely, about 289,906 Kg of rice paddy were purchased and 217, 216 Kg of milled rice were produced annually. Rice processing was profitable in the study area with an estimated net income of 13, 522, 068 Naira per annum. Based on the results obtained from the applied econometric models, socio-economic factors such as the age of processors, educational level, memberships of cooperatives, access to credit facilities, and experience in processing affects EE of rice processing activities. The mean AE, EE and TE scores of rice millers were 0.6320, 0.6220, and 0.5795 respectively. However, it was noted that the most relevant constraints faced by rice processors were lack of credit facilities, high cost of processing equipment, lack of storage facilities, bad road infrastructures, high cost of inputs, poor price information, inadequate training, and lack of extension services.

RECOMMENDATIONS

The rice paddy production should be improved through research and extension, improved seeds variety should be provided for farmers, and farm inputs such as fertilizers and chemicals should be adequately provided for farmers.

Strategies must be developed to facilitates producers access to production inputs and adequate agricultural equipment.

Credit facilities should be provided for millers at low interest rate this will enables millers to have access to modern technologies and equipment's, rice millers would be able to increase the efficiency of their operations and ultimately increase their profits.

Storage facilities should be constructed by government to reduce rice paddy or milled rice spoilage and pest infestations.

The energy sectors should be looked into to reduce cost of diesel.

REFERENCES

Adeyemi, B.B., Okoruwa, V.O., and Ikudaisi, A (2017). Cost Efficiency among Rice Millers in Southwest Nigeria.International Journal of Social Economics,44 (12): 2450 – 2465. https://doi.10.1108/IJSE-06-2015-0137

Alabi, O.O and Chiogor, O.H (2023). Technical Efficiency of Tiger Nut (*Cyperus esculentus*) Production in Katsina State: Socio-Economic Drivers and Implications for Consumers Health Benefits. *Australian Journal of Science and Technology*, 7 (1): 46 – 53

Alabi, O.O., and Anekwe C.E (2023). Economics of Climate Smart Agricultural Practices (CSAPs) Used by Smallholder Sorghum Producers in Nigeria. *Australian Journal of Science and Technology*, 7(1); 65 – 71.

Alabi, O.O., Oladele, A.O and Oladele, N.O (2020). Economic Market Decisions among Marginal Maize Farmers in Abuja, Nigeria: Applications of Double Hurdle Model and Factor Analysis. *Russian Journal of Agricultural and Socio-Economic Sciences*, 8(104): 114 – 125.
DOI: https://doi.org/ 10.18551/rjoas.2020-08.14.

Alabi, O.O., Oladele, A.O., and Maharazu, I (2022). Economies of Scale and Technical Efficiency of Smallholder Pepper (Capsicum species) Production in Abuja, Nigeria. *Journal of Agricultural Sciences*, (Belgrade), 67 (1): 63 – 82. DOI: https://doi.org/10.2298/JAS2201063A.

Appaiah, F., Guisse, R and Dartey, P.K.A (2011). Post-harvest Losses of Rice from Harvesting to Milling in Ghana. *Journal of Stored Products and Post-harvest Research*,2 (4): 64 – 71.

Assefa, A., Hajiand, J and Tegegne, B (2019). Technical Efficiency of Wheat Production by Smallholder Farmers in Soro District of Hadiya Zone, Southern Ethiopia. *East Afr. J. Sci.* 13 (2) 113 – 120.

Akinniran,T.N and Faleye,G.R (2020). Economics Analysis of Rice Production and Processing in Nigeria (1981 -2019). *Int. J. Agric. Environ. Bioresearch*, 5: 113 – 132.

Awudu, A and Wallace, H (2016). Structural Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana. *Econs. Dev. Cult. Change*, 48: 503 – 520.

Bamidele, F.S., Abayomi, O.O., and Esther, O.A (2010). Economic Analysis of Rice Consumption Patterns in Nigeria. *Journal of Agricultural Science and Technology*, 12(1): 1 – 11

Bime, M.J., Fon, D.E., Ngalim, S.B., and Ongla,J (2014). Profitability and Efficiency Analyses of Smallscale Rice Processing Units in Ngoketunjia Division, North West Region, Cameroon *J.Adv.Agric*. 3 : 177 – 182

Danbaba, M (2023). Nigeria Can be Self-Sufficient in Rice in 8 Years. National Accord, 2023.
https://www.nationalaccordnewspaper.com/nigeria-can-be-self-sufficient-in-rice-in-8- years-if-research/ (accessed 19 January 2023)

Degefa, K., Biru, G., & Abebe, G (2020). Economic Efficiency of Smallholder

Farmers in Tomato Production in BakoTibe District, Oromia Region, Ethiopia. *J. Agric. Sci.* 11, 273.

Foyeku, S (2017). Nigeria cannot Attain Self-Sufficiency in Rice Production in 2018. In: S. Foyeku (ed*). Rice Importers, Millers, and Distribution Association of Nigeria*. Retrieved 16 September, 2023. https://www.shipsandport.com.ng

Gujarati, D (2004). *Basic Econometrics*. McGraw-Hill Companies, Tokyo

GAIN Report (2014). Global Agriculture Information Network, United States Department of Agriculture, and Foreign Agriculture Service.

Ibitoye, S.J., Idoko, D., Shaibu, U.M (2014). Economic Assessment of Rice Processing in Bassa Local Government Area of Kogi State, Nigeria. *Asian J. Basic Appl*. Sci.: 1: 8 – 17.

Johnson, M and Ajibola, A (2016). Post-harvest Processing, Marketing, and Competitiveness of Domestic Rice, In: *Gyimah-Brempong, Kwabena, Michael Johnson and Hiroyuki Takeshima (eds), The Nigerian Rice Economy: Policy Options for Transforming Production, Marketing and Trade*, Philadelphia: University of Pennsylvania Press

Johnson, M and Masias, I (2016). *Assessing the State of the Rice Milling Sector in Nigeria: The Role of Policy for Growth and Modernization.* Nigeria Strategy Support Program. International Food Policy Research Institute, Working Paper 40.

Lancon, F., Erenstein, O., Akande, S.O., Titilola, S.O., Akpokodje, G and Ogundele, O.O. (2003). *Rice Processing in Nigeria: A Survey*, West Africa Rice Development Association (WARDA), Abidjan.

Moges, D (2018). Measurements of Technical Efficiency and its Determinants in Wheat Production: The Case of Smallholder Farmers in Wogidi District, South Wollo Zone, Ethiopia. *Food Sci. Qual. Manag*. 81

Obianefo, C.A., Ezeano,I.C., Isibor, C.A., and Ahaneku, C.E.(2023). Technology Gap Efficiency of Small-scale Rice Processors in Anambra State, Nigeria. *Sustainability* 15, 4840 , https://doi.org/10.3390/su15064840

Ojumu, S and Adegoke, A (2014). Economic Analysis of Marketing Locally Milled Rice at Micro Scale in Ogoja Local Government Area of Cross River State, Nigeria. *Journal of Agriculture and Veterinary Sciences*, 6 (1): 31 – 40.

Olaniyi, O.M (2011). Assessment of Postharvest Handling and Quality Control Practices of Rice in North Central Nigeria: A Case Study of Lafia Nasarawa State. *Journal of Development in Sustainable Agriculture*, 6 (2): 143 – 163.

Olukosi, J.O & Erhabor, P.O (2015). *Introduction to Farm Management Economics: Principles and Applications*. Agitab Publishers Limited, Zaria, Kaduna, Nigeria pp77 – 83.

Sadiya, S.S and Hassan, I.I (2018). Post-harvest Loss in Rice: Causes, Stages, Estimates and Policy Implications. *Agric. Res. Technol*. 15: 555964

Sakurai, T., Furuya, J and Futakuchi, K (2006). Rice Miller Cluster in Ghana and its Effect on Efficiency and Quality Improvement. International Association of Agricultural Economics, pp 34 – 45.

Sennuga,S.O., Adeniran,B.T., and Olorunniyi, A.A (2021). Assessment of the

Constraints Associated with the Processing of Paddy Rice: A Case Study of Smallholder Farmers in Gwagwalada, Abuja. *J. Curr. Trends Agric. Environ. Sustain.* 2, 1 – 7.

Tesema, T (2021). Determinants of Allocative and Economic Efficiency in Crop-Livestock Integration in Western Part of Ethiopia Evidence from Horro District: Data Envelopment Approach. *Heliyon*; 1–7 e07390. https://doi.org/10.1016/j.heliyon.2021.e07390

Ugwuanyi, C.A., Balogun, O.S., Akinyemi,O., Balogun, G.F., and Zungum, A (2008). Cost and Returns of Locally Made Rice Marketing in Uzo-Uwani Local Government Area of Enugu State. *Proceedings 10th Annual National Conference NAAE* (7th – 10th 2008).

USAID (2009). Global Food Security Response, West Africa Rice Value Chain Analysis Micro Report, Washington, DC

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A STUDY ON HELMINTH PARASITES IN CHAURIES OF MANANG, NEPAL

Ashutosh Bhatta[*1,2] and Shikha Bista[2]

[1]Division Forest Office Kathmandu, Ministry of Forest and Environment, Bagamati Province, Nepal

[2]Himalayan College of Agricultural Sciences and Technology, Kirtipur, Kathmandu

[*]**Corresponding Author's Email**: ashutoshbhattavet@gmail.com

ABSTRACT

Gastrointestinal helminthes parasites create the most important health problem of Chauries in Nepal for limiting their productivity and in some cases their survival. A study on gastrointestinal parasites in chauries of Manang was conducted from November to mid December 2019. Helminth parasites create the most important health problem of Chauries in Nepal for limiting their productivity and in some cases their survival. Altogether a total of 100 faecal samples were collected from Manang in zip lock bags, properly labelled, transported to the Parasitology Laboratory of Himalayan College of Agricultural Sciences and Technology. The samples were examined qualitatively by sedimentation technique and floatation technique for identification of helminths parasites (Soulsby, 1976). Out of 100 samples, 31 (31%) were found to be positive for one or other type of gastrointestinal parasites where 69(69%) samples were negative. The nematode parasites were highest: Strongyle spp 13 (13%), Trichuris spp 9(9%), while trematodes found to be lower; Fasciola spp 5 (5%) and all samples were found to be negative for cestodes. Sex wise higher number of samples were positive in females (36.50%) compared to males (21.62%). Age wise number of samples were positive at >6months of age (41.67%) compared to <6months of age (20%).

Keywords*:* Age-wise, chauries, helminth parasites, Manang, sex-wise, species-wise

INTRODUCTION

Agriculture plays a pivotal role in Nepalese economy. About 66 percent of the population are involved in agriculture (Pradhanang *et al*., 2015). Among the agriculture commodities, livestock subsector plays significant role in the agriculture development and economic empowerment of the country. It contributes 24 percent in the National Agricultural GDP (Pradhanang *et al*.,

2015). The Yak is long-haired large bovine with bushy tail, flat-headed and is common in mountainous region of Nepal, Tibet, Bhutan, Northern India, China including Mongolia and Russia. The Yak was listed by Linnaeus as *Bos grunniens*, the same genus as other domestic cattle. A number of scholars had changed this by the middle of the Nineteenth century to *Poephagus grunniens* on closer examination of features distinguishing the yak from *Bos* (Weiner *et al.*, 2003). Chauries are the hybrid off-springs of yak- cattle. These are known for their ability to withstand low temperature, and have potential to survive on coarse fodder at higher altitude where no other ruminants can survive (Katiyar and Sinha, 1982). They are mostly black in color but white and other colors (fawn) are also common. They are very hardy and can thrive on harsh climatic conditions and provide milk, transport, manure and many others products such as tail and hides in low input system (Neopane and Pokhrel, 2005).

Helminth parasites are a major problem in Chauries causing economic losses, primarily through severe weight loss, poor meat, milk and wool production, and impaired reproductive performance. (Joshi, 1982) has reported the incidence of liverfluke in both yak and their cross breeds in Nepal. Similarly, *Fasciola hepatica, Echninococcus* cysts and nematodes were found in yaks of Nepal (Weiner *et al.*, 2003). (Shrestha and Bidari, 2013) recorded the prevalence of *Strongyle, Eimeria, Ascaris, Trichuris* and *Amphistomum* in the Chauries of Ramechhap district of Nepal. None of the farmer had ever vaccinated their animals. Chauri raiser are unaware of it. The common ectoparasites infestation in Chauri is tick which is more common in summer. Besides tick, leech infestation during rainy season is common problem. Most of the farmers deworm their animal every 6 months against roundworm, fluke and tapeworm. Few farmers report that they only deworm the animal after sign of loose stool and diarrhoea. However, there are no any research conducted and data found on helminthes parasites in Chauries in Manang. These data may be useful for the planning measures to control gastrointestinal parasitic diseases and to measure impact on productive performance of Yak and Chauri.

National Research Scenario

Qualitative analysis of 44 fecal samples of yaks from Lehe VDC of Manaslu Conservation Area showed the positive for parasite in 36 samples (81.82%). *Strongyle* showed the highest infection (47.23%) while the least was with *Amphistomum* (8.34%). Infection with *Trichuris, Ascaris, Eimeria* were also reported in the present study. The pattern of infection was both mixed (52.78%) and single (47.23%) (Byanju *et al.*, 2012).

Fifty-two fecal samples of Chauries from Gumdel VDC of Ramechhap district were analysed for study of gastrointestinal (GI) parasites and 47 samples were found positive representing 90.38% prevalence. The mode of infection was either mixed (57.44%) or single (42.55%). Among the gastrointestinal parasites, Strongyle (52%) showed the highest infection followed by *Eimeria* (23.07%), *Ascaris* (19.23%), *Trichuris* (11.53%), and *Amphistomum* (5.76%) (Shrestha and Bidari, 2013).

To determine the prevalence and associated risk factors of gastrointestinal and liver parasites in yak in the cold desert area of the Mustang District, Nepal, fecal samples were collected over a period of three months from 96 yaks from the high Himalayan District of Mustang, Nepal. The samples were tested for the presence of parasites by direct smear, sedimentation, and floatation techniques. Yak herders were surveyed with pre-tested questionnaires by participatory appraisals to explore their knowledge and awareness of parasitic diseases and health management. Examination of fecal samples revealed that 82 were positive for one or more parasites, giving an overall prevalence of 85.42%, in which 6.25% had single and 79.17% had multiple parasitic infections. Animals with poor body condition scores and young age were more susceptible than their counterparts (Acharya *et al.*, 2016).

International Research Scenario

To investigate seasonal prevalence of parasitic infection of yak in two yak rearing districts (West Kameng and Tawang) of Arunachal Pradesh, India showed that out of 895 sample fecal samples, 5.47% samples were positive for protozoa and helminth infections. Infection rate was the highest during spring followed by rainy, autumn and winter seasons. The highest prevalence was of *Strongyle* (51.02%) followed by *Eimeria* (34.69%), *Trichuris globulosa* (14.28%), *Strongyloides* (10.20%), *Dicrocoelium* and *Mammomonogamus laryngeus* (8.16%) *Amphistome spp* and *Toxocara vitulorum* (6.12% each) and *Fasciola gigantica* (4.08%). On necropsy unilocular cysts of *Echinococcus granulosus* and adult worms of *Fasciola gigantica* were isolated and identified. Analysis of data revealed that, infection was more in unorganized herd compared to organized herd (Bam *et al.*, 2012).

Occurrence of gastrointestinal parasites in domesticated yaks of North and East districts of Sikkim was studied during the year 2001 to 2008. Of the 4,792 animals examined, 991 (20.68%) were found positive for different gastrointestinal parasites. The overall occurrence of different parasites recorded was *Strongyles* (17.36%), *Strongyloides spp*. (4.34%), *Coccidia* (4.55%), *Toxocara spp*. (2.25%),

Trichuris spp. (2.88%), *Amphistomes* (0.52%) and *Moniezia spp*. (3.07%). The infestation was more in Sub-Alpine low humid area (29.34%) as compared to Alpine dry zone (19.0%) and Cold Desert zone (10.05%). The faecal egg counts (eggs per gram) of nematodes ranged from 100 to 2 900, with higher loads during rainy and post-rainy seasons. The infection was higher in calf (1–5 months) and the parasites mostly recorded were *Haemonchus spp*., *Toxocara spp*. and *Eimeria spp*. The seasonal distribution of parasitism indicated a higher percentage of infestation in autumn (26.02%) and summer (21.57%) as compared with spring (20.65%) and winter (13.73%). On copro culture of positive samples, the nematode infestations in order of prevalence were *Haemonchus spp, Bunostomum spp, Oesophagostomum spp* and *Nematodirus spp* (Rahaman *et al.,* 2010).

The helminthological survey carried out on ruminants of Ladakh during (Oct.2007 - Sep.2008) revealed that out of the 19 and 14 samples of wild and domesticated yaks examined 9 (47.36%) and 6 (42.85%) were found positive for trematode infection. It was observed that the intensity of infection was higher in wild as compared to domesticated animals. The prevalence of these parasites was found to vary with respect to various factors, viz; season, age, and sex. Of these, the most important factor responsible for the prevalence of helminthes parasites in the both host species (wild and domesticated) was climate. During rainy season the prevalence was higher (47.36%) as compared to the dry season (42.85%). The study also revealed a difference in prevalence with respect to the age of the host. The animals below 3 years were more infected (50.00%) as compared to those who were above three years and below ten years (33.33%). The prevalence of infection was found again increasing 6/11 (54.54%) with respect to the increasing age. The eggs collected from the samples were identified as *Fasciola gigantica, Fasciola hepatica, Paramphistomum cervi* and *Dicrocoelium dendriticum*. Identification of eggs was done on the basis of various morphological and morphometric characters (Kuchai *et. al.,* 2010).

The study (Goswami *et al.,* 2013) in Arunachal Pradesh and Sikkim showed that (26.31%) yaks were found positive in Arunachal Pradesh and (20.00%) Yaks were found positive in Sikkim for gastrointestinal parasitic infection with overall prevalence of 24.13%. The percentage of infection of *Strongyle spp*. and *Eimeria spp.* were 95 % and 10% in Arunachal Pradesh and 75% and 25% in Sikkim, respectively. Mean faecal egg counts of infected yaks in Arunachal Pradesh and Sikkim were 185 and 168 respectively. It can be concluded from this study that, although a moderate percentage of yaks were suffering from gastrointestinal parasitic infections with less faecal egg count which was responsible to contaminate the pasture and aid the spread of infections to healthy yaks.

This study was carried out to study gastrointestinal parasites of migratory Chauries in Manang district, determine sex-wise occurrence, determine age-wise occurrence of gastrointestinal parasites of migratory chauries.

MATERIALS AND METHODS

Study Site

The study was conducted in the Manang district in the western Nepal. It is located at 28°40'0N 84°1'0E with an altitude of 3,519 metres above sea level (11,545 ft). The district, with Chame as its district headquarters, covers an area of 2,246 km2 (867 sq mi). Its population density is 3persons/km^2. This study was carried out during November to mid-December, 2019. The samples were collected from Upper Pisang, Lower Pisang, Humde, Brakha, Manang Village, and some chauri sheds situated at Upper Manang (up to 4000 meters above sea level).

Collection of Samples

Random sampling techniques were used to select the animals for collection of fecal samples in this study. Samples were collected per-rectally using surgical gloves or collected opportunistic fresh fecal samples. Collected sample were kept in labelled, individual, clean sample collecting plastic zip lock bags each sample was labeled with description of the animal which include: name, age, sex. It was preserved with an equal volume of 5%-10% buffered formalin for fixation of samples (Hendrix, 2006). Collected fecal samples were stored inside refrigerator at 4°C until the time of examination if processing was not possible to prevent the development and hatching of the egg (Kassa, et al., 2016). The plastic bags were kept in ice box and transported to parasitology lab of HICAST for laboratory examination.

Qualitative Sedimentation method

The sedimentation technique as described by Soulsby (1978) was used to detect the presence of eggs of parasites in the samples.

Procedure for sedimentation technique

About 3 grams of faeces were grinded with water in mortar and pestle and the suspension was passed through a coarse mesh sieve and the debris was discarded. The filtrate was allowed to stand for 5 min in a beaker. Then, the supernatants was discarded and sediment was re–suspended with water (till the suspension became clear), and allowed to sediment for next 5 minutes. Finally the supernatant was discarded and few drops of the sediment were placed on a grease-free glass slide

and observed under the microscope in low magnification (10X and 40X); Microscopic examination was performed for the detection of eggs of helminthes parasites as described by Soulsby (1978).

Flotation method

The floatation technique is widely used for the detection of nematode and cestode eggs. Eggs of cestodes and nematodes are relatively small and light. This techniques, ensures the eggs to float in the floatation liquid.

Procedure for flotation technique

About 3 g of faecal sample was grinded in mortar and pestle and few drops of water was added and again grinded to make uniform suspension. Then filtered through a tea strainer into beaker. It was then transfer into test tube and added 50ml of floatation fluid, saturated NaCl solution The test tube was tube was placed on test tube stand Cover slip was gently placed on top of test tube And left for 20 min and then cover slip was placed on a slide and examined at 10); Microscopic examination was performed for the detection of eggs of helminth parasites as described by Soulsby (1978).

RESULTS AND DISCUSSION

Overall occurrence of Parasites

Out of 100 faecal samples, 31 samples were found to be positive for one or more type of gastrointestinal parasites where 69 samples were found to be negative.

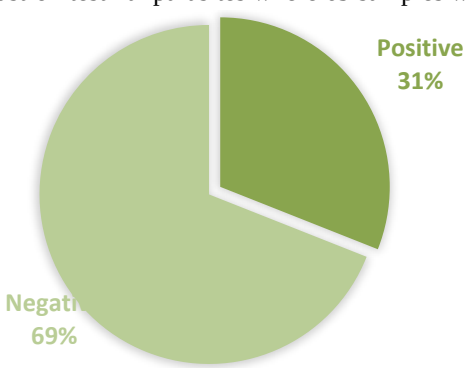

Figure 1. Prevalence of helminth parasite in sampled population

Species-wise occurrence of Parasites

Out of 100 feacal samples examined, the nematode parasites was found to be highest (22%) followed by trematodes (9%) and all samples were found to be

negative for cestodes. The most common parasites encountered were *Strongyle spp. 13 (13%), Trichuris spp. 9 (9%), Fasciola spp 5(5%)* and *Paramphistomum spp. 4 (4%), all samples were found to be negative in cestodes*.

Table 1. Species wise occurrence of parasites in the study site

Species	Number Of Positive Samples (%)
Fasciola spp	5 (5%)
Paramphistomum spp	4 (4%)
Strongyles spp	13 (13%)
Trichuris spp	9 (9%)

Age-wise occurrence of parasites

Samples from different age group were collected and studied for gastrointestinal parasites infestation. Age-wise, the highest presence of gastrointestinal parasites were found to be in the group of >6 months 25(41.67%) and lowest in the group of <3months 0 (0%).

Table 2. Age wise occurrence of different parasites

Age (months)	Total Sample	*Fasciola spp*	*Paramphistomum spp*	*Strongyles spp*	*Trichuris spp*
0-3	10	0	0	0	0
3-6	30	3	1	1	1
>6	60	8	3	6	8

Table 3. Age wise occurrence

Age	Positive Sample (%)
0-3 months	0 (0%)
3-6 months	6 (20%)
>6 months	25 (41.67%)

Table 4. Sex-wise occurrence of parasites in the study population

Sex	Total	Positive	Percentage
Male	37	8	21.62
Female	63	23	36.50

DISCUSSION

The present study was carried out to find out the gastrointestinal parasites in the migratory chauries of Manang district of Nepal. The rate of gastrointestinal parasites is influenced by the climatic conditions, deworming practice, habit and habitat of animals, sanitary condition and feeding. In the present study, the overall occurrence of gastrointestinal parasites was found to be 31%.

Byanju *et al.,* (2012) in Manaslu conservation area found 81.82% positive cases of gastrointestinal parasite in Yaks which is higher than my study, and the higher prevalence may be due to dense stocking of the chauries and no deworming practices plus the samples collected on present study was on winter season where the larvae of the parasites may not hatch easily due to cold climatic conditions. The major reason of low prevalence in present study may be due to extremely cold climatic condition.

Shrestha and Bidari (2013) in Ramechhap found 90% prevalence of the helminthes parasite in chauries which is higher than the present study, which may be due to favorable agro climatic conditions of that place, constant exposure of infestation and availability of infective stage larvae on the grazing ground because of favourable climatic condition and lesser altitude.

Acharya *et al.,* (2016) found the prevalence 85.42% of gastrointestinal and liver parasite in yaks of lower Mustang which is higher than our finding, this may be due to the lack of treatment in the yaks of that area and also may be related to warmer climatic condition and humidity.

Rahaman *et al.,* (2010) found 20.68% prevalence of Helminthes parasites in domesticated Yaks of Sikkim which is similar to present study. But prevalence of trematode was not observed in this study, which might be due to the absence of intermediate host snail in the much cold climatic condition of Sikkim. The composition of different parasites recorded was S*trongyles*, *Strongyloides spp*., *Coccidia*, *Toxocara spp.*, *Trichuris spp. Amphistomes* and *Moniezia spp.* The infestation was more in Sub-Alpine low humid area (29.34%) as compared to Alpine dry zone ((19.0%) and Cold Desert zone (10.05%). The faecal egg counts (eggs per gram) of nematodes ranged from 100 to 2900, with higher loads during rainy and post-rainy seasons. This finding was may be due to the fact that the study was carried out from 2001 to 2008 which revealed more gastrointestinal parasites in a long duration.

Kuchai *et al.,* (2010) reported the total prevalence of 45.45% of helminths parasite in Ladakh which is higher than our study. The yak of Ladakh both wild and domestic made no exception regarding helminthes infection as is the case with other ruminants of this region. Other ruminants were also infested with the similar types of helminthes parasite. The constant exposure of the domestic ruminants with the Yaks may have spread the infestation.

Goswami *et al.*, (2013) reported the prevalence of 26.31% of helminthes parasite in Arunachal Pradesh, India which is almost similar to the present study. The similarity might be due to similar climatic condition for the parasite epidemiology.

One of the reasons for lower prevalence during this study might be sampling period, which was during the month of November and December. This period is the peak winter season, which is not the main period for helminth infection in the grazing animals in Nepal. Thus, the dry winter season limit development and survival of parasite stages in the environment and as a result, host contact and parasite transmission is also simultaneously reduced. So, this can conclude the low prevalence rate observed during the study. The lower prevalence in this study may be due to the higher altitude and location of my research area. The grazing pasture land of chauries consists of herbal medicinal plants which prevent them from suffering from helminth parasites and those plants might also have acted as a deworming agent. The chauries found in Manang are sometimes acquainted with the other ruminant animals like mountain sheep & mountain goats (*Chyangras*) but the chauries dwell on the higher altitude due to which the transmission of parasites from other animals is minimal. Also the chauries are sometimes dewormed when they severely show some gastrointestinal disorders like diarrhea and constipation so this might have played a major role in reducing the number of positive cases in my study.

CONCLUSION

A total of 31 samples showed positive cases representing 31% positive. During the study, it was found that the farmers were not familiar about helminth parasites of Chauri. However, some farmers were familiar with the deworming of Chauries. The present study indicated that sex and age are important factors which influence the occurrence of gastrointestinal helminth parasitic influence in Chauries. However, the combination of strategic use of anthelmintics with traditional veterinary medicine and good management practice could improve the control of helminth parasitic infection in Chauries.

SUGGESTIONS

This finding shall be taken into account when formulating control strategies for gastrointestinal helminths in *chauries* and other ruminants of that region as well.

It is suggested to carryout detailed study on identification and epidemiology of helminths parasites of Chauri in different areas of country. This may help in developing the strategic control program.

REFERENCES AND BIBLIOGRAPHY

Acharya, K.P., Nirmal, B.K., Kaphle, K., Mahato, M.K., Yadav, G.P. and Rana, H.B. (2016) *Prevalence of gastrointestinal and liver parasites in yaks in the cold desert area of lower Mustang Nepal*, Asian Pacific Journal of Tropical Disease, 6(2):pp147-150.

Ansari, M. Z. & Rai, M. K. (1991) Studies on occurrence and incidence of hydatic disease in Yak in Sikkim, *Indian Veterinary Journal*, (68):pp112-114.

Bam, J., Deori, S., Paul, V., Bhattacharya, D., Bera, A.K., Bora, L. and Baruah, K.K. (2012) Seasonal prevalence of parasitic infection of yaks in Arunachal Pradesh, India. *Asian Pacific Journal of Tropical Disease*, 2(4): pp264-267

Byanju, R., Shrestha, S.P. and Khanal, D.R. (2011) Prevalence of gastrointestinal parasites in yaks of Lehe VDC, Manaslu Conservation Area. *Nepal Journal of Science and Technology*, 12:pp366-369.

Deng *et al.,* (1986) *Yak disease. Sichuan Husbandry and Veterinary* 1:pp25.

Goswami, A., Laha, R., Sarma, D. and Chatlod, L.R. (2013). A report on gastrointestinal parasitic infections in yaks. *Indian Journal, Hill Farming*, 26:pp42-44.

Hendrix, C.M., (2006). Diagnostic parasitology for veterinary technician., 3rd Ed. China

Huang, S. Y., Xie, Y. J., & Li, B. S. (1984) Study of hypoderm in Yak in the Huangcheng area of Gansu Province. *Journal of Veterinary Science and Technology*, 2: pp35-37.

Jiang, X. L., Zhow, W. L., Gong, G. J., & Liu, S. M. (1997). Findings on *Trichostrongylus orientalis* in yak in Sichuan. *Chinese Journal of Veterinary Medicine*, 13: pp19-20.

Joshi, D. D. (1982) *Yak and Chauri Husbandry Nepal (1st edition.)*. Kathmandu

Kassa D, Mengestie A, Ayalew N, Belaynew A, Mebrie Z, M.T., 2016. A Review on Diagnostic Techniques in Veterinary Helminthology. Nat. Sci. 14, 109–118.https://doi.org/10.7537/marsnsj140716.15.Key

Katiyar, R. D., & Sinha, S.B. (1982) Yak breeding and their health problems in Sikkim. *Livestock research* 2: pp1-9.

Kuchai, J.A., Chishti, M.Z., Ahmad. F., Rasool, M., (2010) Prevalence of Trematode Parasitic Infestation in Yak of Ladakh *(Bos grunniens). Pakistan Journal of wildlife*. 1(2): pp64 66.

Li, Z. H., Huan, Z. J., Jing, P. M., & Zhou, Z. R. (1985) An investigation on *Echinococcosis* in Yak. *Chinese Journal of Veterinary Science and Technology*, 1:pp25-26.

Muhhamadev, S.A. (1981*) Helminth of Cattle and Yak in the Tajik SSR*, Dushanbe USSR pp:183.

Neopane, S.P. and Pokhrel, P.K. (2005) *Indigenous Cattle of Nepal*, Animal breeding division Nepal Agriculture Research Council, Nepal. Pakhribas Agricultural Centre (PAC), Pakhribas, Dhankuta, Nepal, 10(2):pp10-14

Pradhanang, U.B., Pradhanang, S.M., Sthapit, A., Krakauer, N.Y., Jha, A. and Lakhankar, T. (2015) *National Livestock Policy of Nepal: Needs and Opportunities.* Agriculture 5*:* pp103-131

Rahman, H., Pal, P. and Bandyopadhyay, S., (2010) Occurrence of gastrointestinal parasites in domestic yaks in Sikkim. *Indian Journal of Animal Sciences*, 80(3):pp195-198

Rai, M. K. (1988) Studies on helminth parasites of Yak in Sikkkim. *Journal of Veterinary Parasitology*, 2:pp77-78.

Shrestha, S. and Bidari, Y.R. (2013) Prevalence of gastrointestinal parasites in Chauries of Gumdel VDC of Ramechhap District, Nepal. *Net Journal of Agricultural Science*, 1(3):pp73-74

Soulsby, E.J.L., (1968) *Helminths, arthropods and protozoa of domesticated animals,6th edition*, The English Language Book Society and Bailliere, Tindall and Cassell Ltd pp 207-218.

Weiner, G., Jianlin, H. and Ruijun, L. (2003) *Management of Yak. The Yak (2nd edition)*.FAO Regional Office for Asia and Pacific, Bangkok.

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EFFECTS OF SEEDING RATE AND GENOTYPE × SEEDING RATE INTERACTIONS ON PROMISING WHEAT GENEOTYPES AT RUPANDEHI

Sumina Bhandari[1], Binayak P. Rajbhandari[1], and Narayan Khatri[2]

[1]Himalayan college of Agricultural Sciences and Technology (HICAST)
Kathmandu, Nepal
[2]NWRP, NARC, Omsatiya, Rupandehi
Corresponding Author: binayakprajbhandari@gmail.com

ABSTRACT

The study was conducted during winter season of 2022 at National Wheat Research Program of the National Agriculture Research Council at Omsatiya, Rupandehi with the objective to identifying appropriate seeding rate for promising wheat genotypes. The experimental design was split pot with three replications. The main plot comprised of three seeding rates (90,120 and 150 kg/ha) and sub plot consisted of six promising wheat genotypes (NL1330, NL1345, NL1425, NL1450, BL1488, Bandganga (control)). Results revealed that among the tested genotypes, NL 1450 produced the highest grain yield of 4471kg/ha at seeding rate of 150kg/ha which was statistically at par with 120 kg/ha followed by BL1488 at seeding rate of 120 kg/ha. That genotype NL 1450 also had the maximum number of kernels per spike as compared to other genotypes. The genotypes X seeding rate interaction effect on all the yield attributing characters was found statistically non-significant. However, genotype NL1450 being the highest grain yielder should be tested further for confirming its superiority for release.

Keywords: Seeding rate, wheat, genotypes, yield, harvest index,

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important staple cereal crops grown throughout the world providing a significant source of food and nutrition to human as well as to the livestock. Wheat is consumed in most areas of the globe for nutrition of the population. It has been estimated that wheat is contributing to

almost one fourth of the total dietary energy and protein to the diets of developing countries. Obviously, there is a high demand for wheat globally. Demand for surplus wheat production is related to the health and nutritional status of the people. Similarly, in the global context, wheat is grown in the largest area than any other food crops or cereal crops. In 2000, the world production of wheat was 761 million tones, making it the second most produced cereal crop after maize (Haiyan, 2014). Wheat is the third most important cereal crop largely grown in rice-wheat cropping system, and occupies more than 30% of the rice area and 80% of the wheat area in Nepal (NWRP, 2015). As per the Ministry of Agriculture and Livestock Department 716,978 ha. of land is under wheat cultivation with the total production of 2,144,569 Mt (MoALD, 2078/79). The highest production of wheat was done on Madhesh province which is 628,909 Mt. and the least in Gandaki province that is 99,038 Mt. Wheat has been contributing only 5.67% of the national GDP (MoALD, 2079/80).

There is increasing demand of wheat and its products as the population has been increasing. These data indicate the urgency of developing new high yielding wheat genotypes with optimum planting density, sowing time and seeding rates for increasing the total wheat yield in the country. Even two decades back, Gelata *et al*., (2002) had reported that optimum seeding rate is an important production factor for achieving higher grain yield in most of the crop fields. Seeding rate affected plant population, days to flowering, plant height, grain yield, kernel weight, flour yield, flour protein, and mixing time and tolerance of wheat.They therefore suggested that seeding rate should be considered as a factor in obtaining higher grain yields with good end-use quality. This study was conducted with the objective of identifying optimum seeding rate for promising wheat genotypes being tested at the NWRP.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted in the National Wheat Research Program (NWRP), Omsatiya, Rupandehi. The climate is of subtropical type with three distinct seasons, summer, rain and winter. The meteorological data such as temperature, relative humidity and total rainfall during the entire experimental period (December 2022 to April 2023) was recorded from the meteorological station of NWRP, Bhairahawa, 2022-2023.

The mean maximum and minimum temperatures in the research site were 31.12°C in March 2023 and 19.2°C in January 2023. The maximum of 71.1 mm in April and minimum of 0 mm rainfall was recorded in the month of December 2022, January and February of 2023. The relative humidity ranged from 96.2 % in December 2022 to 57.6 % in April 2023.

Selection of plant material

SN	Genotypes	Notation
1.	NL1330	G1
2.	NL1345	G2
3.	NL1423	G3
4.	NL1450	G4
5.	BL1488	G5
6.	Bandganga (Control)	G6 ©

A total of five promising and one released (Control) wheat genotypes available at NWRP were used in the experimental field (Table1).

Table 1. Wheat varieties selected for the study, NWRP, 2022/23

Details of treatment and experimental design

Design: Split plot; Main plot: Seeding rate (T1-T3) @ 90,120 and 150 kg/ha); Sub plot: Genotypes (G) (six genotypes); Replication: 3; Total no. of treatments: 18 (3 main plot and 6 sub-plots); Plot size: 4m*2m; Replication-replication distance: 1 m; Plot-plot distance: 0.5 m. Number of plants used for measurement per replication = 20.

Agronomic practices

Seeds the selected genotypes sown in December 1st, 2022.

Tagging, and weeding were done as appropriate.

Irrigation was provided during CRI and flowering stages.

Recommended doges of the chemical fertilizers were applied at the rate of 120:50:50 kg/ha (N: P_2O_5:K_2O, respectively). The fertilizers viz. DAP, MOP and urea were applied @ 108.7g/plot, 83.3g/plot and 87.9g/plot (in 2 equal doses), respectively.

Harvesting was done manually on different dates after the plant attained maturity. From each plot grain of different genotypes were collected and the yield was measured.

Data measurement

The data were collected at the different growth stages and after harvesting as well. Various yield attributing traits such as number of tillers per sqm, spike length, effective tillers, no. of kernels per spike, kernel weight per spike, kernel yield, straw (above ground bio-mass) yield were measured employing standard methods. Likewise, 1000 kernel weight and harvest index (HI) were calculated.

RESULTS AND DISCUSSION

Effect of seeding rate and genotype X seeding rate on:

a. Tillers per sqm

Number of tillers per sqm is an important yield attributing character, and increased with seeding rate (Table 2). It ranged from 195 to 343 per sqm in this experiment. It was found that genotype NL1450 (G4) had the statistically significant maximum number of tillers per sqm (343) with seeding rate @ 90 kg/ha as (Table 2). Genotype 2 had the highest numbers of tillers at seeding rate 120 kg/ha as well and Bandganga (Control) had the least. The number of tillers increased in all genotypes with the increase in seeding rate from 90 to 120 kg/ha. It should however be noted that the number of tillers per sqm was statistically higher in G4 only as compared to Control (G6). Genotype X seeding rate interaction was not found statistically significant. This result agreed to Gelata et al., (2002), and Iqtidar et al., (2010).

Table 2. Effect of seeding rate and genotype on tillers per sqm

	Genotypes					
Treatments	G1	G2	G3	G4	G5	G6©
T1: 90 kg/ha	230	245	195	229	242	202
T2: 120 kg/ha	274	314	252	270	254	229
T3: 150 kg/ha	313	309	313	343*	296	290
LSD=46.6						
CV%=10.8						

b. Number of kernels per spike

The number of kernels per spike and kernel weight contribute to yield depending on agro-ecological conditions as well as genotype. From the statistical data, it was evident that the seeding rate X genotype interaction was found non-significant with the number of kernels per spike. At seeding rate of 90 kg/ha, genotype NL1330 (G1) had the highest number of kernels per panicle while genotype

NL1345 and NL1425 had the least. Similarly, NL1450 (G4) had the highest number (49) of kernels per spike at seeding rate 120 kg/ha and 150kg/ha (Table 3). These differences were statistically significant as compared to G6 (control).

Table 3. Effect of seeding rate and genotype on number of kernels per spike

	Genotypes					
Treatments	G1	G2	G3	G4	G5	G6©
90kg/ha	49*	42	42	46	44	40
120kg/ha	44	41	46	49*	43	39
150kg/ha	43*	40	39	49*	38	34
LSD=7.9						
CV%=10.5						

c. 1000 kernels weight

Already released variety Bandganga had the highest kernel weight as compared to all the other promising genotypes (Table 4). These differences were statistically significant. Although statistically insignificant the seeding rate X genotype interaction was found indirectly proportional.

Table 4. Effect of seeding rate and genotypes on 1000 kernels weight (g)

	Genotypes					
Treatments	G1	G2	G3	G4	G5	G6©
90kg/ha	39.00	38.16	34.00	38.59	41.83	49.57
120kg/ha	39.37	36.15	36.97	35.11	40.93	47.89
150kg/ha	38.77	36.63	34.99	33.44	40.45	48.49
LSD=4.32 CV%=7						

d. Adjusted grain yield (AGY)

Statistically, it was found that the seeding rate and seeding rate X genotype interaction was found significant with the adjusted grain yield at 0.05 level of significance. It is evident from Table 5 that genotype NL1450 (G4) had the statistically significant and the highest adjusted grain yield at seeding rate 120 kg/ha and 150 kg/ha as compared to G6 (Control) and other promising genotypes.

When a graphical representation of the comparison was done (Figure 1), it was found that there was 9.4% increment in the yield of NL1450 followed by BL1488 with 6.0% yield increment.

Table 5. Effect of seeding rate and genotype on adjusted grain yield (Kg)

Treatments	Genotypes					
	G1	G2	G3	G4	G5	G6 ©
90kg/ha	3936	3366	3961	4029	3826	3914
120kg/ha	3924	3655	3754	4291*	4125	3819
150kg/ha	3842	3541	3845	4471*	4445*	3959
F-test				*	*	*
LSD=363.5						
CV%=4.9						

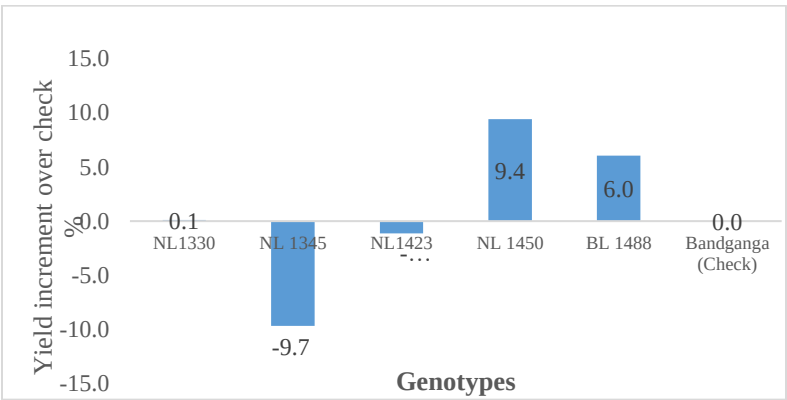

Figure 1. Graph showing the yield increment over control variety

Straw yield

Straw is an important output of wheat. It is used for bedding of livestock and then for compost making. Genotype NL1330 (G1) was found to have the statistically significant and the highest straw yield at all three seeding rates (90kg/ha, 120kg/ha and 150kg/ha). Also, all the seeding rates and genotypes had more or less similar amount of the straw yield which were higher than in control genotype (Table 6).

Table 6. Effect of seeding rate and genotype on straw yield (kg)

Treatments	Genotypes					
	G1	G2	G3	G4	G5	G6©
90kg/ha	4444*	3720	3771	3963	3826	3507
120kg/ha	4431*	3952	3653	4359*	4106	3593
150kg/ha	4606*	3717	3799	4283*	4549*	3517
LSD=585.8						
CV%=8.6						

e. Harvest Index (HI)

From the Table 7, all the seeding rates had comparatively similar harvesting index as per each genotype. Hence, there was no any benefit of using higher seeding rate. The cotrol genotype had the highest HI as compared to all promising genotypes. The difference was statistically significant. It was due to lower straw yield of the control genotype as compared to all promising genotypes.

Table 7. Effect of seeding rate and genotype on harvest index (%)

	Genotypes					
Treatments	G1	G2	G3	G4	G5	G6©
90kg/ha	47	48	52	50	50	53*
120kg/ha	47	48	51	50	50	52*
150kg/ha	46	49	51	51	49	53*
LSD= 0.028						
CV%= 3.3						

CONCLUSION

From the research experiment, genotype NL1450 was found to be the high yielding genotype with the yield of 4471 kg/ha at the seeding rate of 150kg/ha and had the highest kernels per Spike (49). All the growth and yield parameters of wheat was non-significantly influenced by the genotype X seeding rate interaction. However, grain yield was increased with the increased seeding rate.

REFERENCES

FAO. (2015). *World food and agriculture statistical pocket book*. Food and Agriculture Organization,

Geleta B. , Atak M. , Baenziger P. S. , Nelson L. A. , Baltenesperger D. D., Eskridge, K. M., Shipman, M. J. and Shelton, D. R.. (2002). Seeding Rate and Genotype Effect on Agronomic Performance and End-Use Quality of Winter Wheat, *Crop Sci*., 42(3), 827-832 available at: **https://doi.org/10.2135/cropsci2002.8270**

Ghulam Mustafa Laghari, Fateha Chand Oad, Shamasuddun Hussain Tunio, Qamaruddin Chachar, Allah WadhayoGandahi, Mussamil Hussain Siddiquim Syed Waseem Hassan, and Abid Ali. (2011). Growth and yield attributes of wheat at different seeding rates, *Sarhad J Agric*, 27(2), 177-183

Govinda Velu, L. C. (2018). Assesing Genrtic Diversity to brred competitive Biofortified Wheat With Enhanced Grain Zn and Fe Concentration. *Frontiers Plant Science, 9*.

Haiyan Zhao, B. G. (2014). Effects of grown origin, genotype, harvest year, and their interactions of wheat kernels on near infrared spectral fingerprints for geographical traceability. *Food Chemistry*, 152, 316-322.

Holman, J. D. , Haag, L. A. , Schlegel, A. J. , Assefa, Y. (2021). Yield components of dryland winter wheat genotypes and response to seeding rate. *Agronomy J*., 113(2), 1776-1791: https://doi.org/10.1002/agj2.20607

Iqtidar Hussain, Muhammad Ayyaz Khan and Hayatullah Khan (2010). Effect of seeding rates on the agro-physiological traits of wheat, Pakistan. *Sarhad J. Agric.* 26(2), 169-176

Kharel, M. Y. (2021). Economic Production and marketing of wheat in Rupandehi District of Nepal. *Journal of Agriculture and natural resources*, 4(2), 238-245.

MoALD. (2079/80) *Agricultural statistics (2079/80).* Ministry of agriculture and livestock Department

Nasrullah Naseh, AK Dhaka, Bhagat Singh, Amit Kumar and Axay Bhuker, (2020). Suitable genotype and optimization of seeding rate for late sown wheat, *International Journal of Chemical Studies* 2020; 8(1): 515-519 https://doi.org/10.22271/chemi.2020.v8.i1g.831

NWRP (2023) *Meteorological Report.* National Wheat Research Program, Rupandehi

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REVIEW ARTICLES

THE EFFECT OF GRAZING AND THE ASSOCIATED FACTORS ON THE NUTRITIVE VALUE OF HERBAGE IN RANGELANDS

Shankar Raj Barsila
Agriculture and Forestry University, Department of Animal Nutrition and Fodder Production, Rampur, Chitwan, Nepal
Corresponding Author's Email: sbarsila@gmail.com

ABSTRACT

In rangelands, the relationship between plants and animals does not change in equilibrium vegetation conditions. However, the flora's composition is negatively impacted by the emergence of new biological processes and a noticeable decrease in plant growth vigor. The amount of grazing, one of the most crucial management factors, greatly affects the composition and structure of the grassland ecosystem. In non-grazed environments, highly palatable species typically predominate the herbage cover, while in grazed areas, non-palatable species prevail. When the herbage approaches the source of the grazing gradient, the concentrations of CP increase rapidly, while those of NDF and ME decrease rapidly. Animals can obtain certain elements from plants, which determines the nutritional value of feed. Variables such as light, temperature, and maturity all have a major impact on a plant's composition, albeit different types of plants differ in this regard. The edaphic and other biological factors have a considerable impact on the herbage's nutritional value. Early maturity is associated with a decline in CP content, while higher temperatures, more precipitation, and more biomass yield result in a faster allocation of biomass. The nutritional value of the herbage is determined by the regeneration of leaf portions after grazing causes the upper vegetation to become defoliated. This review focuses on the fundamental elements influencing the nutritional content of the herbage in rangelands, as grazing is a significant component in defining the quality of grasslands. The information is gathered using an available literature survey. The primary causes of the variables influencing the herbage's nutritional value in rangelands have been identified and compiled.

Keywords: Grazing, nutritive value, tillering, palatability, leaf: stem ratio

INTRODUCTION

Plants and animals constantly interact within the rangeland ecosystem (McNaughton, 1979). Due to increase in human and livestock populations puts overgrazing pressure in pasturelands and rangelands that causes a significant reduction in the vigour of plant growth, reproduction ability and poor growth and establishment of important valuable plant species which leads to changed botanical composition (Heitschmidt *et al*., 1987). The structure and composition of the grassland ecosystem are highly influenced by grazing intensity which is a key management variable (Hickman *et al*., 2004). Heavy grazing changes in vegetation composition from more palatable grasses and sedges to less palatable grasses and forbs have been reported in northwest China (Sun *et al.*, 2018). Grazing intensity affects the response of plant species richness. (Deng *et al*., 2014) reported that plant species richness decreases with increasing intensity of grazing in the grassland ecosystem. The author reported that at moderate and light grazing intensities observed the highest plant species richness. Spatial heterogeneity in light, soil nutrient availability and vegetation community dynamics is due to the random grazing pattern which can reduce plant competition with environmental resources because the vegetation exists in patches (Bakker *et al*., 2003). Moderate or light grazing intensity can promote the vegetation diversity within patch scale, but heavy grazing intensity can lead to a decrease in the palatable species (intolerant to grazing) and results in an increase in unpalatable species which are more tolerant to grazing (Watt & Gibson, 1988). The density of highly preferred palatable plant species for livestock grazing are decreased due to the over grazing pressure in rangeland(Warren *et al*., 1986).Species richness, diversity and forbs cover in tall grass prairie are significantly increased by grazing practices(Hickman *et al.*, 2004).Heavy grazing increased species richness and diversity but decreased forage quality and production in subalpine grassland in the eastern Pyrenees (Andorra)(Komac *et al*., 2014). Maintenance of grasslands is strongly dependent on the maintenance of biodiversity (Hartnett *et al*., 1996).The herbage cover in non-grazed site predominated mainly of high palatable species while non-palatable species predominated in the grazed site. The grass species are significantly higher in un-grazed sites as compared to a grazed site but forbs species were considerably decreased. The amount of litter was greater inside the un-grazed site and the more bare ground was identified in the grazed site (Amiri *et al*., 2008).

The current analysis generally clarifies that one of the factors influencing the botanical composition of the herbage, the abundance of palatable species, and the species richness in grasslands is the intensity of grazing.

Effect of grazing on nutritive values of forage

Grazing could influence the herbage nutritive value due to the use of young and protein-rich re-growth and to replace the older senescent parts of herbage (Albon & Langvatn, 1992).The CP concentration increases in re-growth of new tissues under grazing pressure and then maturation and lignification process of herbage species are delayed(Garcia *et al*., 2003). Furthermore, grazing could raise the nitrogen availability in the soil through animal excreta and increase the rate of N-mineralization in soil, which enhance the amount of CP in herbage (Shan *et al*., 2011). The finding indicated that different herbage species have different strategies in adapting to grazing, including grazing avoidance (lower palatability) or grazing tolerance (greater re-growth ability) (Zheng *et al*., 2011). Nutritive value and yield of forage changes along with grazing gradient where sudden changes in vegetation composition of the community. At the grassland, rapid replacement of perennial grasses or forbs with weedy persistent annual forbs then the nutritive value of herbage could be changed. The CP concentration in herbage increased rapidly in approaching the source of the grazing gradient and whereas, NDF and ME concentration decreased rapidly(Sasaki *et al*., 2012). The quality of herbage was significantly higher in livestock grazed early in the season or continuously. Increased the herbage quality with increasing intensity of grazing as younger herbage and maintained re-growth was continued during the green season(Henkin *et al*., 2011). Different grazing intensities of cattle affects sward parameters such as diversity of plant species, the structure of sward, herbage growth and forage quality. The total biomass production was higher under the intensive grazing than the extensive grazing. Total crude protein (CP) contents and digestibility of forage were higher under intensive grazing. The crude fibre (CF) content showed a reverse effect (Pavlů *et al*., 2006). The nutritive value of forage plays a significant role in animal nutrition and management of grassland ecosystem in a sustainable manner and quality of forage is affected by grazing management. The concentration of crude protein (CP) in the plot of heavy grazing pressure through all season and heavy grazing in spring and summer and moderate grazing in autumn were higher than rest grazing in spring, moderate grazing in summer and heavy grazing in autumn and rest grazing in spring, heavy grazing in summer and moderate grazing in autumn. The nutritive value of *L. chinensis*was more responsive to grazing disturbance than *Artemisia* spp. And*C. duriuscula*,

and heavy grazing maintained a relatively high crude protein content in all species(Zhai *et al*., 2018). The use of complex mixture (more than three species) of herbage may increase the production of pasture and the productivity of mixture is affected by the management of grazing. When the sward reached 25 cm in height (SH) produced 30% more dry matter (DM) than the alfalfa reached a bud stage (MP). The SH stage produced herbage of better nutritive value than MP stage at first harvesting of the year because they produce more crude protein (CP), in vitro true dry matter digestibility (IVTDMD) and less acid detergent fibre (ADF) and neutral detergent fibre (NDF). More consistency in yield of DM in a complex mixture of forage species than binary legume-grass mixture or grass monoculture in variable environments(Deak *et al*., 2009). The clipping frequencies affect the cumulative yield of herbage. The canopies clipped at 6-week intervals produced more herbage than those clipped at 3-week intervals. Fluctuations in the in vitro organic matter disappearance (IVOMD) and crude protein (CP) were related to changes in sward composition arising from the interaction of time and clipping frequency. The greater the CP concentration when sward clipped at 3-week intervals than those clipped at 6-week intervals.Canopies clipped at 3-wk intervals hadrelatively constant NDF over the growing season,but those clipped at 6-wk intervals increased in NDFas the growing season progressed (Belesky *et al*., 1999). Key herbage species had significantly higher in vitro organic matter digestibility (IVOMD) and crude protein (CP) content in rainy season than in dry season but neutral detergent fibre (NDF) and acid detergent fibre (ADF) did not vary significantly with the season. The above-ground biomass of herbage was significantly higher in the rainy season than the dry season. Cattle spent considerably more time for grazing and goat for browsing in the rainy season than the dry season(Selemani *et al*., 2013). The availability of nutrients in the plat for animal determines the nutritive value of forage. This availability is controlled by the chemical composition of the forage in respect to factors limiting the utilization of cellulose and hemi-cellulose. These include lignin, silica, and the total amount of plant cell wall substances. An important part of nutritive value is that of consumption or voluntary intake which is partly related to cell wall content and bulkiness of the forage. The composition of the plant is controlled to a large extent by light, temperature, and maturity factors, but different plant species vary individually in this respect(Van Soest, 1969).

Overall, the literature that is currently available indicates that grazing modifies the nutritional value by raising the concentration of crude protein and the digestibility of the growing shoots; however, additional edaphic and biological processes may also be at play. It is also assumed that the species that can withstand grazing may continue to exist with a higher fiber content.

Effect of environmental factor on the nutritive value of herbage

More precipitation in a year correspondingly increase the soil water availability and thus promote biomass production of herbage, which might induce the dilution of CP in the herbage biomass (Grant *et al*., 2014). Higher the concentration of CP in herbage biomass in wetter year due to increased availability of nitrogen to the plants because of accelerated N-mineralization(Austin et al., *2004*),and higher capacity to herbage to assimilate nitrogen (Xu and Zhou, 2006). Meanwhile, drought condition could cause severe water stress to herbage resulting in rapid plant maturation and thus decrease N-concentration in herbage(Schiborra *et al*., 2009;Wang *et al*., 2011). Nutritive value of forage was decreased at higher temperature and changes the identity of species and changes to phenology and physiology. Where raised temperatures reduce the nutritive value of grass and similarly may increase methane production by 0.9% with 1^0 C temperature rise. Increase the concentration of neutral detergent fibre (NDF) by 0.4% every 1^0C rise in temperature during the sampling period. NDF was affected by the photosynthetic pathway, with the NDF content of C_4 species than C_3 species. These C_4grasses were commonly founded at warmer sites, so NDF content was greater in tropical herbage. They pointed out that the cultivation of nutritious rich forage plants and reduced animal farming in a warmer region may reduce the pastoral greenhouse gas emission(Lee *et al*., 2017). The influence of environmental factors like light, temperature, drought, soil nutrients influence on forage quality (chemical composition and digestibility) of temperate and tropical grasses. Change in climatic and edaphic factors influence the quality of legume forage with variable levels of condensed tannins, which is an important secondary compound of some tropical and temperate legume species. Properties of tannin and their positive and negative effect influenced on forage quality of legumes. The accumulations of condensed tannin in temperate and tropical legumes were affected by temperature, drought, CO_2concentration, the season of the year and soil fertility. The result founded that higher temperature alone can significantly increase the accumulation of condensed tannin in some temperate legume forage species but not all species. High nutritive value of herbage is characterized by the high concentration of crude protein (CP), high concentration of cellulose digestible organic matter (CDOM), and low concentration of neutral detergent fibre (NDF). For all herbage species, nutritive value is higher in the wetter year than drier year and highest in the early growing season (June) and lowest at the end of the growing season (September). Inter-seasonal and inter-annual variations in nutritive value were much higher for *L. chinensis* and *A. michnoi*than for *C. squarrosa* and *S. grandis*, suggesting higher water use efficiency for the latter two species. Grazing significantly decreased the drought resistance of three herbage species, but not of *S. grandis* (Ren *et al*., 2016).

In conclusion, the review of the literature on the impact of environmental conditions, such as temperature and precipitation, on the nutritional content of herbage indicates that these variables are what determine the nutritive value. Nonetheless, physiological characteristics of the plant, such as C3 and C4, may also influence the nutritional value.

Effects of sampling season on herbage nutritive value

Sampling season affects the nutritive value of herbage(Wang *et al*., 2011). The growing period progressed, herbage cellulose digestible organic matter (CDOM) and crude protein (CP) decreased, while neutral detergent fibre (NDF) increased. The finding indicated that herbage nutritive value reduced as the vegetative period progressed (Ren *et al*., 2016). When plants stop growing, the maturation and lignification process begins cell wall content such as cellulose, hemicellulose and lignin increases while cell substances such as crude protein decrease (McNaughton, 1983). Low responses of nutritive value to grazing in September would also come with reduce plant cover and high risk of wind erosion because sheep need to increase feed intake to meet increased energy requirements from grazing (Glindemann *et al*., 2009). Higher herbage intake in September would also reduce the remaining biomass and energy to be stored in plant stem bases, roots and rhizomes, which are important for the maintenance of plant growth (Johnson &Tieszen, 1976) in next year(Pérez-Harguindeguy *et al*. 2013). High grazing intensity may negatively affect grassland productivity in the long term through the 'carry-over effect'. Supplementary feeding is required at the end of the vegetation period to maintain livestock production in intensely grazed grasslands and to protect the grassland ecosystem (Müller *et al*. 2014).

In summary, the plant maturity factor can affect the nutritive value of herbage; as a plant ages, the distribution of fibrous residues causes the nutritive value to decrease.

Effect of grazing on tillering and leaf: stem ratio of forage

Leaf/stem ratio is an important factor that determines the quality, diet selection, and forage intake (Forbes & Coleman, 1993).The grasses are more tolerant to grazing and defoliation as compared to other herbage species. They have characteristics of sequential leaf production and un-accessible apical meristems in arctic and subarctic environments (Johnson & Tieszen, 1976)comparatively

high level of carbohydrate reserve and possession of clonal growth with physiologically integrated tillers (Archer and Tieszen 1986). Repeated defoliation due to continuous heavy grazing may affect biomass partitioning of a tiller and their population dynamics. If the tiller is repeatedly defoliated, support from physiologically integrated neighboring tillers is cut off(Jónsdóttir *et al*., 1989). The energy level and nutrient reserve are decreased, which can reduce the production of biomass, the survival of tiller and rate of flowering(Mattheis & Tieszen, n.d.).The defoliation effect in graminoids tillering depends on the number of available resources and whether the apical meristem is damaged or not (Jameson, 1964). The moss was not grazed by livestock but more sensitive to trampling. The dry weight of moss was four times greater in un-grazed sites as compared to grazed sites (Jónsdóttir & Jonsdottir, 1991).

In fact, the defoliation by gazing alters the leaf: stem proportions due to sparing of nutrient reserves for the growth of young tillers and leaves respectively. The leaf: stem ratio further determines the intake and preference by grazing livestock. There is much accumulation of NSC than the fibres, however it depends on season and herbage species, net photosynthesis and time of defoliation etc.

Nonstructural Carbohydrate Accumulation

The carbohydrates are classified as structural and nonstructural forms. The polysaccharides such as pectin, glycogen, cellulose and hemicellulose are structural carbohydrates because they are a component of the cell wall and provide structural support to the herbage plants (Raven *et al*., 2005). Nonstructural carbohydrates assists in energy transport and energy storage and intermediary metabolism in the plant(Moore & Hatfield, 1994). Intermediary metabolism involves the pathways that synthesize, degrade, and transform important metabolites as well as conserve energy. A nonstructural carbohydrate indicates the simple sugars (glucose, fructose, and sucrose), fructan, and starch. Total nonstructural carbohydrates (TNC) is a term used to describe these carbohydrates, which is commonly used as an indicator of herbage quality(Jensen *et al*., 2014).The accumulation of nonstructural carbohydrates in herbage occurs when carbohydrate production from photosynthesis is greater than the amount required for herbage growth and development (Watts & Chatterton, 2004). Excess carbohydrates produced from photosynthesis process are substituted as reserve carbohydrates, which are deposited during the day time and some portion are loosed at night by respiration to produce energy for growth and maintenance(Preiss & Levi, 1980).The combination of these processes results in a daily cycle that usually causes nonstructural carbohydrate concentrations to be highest in the afternoon and lowest in the morning. Fructan is reserve

carbohydrate for vegetative tissues and starch serves as a reserve carbohydrate for seeds of cool-season grasses. Fructan is stored in stem vacuole which is translocated from leaf vacuole, therefore cool-season herbage commonly accumulates the high amount of fructan in stem base or lower stem (Longland & Byrd, 2006).The herbage accumulates the carbohydrate in different parts. The sucrose stored higher concentration (8.9% on a dry weight basis) in the root and upper two-third of leaf blades and fructan stored higher concentration (36.2% on a dry weight basis) in the lower half of debris (Sprague and Sullivan, 1950).The grasses and legumes during warm-season commonly produce less amount of total nonstructural carbohydrate than cool-season grasses and legumes, because they do not produce fructan. Warm-season legumes and grasses use starch instead of fructan as their chief reserve of carbohydrate (Chatterton *et al*., 1989).Animal preference is highest in afternoon cut hay as compared to morning cut hay related with raised total nonstructural carbohydrate (TNC) and in vitro true dry matter disappearance, and reduced neutral detergent fibre (NDF) (Fisher *et al*., 1999). The concentration of nonstructural carbohydrate in forage is seasonal variation. (Pollock & Jones, 1979) documented fructan metabolism monthly in the cool-season grasses meadow fescue (*Festucapratensis* L.), timothy (*Phleumpratense* L.), and perennial ryegrass (*Loliumperenne* L.). They found that, fructan stored was highest in fall and winter, with maximal amount documented in December, when growth was restricted but photosynthesis continued. The highest concentrations of nonstructural carbohydrates of tall fescue and Kentucky bluegrass (Poapratensis L.)founded in the spring and fall months (Cubitt *et al*., 2007). Both pasture and hay samples followed seasonal trends in spring, with maximum levels in early-April and minimum in May and June(Kagan *et al*., 2011). This trend indicated that seasonal variations in nonstructural carbohydrate concentration are correlated with the growth stage of the plant. Less amount of nonstructural carbohydrate is accumulated during a rapidly growing stage (i.e. young stage) because the energy required producing new growth. Therefore, with a season and maturity stage of plant will greatly affect the concentration of nonstructural carbohydrate. Environmental factors such as photo-synthetically active radiation (PAR), precipitation and temperature can affect the production and utilization of nonstructural carbohydrate. (Chatterton *et al*., 1989) demonstrated that, while cooler temperatures (5-10^{o} C) have been associated with maximum carbohydrate concentrations, warmer temperatures (15-25^{o}C) have been associated with minimum carbohydrate concentrations. The carbohydrates either reduced or remained at low concentrations under rainfall and temperature conditions that promoted grass growth. (Waite & Boyd, 1953) identified low concentrations of fructan during periods of growth after rising temperatures due to utilization of carbohydrate reserves. The photosynthetically active radiation

(PAR) has a significant influence on the concentration of nonstructural carbohydrate. Low PAR generally results in reduced nonstructural carbohydrate concentrations and high PAR commonly results in higher nonstructural carbohydrate accumulation.(Ciavarella *et al*., 2000) documented that lower the concentrations of nonstructural carbohydrate of forage in shaded areas as compared to forage grown to open non-shaded areas.

Effect of grazing on herbage productivity of grasslands

The role of herbivores in controlling plant species richness is a critical issue in the conservation and management of grassland biodiversity. The herbivores often, but not always, increase plant diversity (Olff & Ritchie,1998). Ward (2006) documented that the higher coverage of perennial, erect, tall species with longer growing season were observed in the protected grasslands and grazing increased mostly small, prostrate, rosette plants. The identification of easily measured plant functional traits that consistently predict grazing response in a wide spectrum of rangelands would be a major advance. Plant height was the best single predictor of grazing response, followed by leaf mass. The best prediction of species to grazing response was achieved by combining plant height, life history and leaf mass. Specific leaf area (SLA) was a comparatively poor predictor of grazing response (Diaz et al., 2001).

The potential benefits of herbivore to plants have been debated over the last decade. Several investigators claim that removal of or damage to the productive, absorptive, or reproductive tissue of plants by herbivores benefits some plant species by increasing their net primary productivity, seed production, or longevity, and that these changes increase plant fitness and result in the evolution of herbivore-plant mutualisms (Belsky, 1986).Grazing can alter the spatial heterogeneity of vegetation, influencing ecosystem processes and biodiversity (Adler et al., 2001).Most soils under grazed pasture, compaction to greater depth, and other changes in soil physical properties, are more likely in recently tilled or wet soils (Greenwood & McKenzie, 2001). Pastoral fallowing over a growing season (October–May) has a profound effect on standing biomass and sward structure, and should have an impact on below ground plant growth and soil biological activities (Nie *et al*., 1997).

Stocking rate and grazing disturbances

The grazing disturbs plant species composition in permanent grasslands (Hickman et al. 2004). Increased stocking rate stimulates the functional properties

such as increase in ruderal and competitive species (Grime *et al*., 1988); early flowering and seed dispersal, rosette habit, and lower minimum height (Pakeman, 2004). Conversely, low-stocking rate favors stress-tolerant grasses (Grime *et al*., 1988) and forbs but depending on the starting floristic composition and site conditions (Dumont *et al*., 2009). In a sheep grazed pasture, the richness of dicot species found increased with increasing stocking rate (Bullock *et al*., 2001), however, the intensity of grazing might govern such results. Stocking rate can influence the plant diversity of permanent grasslands through two mechanisms: removal of vegetation and trampling (Gaujour *et al*., 2012). Grazing by herbivores leads to spatial heterogeneity of the plant canopy (Wallace, 1987), light penetration to lower canopy (Rook & Tallowin, 2003), and in such situations the creeping vines could grow faster (Pavlu *et al*., 2007). Trampling induces gap in the pasture and larger ruminants are better species as compared to others (Stoneburner *et al*., 2021). Thus, maintained gaps could be the source for seedling recruitment and species diversity (Lavorel *et al*., 1994). Stocking rate dramatically influences botanical composition of grasslands, working on the recruitment, survival, and dispersion of species (Gaujour *et al*., 2012).

CONCLUSION

All things considered; it is possible to conclude that grazing disturbance may change the grassland niches. Because too much aboveground biomass is removed, the floristic composition would decrease and heterogeneity would primarily rise as the stoking rate increased. The level of herbage defoliation and trampling in the grazed pastures would be interesting areas of rangelands research in the rears to come.

REFERENCES

Adler, P., Raff, D., &W. Lauenroth. (2001). The effect of grazing on the spatial heterogeneity of vegetation. *Oecologia*, 128(4), 465-479.

Albon, S. D., & R. Langvatn. (1992). Plant Phenology and the Benefits of Migration in a Temperate Ungulate. *Oikos*, *65*(3), 502. https://doi.org/10.2307/3545568.

Amiri, F., Ariapour, A., & Fadai, S. (2008). Effects of livestock grazing on vegetation composition and soil moisture properties in grazed and non-grazed range site. *Journal of Biological Sciences*, *8*(8), 1289-1297.

Archer, S.R., and L.L. Tieszen. (1986). Plant response to defoliation: hierarchical considerations. p. 45-59. In: *O. Gudmundsson (ed.) Grazing research at northern latitudes*. Plenum Publ. Corp .

Austin, A. T., Yahdjian, L., Stark, J. M., Belnap, J., Porporato, A., Norton, U., Ravetta, D. A., &S. M. Schaeffer. (2004). Water pulses and biogeochemical cycles in arid and semiarid ecosystems. *Oecologia*, 141(2), 221–235. https://doi.org/10.1007/s00442-004-1519-1.

Bakker, J. P., Bos, D., & De Vries, Y. (2003, October). To graze or not to graze: that is the question. In *Proceedings of the 10th International Scientific Wadden Sea Symposium* (Vol. 67). Ministry of Agriculture, Nature Management and Fisheries.

Belesky, D. P., Fedders, J. M., Turner, K. E., & Ruckle, J. M. (1999). Productivity, Botanical Composition, and Nutritive Value of Swards Including Forage Chicory. *Agronomy Journal*, 91(3), 450–456. https://doi.org/10.2134/agronj1999.00021962009100030015x.

Belsky, A. J. (1986). *Does herbivory benefit plants? A review of the evidence*. The American Naturalist, 127(6), 870-892.

Bullock, J.M., Franklin, J., Stevenson, M.J., Silvertown, J., Coulson, S.J., Gregory, S.J., Tofts, R. (2001). A plant trait analysis of responses to grazing in a long-term experiment. *J. Appl. Ecol*., 38:253–267. doi:10.1046/j.1365-2664.2001.00599.x.

Chatterton, N. J., Harrison, P. A., Bennett, J. H., & Asay, K. H. (1989). Carbohydrate Partitioning in 185 Accessions of Gramineae Grown Under Warm and Cool Temperatures. *Journal of Plant Physiology*, 134(2), 169–179. https://doi.org/10.1016/S0176-1617(89)80051-3.

Ciavarella, T. A., Simpson, R. J., Dove, H., Leury, B. J., & Sims, I. M. (2000). Diurnal changes in the concentration of water-soluble carbohydrates in Phalaris aquatica L. pasture in spring, and the effect of short-term shading. *Australian Journal of Agricultural Research*, 51(6), 749. https://doi.org/10.1071/AR99150.

Cubitt, T. A., Stanair, W. B., Kronfeld, D. S., Byrd, B. M., & Harris, P. A. (2007). Environmental effects on nutritive value of equine pastures in Northern Virginia: *Pferdeheilkunde Equine Medicine*, 23(2), 151–154. https://doi.org/10.21836/PEM20070207.

Deak, A., Hall, M. H., & Sanderson, M. A. (2009). Grazing Schedule Effect on Forage Production and Nutritive Value of Diverse Forage Mixtures. *Agronomy Journal*, 101(2), 408–414. https://doi.org/10.2134/agronj2007.0365.

Deng, L., Sweeney, S., & Shangguan, Z. P. (2014). Grassland responses to grazing disturbance: plant diversity changes with grazing intensity in a desert steppe. *Grass and Forage Science*, *69*(3), 524-533.

Díaz, S., & Cabido, M. (2001). Vive la différence: plant functional diversity matters to ecosystem processes. *Trends in ecology & evolution*, *16*(11), 646-655.

Díaz, S., Noy-Meir, I., & Cabido, M. (2001). Can grazing response of herbaceous plants be predicted from simple vegetative traits? *Journal of Applied Ecology*, 38(3), 497-508.

Dumont, B., Rook, A. J., Coran, C., & Röver, K. U. (2007). Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 2. Diet selection. *Grass and Forage Science*, 62(2), 159-171.

Fisher, D. S., Mayland, H. F., & Burns, J. C. (1999). Variation in ruminants' preference for tall fescue hays cut either at sundown or at sunup. *Journal of Animal Science*, 77(3), 762. https://doi.org/10.2527/1999.773762x.

Forbes, T. D. A., & Coleman, S. W. (1993). Forage Intake and Ingestive Behavior of Cattle Grazing Old World Bluestems. *Agronomy Journal*, 85(4), 808–816. https://doi.org/10.2134/agronj1993.00021962008500040006x.

Garcia, F., Carrère, P., Soussana, J. F., & Baumont, R. (2003). The ability of sheep at different stocking rates to maintain the quality and quantity of their diet during the grazing season. *The Journal of Agricultural Science*, *140*(1), 113–124. https://doi.org/10.1017/S0021859602002769.

Gaujour, E., Amiaud, B., Mignolet, C., & S. Plantureux (2012). Factors and processes affecting plant biodiversity in permanent grasslands. A review. *Agronomy for sustainable development*, 32(1), 133-160.

Glindemann, T., Wang, C., Tas, B. M., Schiborra, A., Gierus, M., Taube, F., & Susenbeth, A. (2009). Impact of grazing intensity on herbage intake, composition, and digestibility and on live weight gain of sheep on the Inner Mongolian steppe. *Livestock Science*, 124(1–3), 142–147. https://doi.org/10.1016/j.livsci.2009.01.007

Grant, K., Kreyling, J., Dienstbach, L. F. H., Beierkuhnlein, C., & Jentsch, A. (2014). Water stress due to increased intra-annual precipitation variability reduced forage yield but raised forage quality of a temperate grassland. *Agriculture, Ecosystems & Environment*, 186, 11–22. https://doi.org/10.1016/j.agee.2014.01.013

Greenwood, K. L., & McKenzie, B. M. (2001). Grazing effects on soil physical properties and the consequences for pastures: a review. *Animal Production Science*, 41(8), 1231-1250.

Grime, J. P. (1988). The CSR model of primary plant strategies—origins, implications and tests. In *Plant evolutionary biology* (pp. 371-393). Dordrecht: Springer Netherlands.

Hartnett, D. C., Hickman, K. R., & Walter, L. E. (1996). Effects of bison grazing, fire, and topography on floristic diversity in tallgrass prairie. *Rangeland Ecology & Management/Journal of Range Management Archives*, *49*(5), 413-420.

Heitschmidt, R. K., Dowhower, S. L., & Walker, J. W. (1987). Some effects of a rotational grazing treatment on quantity and quality of available forage and amount of ground litter. *Rangeland Ecology & Management/Journal of Range Management Archives*, *40*(4), 318-321.

Henkin, Z., Ungar, E. D., Dvash, L., Perevolotsky, A., Yehuda, Y., Sternberg, M., Voet, H., & Landau, S. Y. (2011). Effects of cattle grazing on herbage quality in a herbaceous Mediterranean rangeland: Cattle grazing effects on range quality. *Grass and Forage Science*, 66(4), 516–525. https://doi.org/10.1111/j.1365-2494.2011.00808.x.

Hickman, K. R., Hartnett, D. C., Cochran, R. C., and Owensby, C. E., (2004): Grazing management effects on plant species diversity in tallgrass prairie. Journal of Range Management, 57: 58–65.

Jameson, D. A. (1964). Effect of defoliation on forage plant physiology. *Forage Plant Physiology and Soil-Range Relationships*, *5*, 67-80.

Jensen, K. B., Harrison, P., Chatterton, N. J., Bushman, B. S., & Creech, J. E. (2014). Seasonal Trends in Nonstructural Carbohydrates in Cool- and Warm-season Grasses. *Crop Science*, 54(5), 2328–2340. https://doi.org/10.2135/cropsci2013.07.0465.

Johnson, D. A., & Tieszen, L. L. (1976). Aboveground biomass allocation, leaf growth, and photosynthesis patterns in tundra plant forms in arctic Alaska. *Oecologia*, 24(2), 159–173. https://doi.org/10.1007/BF00572757.

Jónsdóttir, I. S., & Jonsdottir, I. S. (1991). Effects of Grazing on Tiller Size and Population Dynamics in a Clonal Sedge (Carex bigelowii). *Oikos*, 62(2), 177. https://doi.org/10.2307/3545263

Jónsdóttir, I. S., Callaghan, T. V., & Jonsdottir, I. S. (1989). Localized Defoliation Stress and the Movement of 14 C between Tillers of Carex Bigelowii. *Oikos*, 54(2), 211. https://doi.org/10.2307/3565269.

Kagan, I. A., Kirch, B. H., Thatcher, C. D., Strickland, J. R., Teutsch, C. D., Elvinger, F., & Pleasant, R. S. (2011). Seasonal and Diurnal Variation in Simple Sugar and Fructan Composition of Orchardgrass Pasture and Hay in the Piedmont Region of the United States. *Journal of Equine Veterinary Science*, 31(8), 488–497. https://doi.org/10.1016/j.jevs.2011.03.004.

Komac, B., Domènech, M., & Fanlo, R. (2014). Effects of grazing on plant species diversity and pasture quality in subalpine grasslands in the eastern Pyrenees (Andorra): Implications for conservation. *Journal for Nature Conservation*, *22*(3), 247-255.

Lascano, C. E., Schmidt, A., & Barahona, R. (n.d.). *Forage quality and the environment*. 20.

Lavorel, S., Lepart, J., Debussche, M., Lebreton, J. D., & Beffy, J. L. (1994). Small scale disturbances and the maintenance of species diversity in Mediterranean old fields. *Oikos*, 455-473.

Lee, M. A., Davis, A. P., Chagunda, M. G. G., & Manning, P. (2017). Forage quality declines with rising temperatures, with implications for livestock production and methane emissions. *Biogeosciences*, 14(6), 1403–1417. https://doi.org/10.5194/bg-14-1403-2017

Longland, A. C., & Byrd, B. M. (2006). Pasture Nonstructural Carbohydrates and Equine Laminitis. *The Journal of Nutrition*, 136(7), 2099S-2102S. https://doi.org/10.1093/jn/136.7.2099S

Mattheis, P. J., & Tieszen, L. L. (n.d.). Responses of Dupontia fischeh to Simulated Lemming Grazing in an Alaskan Arctic Tundra. 19.

McNaughton, S. J. (1979). Grazing as an optimization process: grass-ungulate relationships in the Serengeti. *The American Naturalist*, *113*(5), 691-703.

McNaughton, S. J. (1983). Physiological and ecological implications of herbivory. In *Physiological plant ecology III: responses to the chemical and biological environment* (pp. 657-677). Berlin, Heidelberg: Springer Berlin Heidelberg.

Moore, K. J., & Hatfield, R. D. (1994). Carbohydrates and forage quality. *Forage quality, evaluation, and utilization*, 229-280.

Müller, K., Dickhoefer, U., Lin, L., Glindemann, T., Wang, C., Schönbach, P., Wan, H., Schiborra, A., Tas, B. &M. Gierus. (2014). Impact of grazing intensity on herbage quality, feed intake and live weight gain of sheep grazing on the steppe of Inner Mongolia. *The Journal of Agricultural Science* 152: 153-165.

Nie, Z. N., Mackay, A. D., Valentine, I., Barker, D. J., & Hodgson, J. (1997). Influence of pastoral fallow on plant root growth and soil physical and chemical characteristics in a hill pasture. *Plant and Soil*, *197*, 201-208.

Noy-Meir, I., Gutman, M., &Y. Kaplan. (1989). Responses of Mediterranean grassland plants to grazing and protection. *The journal of Ecology*, 290-310.

Olff, H., &M. E. Ritchie. (1998). Effects of herbivores on grassland plant diversity. *Trends in ecology & evolution*, 13(7), 261-265.

Pakeman, R. J. (2004). Consistency of plant species and trait responses to grazing along a productivity gradient: a multi-site analysis. *Journal of Ecology*, *92*(5), 893-905.

Pavlů, V., Hejcman, M., Pavlů, L., Gaisler, J., & Nežerková, P. (2006). Effect of continuous grazing on forage quality, quantity and animal performance. *Agriculture, Ecosystems & Environment*, 113(1–4), 349–355. https://doi.org/10.1016/j.agee.2005.10.010.

Pavlů, V., Hejcman, M., Pavlů, L., Gaisler, J., & Nežerková, P. (2006). Effect of continuous grazing on forage quality, quantity and animal performance. *Agriculture, Ecosystems & Environment*, 113(1–4), 349–355. https://doi.org/10.1016/j.agee.2005.10.010.

Pérez-Harguindeguy, N., Díaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., et al. (2013). New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany* 61: 167-234.

Pollock, C. J., & Jones, T. (1979). Seasonal Patterns of Fructan Metabolism in Forage Grasses. *New Phytologist*, 83(1), 9–15.

Preiss, J., & Levi, C. (1980). Starch Biosynthesis and Degradation. In Carbohydrates: Structure and Function (pp. 371–423). Elsevier. https://doi.org/10.1016/B978-0-12-675403-2.50016-8.

Raven, P. H., R. F. Evert, and S. E. Eichhorn. (2005). Biology of plants. W. H. Freeman and Company, New York, NY. p. 15-19.

Ren, H., Han, G., Lan, Z., Wan, H., Schönbach, P., Gierus, M., & Taube, F. (2016). Grazing effects on herbage nutritive values depend on precipitation and growing season in Inner Mongolian grassland. *Journal of Plant Ecology*, 9(6), 712–723. https://doi.org/10.1093/jpe/rtw011.

Ren, H., Han, G., Schönbach, P., Gierus, M., & Taube, F. (2016). Forage nutritional characteristics and yield dynamics in a grazed semiarid steppe ecosystem of Inner Mongolia, China. *Ecological Indicators*, *60*, 460-469.

Rook, A. J., & Tallowin, J. R. (2003). Grazing and pasture management for biodiversity benefit. *Animal Research*, *52*(2), 181-189.

Rook, A. J., Dumont, B., Isselstein, J., Osoro, K., Wallis DeVries, M. F., Parente, G., & Mills, J. (2004). Matching type of livestock to desired biodiversity outcomes in pastures–a review. Biological conservation, 119(2), 137-150.

Sasaki, T., Ohkuro, T., Jamsran, U., & Takeuchi, K. (2012). Changes in the herbage nutritive value and yield associated with threshold responses of vegetation to grazing in Mongolian rangelands: Grazing impacts on the herbage nutritive value and yield. Grass and Forage Science, 67(3), 446–455. https://doi.org/10.1111/j.1365-2494.2012.00862.x

Schiborra, A., Gierus, M., Wan, H. W., Bai, Y. F., & Taube, F. (2009). Short-term responses of a Stipa grandis/Leymus chinensis community to frequent defoliation in the semi-arid grasslands of Inner Mongolia, China. Agriculture, Ecosystems & Environment, 132(1–2), 82–90. https://doi.org/10.1016/j.agee.2009.03.002.

Selemani, I. S., Eik, L. O., Holand, Ø., Ådnøy, T., Mtengeti, E., & Mushi, D. (2013). Variation in quantity and quality of native forages and grazing behavior of cattle and goats in Tanzania. Livestock Science, 157(1), 173–183. https://doi.org/10.1016/j.livsci.2013.08.002.

Shan, Y., Chen, D., Guan, X., Zheng, S., Chen, H., Wang, M., & Bai, Y. (2011). Seasonally dependent impacts of grazing on soil nitrogen mineralization and linkages to ecosystem functioning in Inner Mongolia grassland. Soil Biology and Biochemistry, 43(9), 1943–1954. https://doi.org/10.1016/j.soilbio.2011.06.002.

Sprague, V. G., & Sullivan, J. T. (1950). Reserve carbohydrates in orchard grass clipped periodically. *Plant Physiology*, *25*(1), 92.

Stoneburner, A. L., Meiman, P. J., Ocheltree, T. W., Nissen, S. J., & Bradfield, S. J. (2021). Simulated trampling by cattle negatively impacts invasive yellow-flag iris (Iris pseudacorus) when submerged. *Invasive Plant Science and Management*, *14*(4), 232-239.

Sun, Y., Angerer, J. P., & Hou, F. J. (2015). Effects of grazing systems on herbage mass and liveweight gain of Tibetan sheep in Eastern Qinghai-Tibetan Plateau, China. *The Rangeland Journal*, *37*(2), 181-190.

Van Soest, P. J. (1969). Composition, Maturity, and the Nutritive Value for Forages. In G. J. Hajny & E. T. Reese (Eds.), Cellulases and Their Applications (Vol. 95, pp. 262–278). AMERICAN CHEMICAL SOCIETY. https://doi.org/10.1021/ba-1969-0095.ch016.

Waite, R., & Boyd, J. (1953). The water-soluble carbohydrates of grasses. I.—Changes occurring during the normal life-cycle. Journal of the Science of Food and Agriculture, 4(4), 197–204. https://doi.org/10.1002/jsfa.2740040408

Wallace, L. L. (1987). Effects of clipping and soil compaction on growth, morphology and mycorrhizal colonization of Schizachyrium scoparium, a C 4 bunchgrass. *Oecologia*, *72*, 423-428.

Wang, C., Wang, S., Zhou, H., Li, Z., & Han, G. (2011). Influences of grassland degradation on forage availability by sheep in the Inner Mongolian steppes of China: forage degradability and availability. *Animal Science Journal*, 82(4), 537–542. https://doi.org/10.1111/j.1740-0929.2011.00878.x.

Ward, D. A. V. I. D. (2006). Long-term effects of herbivory on plant diversity and functional types in arid ecosystems. *Conservation Biology Series-Cambridge-*, *11*, 142.

Warren, S. D., Nevill, M. B., Blackburn, W. H., & Garza, N. E. (1986). Soil response to trampling under intensive rotation grazing. *Soil Science Society of America Journal*, *50*(5), 1336-1341.

Watt, T. A., & Gibson, C. W. D. (1988). The effects of sheep grazing on seedling establishment and survival in grassland. *Vegetatio*, *78*, 91-98.

Watts, K. A., & Chatterton, N. J. (2004). A review of factors affecting carbohydrate levels in forage. *Journal of Equine Veterinary Science*, 24(2), 84–86. https://doi.org/10.1016/j.jevs.2004.01.005.

Xu, Z. Z., & Zhou, G. S. (2006). Combined effects of water stress and high temperature on photosynthesis, nitrogen metabolism and lipid peroxidation of a perennial grass Leymus chinensis. *Planta*, 224, 1080-1090.

Zhai, X., Zhang, Y., Wang, K., Chen, Q., Li, S., & Huang, D. (2018). Grazing effects on the nutritive value of dominant species in steppe grasslands of northern China. *BMC Ecology*, 18(1), 30. https://doi.org/10.1186/s12898-018-0186-8.

Zheng, S., Lan, Z., Li, W., Shao, R., Shan, Y., Wan, H., Taube, F., & Bai, Y. (2011). Differential responses of plant functional trait to grazing between two contrasting dominant C3 and C4 species in a typical steppe of Inner Mongolia, China. *Plant and Soil*, 340(1–2), 141–155. https://doi.org/10.1007/s11104-010-0369-3.

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APPLICATIONS OF NANOBUBBLE AERATION TECHNOLOGY FOR AQUACULTURE PRACTICES: A REVIEW

Hare Ram Devkota[1,2,3*], Dilip Kumar Jha[1], Tista Prasai Joshi[2], Shreemat Shrestha[3]

[1] Agriculture and Forestry University, Rampur, Chitwan, Nepal
[2] Nepal Academy of Science and Technology, Lalitpur, Nepal
[3] Nepal Agricultural Research Council, Lalitpur, Nepal
*Corresponding author * Email:* hdevkota6@gmail.com

ABSTRACT

Notably, there has been widespread interest in the multiple possible uses of nanobubbles (NB) with a diameter of less than 100 nm. The introduction of NB technology in Japan, the United States, Europe, and other countries shows that it has enormous potential, even in the early stages of exploration in various industries. However, the full extent of its impact on aquaculture is not yet fully understood. Nanobubbles have shown promising results in improving water quality in aquaculture systems, increasing oxygen levels, and promoting fish health. However, further research and experiments are needed to determine the optimal conditions for their application and to fully understand their long-term effects on fish growth and overall production efficiency. Not only fish productivity highly positively correlated with dissolved oxygen (DO) concentration in the aquatic environment but also the size of the bubbles is inversely related to the solubility and stability of DO. Therefore, it plays a crucial role in this interdependence. However, it is worth noting that existing aquaculture practices often unknown the importance of oxygen nanobubbles. These nanobubbles can be quickly generated and distributed on the water surface using various devices, creating millions of oxygens nanobubbles in a limited volume of water to have a significant impact on the regulation of aquatic environments. Using nanobubbles in aeration technology is a promising option for the blue revolution in aquaculture practices. The article offers a comprehensive overview, providing valuable insights into the significance and potential benefits of NB technology in the aquaculture sector.

Keywords: Aeration, Aquaculture, Dissolved Oxygen and Oxygen Nanobubble

INTRODUCTION

Aquaculture plays a crucial role in the global fisheries industry. Intensive aquaculture aims to provide agricultural fish with essential resources, including access to quality water and sufficient food. The primary focus was identifying and prioritizing the key factors of DO that played a significant role in aquaculture development. According to Mallya, (2007), low dissolved oxygen levels can pose a hazard and impact the water's ability to sustain biological agents. Consequently, a large focus has been placed on research to increase dissolved oxygen levels in water. Numerous factors, such as their diet and water quality, affect the health of aquatic organisms, where dissolved oxygen governs the overall health of aquatic animals' DO concentration (Guo et al., 2011). Additionally, studies have shown that higher concentrations of DO can increase these organisms' growth rates (Boyd, 2017). Numerous studies are underway to enhance water quality metrics by implementing different aeration techniques. Rognerud et al. (2020) have recently improved the solubility and stability of DO. A range of biological and non-biological activities influence the solubility of substances in an aquatic environment. These activities, such as respiration, photosynthesis, and diffusion, contribute to DO solubility, which is dynamic (Sarkar et al., 2022). The solubility of gases is also influenced by water temperature, atmospheric air, and water pressure, which are interconnected and maintained in equilibrium in nature (Heinemann & Weinhardt, 2004 ; Meegoda et al., 2018). Consequently, over time, the DO levels fall below the anticipated range, resulting in severe consequences for the aquatic ecosystem. The fact that innovative progress has been made in water aeration technology indicates that efforts have been made to address the anoxic condition of the pond. The prevailing belief is that 70% of the gas injected into water is diffused out of the water into the atmosphere. According to Suryadi et al., (2020), active aeration produces more microbubbles than passive aeration, where the research shows that passive aeration methods make 20% of microporous tubes, 25% of porous stone, and 44% of ceramic diffusers dissolve gas in water. On the other hand, active methods demonstrate higher gas solubility, with 60% achieved through the venturi nozzle and 80% through the oxygenation cone.

Creating the first microbubbles (MBs) in Japan involves a turbulent mixture. The size fluctuation of the bubbles showed a discrepancy, with a microbubble measuring approximately 200 nm (Akimi, 2017). This microbubble also exhibited distinct physical characteristics of solubility and stability (Agarwal et al., 2011). The International Organization for Standardization (ISO) has defined the size of

bubbles as less than 100 m in diameter, commonly referred to as fine bubbles (Hata et al., 2019). The primary objective of the inaugural International Symposium on NB was to implement NB technology to enhance aquaculture production (Akimi, 2017). NB exhibits distinctive advantageous characteristics that result in the generation of hydroxyl radicals. These radicals, including H+, OH-, and H2O2, possess high reactivity and are crucial in eliminating bond impurities. Moreover, NB aids in enhancing fish population density without compromising the quality of water. Additionally, it helps mitigate the harmful effects of pathogens in fish (Mead et al., 1976). The dissolving performance of NB is more effective than that of ordinary gas bubbles. According to Beijnen Yan (2021), the oxygen dissolving efficiency in the NB is 85 percent, which is significantly higher than that of conventional aeration by over three times. According to Mahasri et al. (2018), NB generators experienced increased DO levels of up to 25 ppm from an initial level of 6.5 ppm. The performance of NB aeration is significantly superior to that of other standard aeration methods. According to Gilmour Zimmerman, (2020), a traditional surface aeration system generates sludge and disperses harmful gases into water columns, producing oxidation of the surface water. The technology has distinct characteristics that contribute to the overall health and productivity of the pond ecosystem. According to Meegoda et al., (2018) and Batagoda et al., (2019), high oxygen levels at the bottom are crucial in reducing toxicity through oxidation. This process converts organic sediments and waste into fish feed, enhancing fish productivity and accelerating growth. The lack of understanding about the unique beneficial properties of NB has prevented it from becoming a critical area. The usefulness of this property extends to various fields such as chemistry, physics, agriculture, medicine, the environment, and industry. The paper comprehensively analyzes the characteristics, manufacturing, and use of NBs in aquaculture. It examines their impact on fish growth, production, live fish transportation, and disease treatment, as depicted in Figures 1 and 2.

CHARACTERISTICS OF NB

The unique properties of the NB can be attributed to its small size. According to the ISO, the recommended size limit is 100 nm. There is a positive correlation between the size of gas bubbles and the dissolution rate when the merging of bubbles increases in size. A decrease in surface area and velocity coincides with this, which eventually causes the bubbles to rise to the surface and burst. Bernoulli (1738; Hoare & Pelton (2007) observed and studied this phenomenon. when the small-sized bubble undergoes Brownian motion and eventually bursts within the water column. This process leads to the formation of NB and makes the bubble soluble. The high interior pressure and negative potential of NBs contribute to the

acceleration of gas dissolution (Meegoda et al., 2018). The explosion of a microbubble (MB) converts into a nanobubble (NB) with specific properties, where a gas bubble containing an oxygen molecule moves slowly and is dissolved in a liquid. This dissolved form is characterized by a negative zeta potential (ZP). According to Michailidi et al. (2020), one of the notable characteristics of NBs is that the particles undergo collisions for extended periods while remaining neutrally buoyant in a water column. In addition, it is worth noting that the internal pressure of liquid NBs is higher than the surrounding pressure. Ljunggren Eriksson (1997) observed a particular characteristic that accelerates the process of gas dissolution in liquid. According to Kundu et al. (2018), the zero point size of nanobubbles tends to decrease solubility over time due to the increase in size and Brownian motion. Based on the experimental findings, it can be concluded that ZP exhibits a negative correlation with salinity, bubble size, and temperature. The size of the bubbles remains unchanged regardless of the temperature of the solution. According to Meegoda et al. (2018), more minor, stable bubbles with higher ZP are observed with higher pH levels and OH ion concentrations. Cerron-Calle et al. (2022) found that NB demonstrates stability in high pH ranges of 5–6 and 8–9. As the negative ZP value increases, there is a corresponding increase in the medium's acidity. This increase in acidity leads to an increase in bubble size, which causes the bubbles to become unstable. Figure 1 illustrates the comprehensive concept of bubble classification, encompassing various factors such as size, formation, dissolution, and stability mechanisms.

NB Production System

The NB production system relies heavily on the pressure and velocity of the liquid. Bernoulli (1738) and Beijnen Yan (2021) describe the velocity of the gas, the internal pressure of the gas, and the bubble relationship when the velocity increases, the internal pressure decreases. This relationship is particularly relevant in the production of NBs, where the pressure of a liquid or gas is often altered through the cavitation process, as explained by (Agarwal et al., 2011). The NB production system can be categorized into three main processes: pressure, dissolution, and electrolysis. Gas-liquid and wave-pressure methods are widely employed to observe the cavitation action. The gas-liquid method is a process that entails the introduction of a substantial pressure of either a liquid or gas into a gas-liquid medium to produce NB. The production methods for NB are in detail below.

Gas-liquid pressure method

Commercial NB generators utilizing the Bernoulli principle are available on the market. According to Minible (2020), the MiniBle series faucet aerator produces

a significant number of 100-nm-sized NBs, specifically 600 million per square cm of liquid pressure ranging from 2 to 3.5 bars. High-pressure liquid on the nozzle creates a suction effect that draws the gas through the flow path. This process forms approximately 90% of the bubbles, which appear milky white-water color (Samuel & Power, 2020). The NB-generated water pump is widely recognized as a popular and frequently utilized instrument. According to Hideki (2014), milky white MB and NBs are emitted by absorbing atmospheric gas, with an average emission of 50 nm of MB.

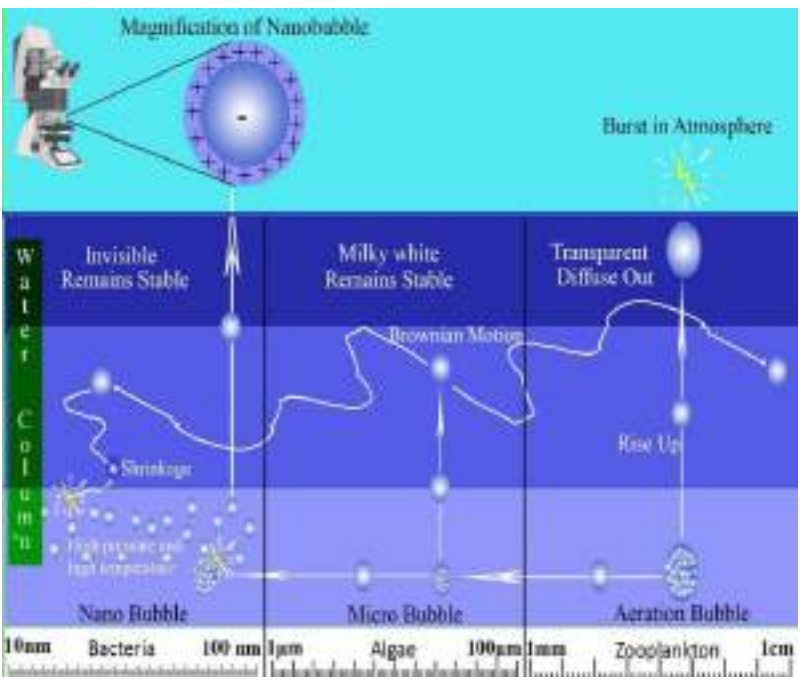

Figure 1. A conceptual overview of different bubbles' classification, stability, solubility, and surface area

The carbon-ceramic porous membrane is a low-pressure working product that applies gas pressure to the liquid. Numerous studies have been carried out to explore the commercialization of NB characterization by using different instruments. NB was characterized using ozone gas in the spiral liquid flow method. The zeta potential (ZP) was measured to be -21, and the initial bubble

size was 247 nm at a concentration of 4.55x1010. Additionally, oxygen gas was used in the venturi nozzle, resulting in a zeta potential of -4.3 and an initial bubble size of 344 nm. These measurements were taken over seven days (Hu & Xia, 2018). A separate study was performed to achieve the same objective, where the ZP was found to be -20. The initial size of the bubbles ranged from 150 to 200 nm, with a concentration of 4.0x109. Etchepare et al. (2017) observed that these bubbles remained stable in water for 60 days. The study utilized air in a splitter-type ejector with a ZP of -20 and an initial bubble size ranging from 700 to 900 nm. According to Cerron-Calle et al. (2022), the ZP at the end of the experiment was measured to be -25. Additionally, the initial bubble size was reported to be within the range of 350–400 nm. The instruments play a significant role in producing stable NBs for commercial purposes, ensuring long-term gas stability in water

Wave Pressure Method

Ultrasound has been found to generate NB that can physically and chemically impact aquatic and water microorganisms. According to Dong et al. (2012), ultrasonic transducers can generate oxygen molecules in water through the compression and rarefaction of acoustic waves. This process causes the covalent bond of water to break, forming tiny gas bubbles containing hydroxyl free radicals. Hydroxyl radicals, being highly reactive, can function as an antipathogen (Uchida et al., 2018). Commercial ultrasonic NB technology, commonly called an ultrasonic algae killer, is prevalent in eradicating algae. According to Cho et al. (2005), when subjected to ultrasound, NB's zeta potential (ZP) ranged from -2 to -28. Additionally, the initial bubble size was reported to be 249 nm, and this size remained unchanged in water for 60 days. Recently, green technology has gained recognition for its environmentally friendly nature, primarily due to its lack of chemical contamination.

Electrolysis

The principles of electrolysis have been well-established for over two centuries. Electrolysis is a straightforward process that involves immersing the anode and cathode in water and applying a minimum direct current voltage (DC). The presence of an electrolyte is unnecessary; the minerals found in water as a conductivity parameter, serve as electrolytes, facilitating the production of bubbles. However, the issue of anode corrosion poses a significant challenge. The selection of corrosion-resistant materials, including titanium, cadmium, and steel, is necessary. According to Hideki (2014), this method can produce micro- or NBs of hydrogen and oxygen, with average sizes varying between 35 and 100nm. The volume of gas produced in this process is a ratio of 2 parts hydrogen to 1 part

oxygen. The current application of this method involves the production of hydrogen fuel, resulting in the generation of oxygen as a by-product. Electrolysis is employed to effectively isolate minuscule hydrogen and oxygen molecules generated by a commercially available product utilized in the aquarium for ornamental fish. The utilization of this method results in an increase of over 50% in DO compared to conventional methods. The use of this option in hydroponics, aquaponics, and ornamental fish farming sectors is a subject of debate and disagreement.

NB measurement technology

Particle size analysis instruments are utilized to perform quantitative measurements using different principles. The text describes different approaches to illustrating bubble measurement methods based on their characteristics. The absorption or transmittance of light on the NB is measured using a dynamic light scattering method. This method is used to analyze the parameters of the bubble formed in deionized water and electrolyte solution, as Xiaotong et al. (2022) described. In the microscope equipped with a video camera, the characteristics of the NB were analyzed using laser light and light diffraction methods. Specifically, a 525 nm laser light deflected the light that passed through the sample (Etchepare et al., 2017). The installed camera measured the quantity of diffracted light coming from the NB. The study utilized a different technique for tracking bubbles, explicitly focusing on 7-9 Brownian-moving bubbles within a given volume of liquid. This method assessed the bubbles' quality and quantity (Ferraro et al., 2020). To quantify NB in its natural environment, the researchers implemented electrical detection and image analysis techniques for characterizing NB (Marui, 2013). In the present era, scientific instruments are developed based on light absorption or transmittance principles.

NB for next-generation aquaculture

Aquaculture is an industry experiencing significant growth, playing a crucial role in meeting the increasing demand for animal protein. In recent days, several issues have emerged, including concerns about disease sensitivity and the safe transportation of products from farms to consumers. Due to the issues above, numerous countries are actively searching for a comprehensive solution. The introduction of NB technology into the fisheries sector is a recent development aimed at addressing the issue. Although the technology is still in its early stages, several countries have already implemented it in various ways within the aquaculture industry. Samuel & Power (2020) state that several countries, including America, Holland, the United Kingdom, Australia, and Japan, utilize it

for various purposes, such as lakes, aquaria, and swimming pool cleaning. Additionally, it is used in the production of prawns, oysters, and spirulina, as well as fish food processing (Phan et al., 2020), wastewater treatment(Li et al., 2023), and irrigation (Minamikawa et al., 2015). The utilization of this technology in India extends to salmon farming and the transportation of salmon fry. Figure 2 provides an example of aquaculture utilizing NB technology.

Figure 2. An overview of NB production methods and the aquaculture application sector of aquaculture

NB used in Fish Culture

Multiple studies have examined different aeration systems used in intensive fish culture. According to James Tidwell (2012), the profitability of the recirculating aquaculture system (RAS) is twice that of traditional aerated pond fish farming (Suryadi et al., 2020). They conducted a study comparing venturi-produced MBs to a standard aeration system to assess the growth performance of tilapia fry at different stocking densities in 15 liters of water. The study found that the growth performance in the venturi system was significantly higher than in the normal aeration system. It has also examined how well the water exchange system, the RAS system, and a mix of the RAS and NB systems produced fish in young groupers, with 600 fish per cubic meter of water. The results indicated that combining RAS and NB treatments improves growth performance and productivity. In a related study, Vannamei shrimp were subjected to an experiment for 56 days. The experiment assessed the economic feasibility of two aeration systems: NB and non-NB. The shrimp were stocked at a density of 400

cubic meters. The results showed that the NB aeration system had a survival rate of 92%, an internal rate of return (IRR) of 18%, and a benefit-cost (B/C) ratio of 1.26. According to Mauladani et al. (2020), it is evident that an NB system is more feasible than a non-NB system. Another study was conducted in 50-m2 ponds with 34,000 juvenile white-leg shrimp at a stocking density of 680 m3 for 81 days. The findings indicated that the NB treatment resulted in better outcomes than diffuser-type aeration. Specifically, the NB treatment showed a higher survival rate, improved feed conversion ratio, increased total harvest, and enhanced productivity. Additionally, the NB aeration method led to a reduction in total pathogens. Notably, the total harvest and productivity nearly doubled with NB aeration (Rahmawati et al., 2020). The NB aeration system demonstrates higher fish productivity compared to other aeration systems.

Use of NB in live fish transport

Two fish transport methods exist: closed and open. Practical applications use polythene bags with oxygen and water tanks with supplied oxygen or air. Indian major carp and Chinese carp weighing 300–1500 g was traditional aerated for 2–6 hours. A 600-700 kg distance group and a 50-100 kg distance group received the fish. Long-distance mortality was 100%. found that moving live fish without an appropriate aeration system caused the problem Muzaddadi et al. (2017). The experiment examined Pirarucu (Arapaima gigas) fingerlings for six hours using physiological and water quality tests. One group of fingerlings was placed in 170 g/L plastic bags with NB oxygen supplements. The other group received normal water in 50 g/L plastic bags. We measured water quality before and after transportation. After transport, water temperature, dissolved oxygen, carbon dioxide, and non-ionized ammonia increased, but pH decreased. Cortisol levels remained stable in the study. Fish in normal water did not die. NB oxygen supplements caused a 33% mortality rate and a three-fold increase in stocking density. found more fish per unit of NB water. This study examined the effectiveness of air blower, air NB, and oxygen NB at 100/L, 166/L, and 250/L stocking densities over 10 hours at 26 °C. The comparison between an air blower and oxygen showed that oxygen had different effects. NB transports more fish per liter than the average, increasing its efficiency fourfold Lima et al. (2020). Thongdon et al. (2019) experimented with investigating the dissolved carbon dioxide and oxygen levels in a chicken grunt (*Parapristipoma trilineatum*) over 30 minutes at 20 °C. The fish were subjected to sedation, causing a transition in their respiratory system from branchial to cellular. This transition was a result of the lethal effects of CO_2. During 22 hours, oxygen was transferred from water to tissue to regulate cellular respiration. After 22 hours, the fish are immersed in NB

water rich in oxygen for 2-3 hours. Carbon dioxide nanobubble was given as anesthesia and regained full consciousness after the end of the effects of the anesthetic when it was stored in a fully saturated oxygen nanobubble. CO_2 is a suitable and safe anesthetic for transporting fish over long distances at average water temperatures. A study was conducted in the sturgeon muscle to assess the effectiveness of oxygen, nitrogen oxide, ice, and regular water for long-distance live transport. A group of fish was divided into two conditions: one group was placed in pretreated NB water, which is considered desirable, while the other group was placed in regular water. In a programmable cooling system, the water was intentionally cooled to 0 °C. The fish then put its produced ice into the icebox. A separate water group was transported at a temperature of approximately 19°C. The total duration of transportation for both entities is 36 hours. The mortality rates for the NB and standard groups were 3.2% and 11%, respectively. The weight of the fish in the nanobubble group exceeds that of the water transported (Zhang et al. 2019). Table 1 provides a comprehensive overview of the process and data involved.

NB in Fish Health Management

Ozone NB has shown promise in aquaculture systems for increasing DO levels and lowering bacterial levels. NB-O_3 affected immune gene expression in Nile tilapia (Oreochromis niloticus), comparing fish that were treated and fish that were not treated. According to the findings, NB-O_3 has the potential to be effective in preventing pathogenic bacterial infections Linh et al. (2021). The Jhunkeaw et al. (2020) experiment aimed to investigate the potential infection of Nile tilapia with harmful pathogens. The participants were split into two groups based on the treatment they received. One group got NB, ozone, or the standard treatment in 50 L of water for 10 minutes. The size of NB was 130 nm, which is equal to about 2-3 x10^7 O_3 bubbles/ml of concentration, and the oxidation-reduction potential (ORP) was 834 mV. The other group did not receive any treatment. According to the study, the group treated with NB had a significantly lower bacterial count, with a reduction of 99.29%. According to the test results, the NB-O_3 technology shows promise in suppressing dangerous bacteria and enhancing dissolved oxygen levels for fish health management. Both studies have demonstrated that microbubbles and nanobubbles hurt microorganisms. the study shows that the varying reactions observed have both positive effects on long-drive organisms Jhunkeaw et al. (2021).

Impact of NB on Fish Physiology

The respiratory function of aquatic species is crucial in determining their physiological state. According to Temesgen et al. (2017), aquatic organisms

engage in cellular and branchial respiration when the size of NB in the water is below 0.2 micrometers. Despite the significantly smaller skin pores (Inatsu et al., 2011), they can still diffuse from the skin to the underlying tissue. Tissues absorb significant quantities of NB to sustain cellular and branchial respiration. The lack of DO in water leads to the release of the catecholamine stress hormone in cells, resulting in elevated plasma cortisol levels in fish (Sumpter & J., 1997). According to Lewis & Lee (2007), the increase in heart rate and gill function occurs at a faster rate than is typically expected. In this situation, branchial breathing is often inadequate to meet the body's oxygen requirements. The relationship between stress feed efficiency and feed conversion ratio is crucial for proper feed assimilation (Afridha, 2021). The behavior of an NB under extreme conditions of high temperature (5000K) and pressure (1000 atm) is characterized by explosive bursting. The increase in temperature of the NB inside the tissue positively impacts the expansion of blood vessels. This expansion allows for greater oxygen flow to the gills, which is essential for their proper physiological functioning play a crucial role in maintaining the physiological health of fish through dual respiration, blood purification, and excretion or neutralization of toxic materials produced in the body. The impact of NB technology on the physiological is positive (Akimi, 2017).

CONCLUSION

Aquaculture is poised to benefit significantly from nanobubble (NB) aeration technology, as explored in this comprehensive overview. The first part of the discussion looks at NB properties, how they are made, and what they can be used for, focusing on how much more gas- and solvent-stable they are than regular bubbles. Factors influencing NB size, formation, dissolution, and stability, such as pressure, temperature, pH, and zeta potential, are elucidated. The paper then delves into the potential advantages of NBs for aquatic organisms, summarizing studies comparing their performance with other aeration systems across diverse species, stocking densities, and water quality conditions. We also look at how NBs affect the breathing of fish cells and branches, the cleaning of their blood, and their stress hormone levels. We focus on how NB-O3 technology can stop pathogenic bacteria. It is important to note that changing regular bubbles to NBs by changing existing aeration instruments is discussed. This shows how microbubbles (MB) and NBs differ regarding how stable and soluble they are in gas. Gas dissolution performance is inversely proportional to bubble size, solubility, and stability. In conclusion, NB aeration technology emerges as a promising solution to address low oxygen content in aquaculture water, offering benefits for fish culture, live fish transport, and fish health management.

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Table 1. Examples of the contribution of NB to live fish transportation and water quality management

Species	Condition	SD	Water quality					Mor. (%)	Before transportation		After transportation		Time (hour)	Reference
			DO (mg/L)	NH3 mg/L	CO2 (mg/L)	Temp (0C)	pH							
Juvenile pirarucu	Normal water	50g/L	5.6	0.05	2	27.8	7	0	4.45 (C)	41.9 (G)	7.67 (C)	104.6(G)	6	(Lima et al., 2020)
	NB water	170g/L	15	1.34	12	31.42	6	33	2.33 (C)	44.18(G)	115.11 (C)	132.13 (G)	6	
Sturgeon muscle	Normal water	NA	8.8	NA	NA	19.1	7.9	11.1	NA	5(G)	NA	100(G)	6	(Zhang et al., 2019)
	NB waterless	NA	91.20%	NA	3.1	1.3	7.2	3.2	19.3 (P)	4.7(F)	19 (P)	4.7 (F)	36	
Tilapia fry	Air blower	100 (no/L)	4.8	0.12	NA	26.8	6.1	4.8	NA	NA	NA	NA	10	(Thongdon et al., 2019)
	Air NB	166 (no/L)	25	0.4	NA	26.9	7.7	7.6	NA	NA	NA	NA	10	
	Oxygen NB	250 (no/L)	11	0.3	NA	26.10	6-6.4	2.5	NA	NA	NA	NA	10	

Note: SD = stock density, G = blood glucose level, C = blood cortisol level, P = protein (%), F = fat (%), NA = not available

REFERENCES

Afridha, J. (2021). Natural Feed vs Artificial Feed. (*News*)*Dilihat*, 1–3. https://nanobubble.id/blog/natural-feed-vs-artificial-feed

Agarwal, A., Ng, W. J. & Liu, Y. (2011). Principle and applications of microbubble and nanobubble technology for water treatment. *Chemosphere*, *84*, 1175–1180. https://doi.org/10.1016/j.chemosphere.2011.05.054

Akimi, S. (2017). Fundamentals and Applications of Micro/Nano Bubbles. *1st International Symposium on Application of High Voltage, Plasmas & Micro/Nano Bubbles to Agriculture and Aquaculture*. http://webs.rmutl.ac.th/assets/upload/files/2017/01/20170106155252_97638.pdf

Batagoda, J. H., Hewage, S., Dailsha, A. & Meegoda, J. N. (2019). Nano-ozone bubbles for drinking water treatment. *Journal of Environmental Engineering and Science*, *14*, 57–66. https://doi.org/10.1680/jenes.18.00015

Beijnen, Johan. V. & Yan, G. (2021). A breath of fresh air: how nanobubbles can make aquaculture more sustainable. *News*, https://thefishsite.com/articles/a-breath-of-fresh-air-how-nanobubbles-can-make-aquaculture-more-sustainable-dissolved-oxygen

Bernoulli, D. (1738). Danielis Bernoulli Hydrodynamica, sive de viribus et motibus fluidorum commentarii. *Rara*. https://doi.org/10.3931/e-rara-3911

Boyd, C. E. (2017). General relationship between water quality and aquaculture performance in ponds. *Environment*, *III*, 147–166. https://doi.org/10.1016/b978-0-12-804564-0.00006-5

Cerron-Calle, G. A., Magdaleno, A. L., Graf, J. C., Apul, O. G. & Garcia-Segura, S. (2022). Elucidating CO2 nanobubble interfacial reactivity and impacts on water chemistry. *J Colloid Interface Sci*, *607*, 720–728. https://doi.org/10.1016/j.jcis.2021.09.033

Cho, S. H., Kim, J. Y., Chun, J. H. & Kim, J. D. (2005). Ultrasonic formation of nanobubbles and their zeta-potentials in aqueous electrolyte and surfactant solutions. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *269*, 28–34. https://doi.org/10.1016/j.colsurfa.2005.06.063

Dong, Chen, Sanjay, Sharma, K. & Mudhoo, A. (2012). *Handbook on applications of ultrasound: sonochemistry for sustainability*. 696–696.

Etchepare, R., Oliveira, H., Nicknig, M., Azevedo, A. & Rubio, J. (2017). Nanobubbles: Generation using a multiphase pump, properties and features in flotation. *Minerals Engineering*, *112*, 19–26. https://doi.org/10.1016/j.mineng.2017.06.020

Ferraro, G., Jadhav, A. J. & Barigou, M. (2020). A Henry's law method for generating bulk nanobubbles. *Nanoscale*, *12*, 15869–15879. https://doi.org/10.1039/d0nr03332d

Gilmour, D. J. & Zimmerman, W. B. (2020). Microbubble intensification of bioprocessing. *Elsevier*, *77*, 1–35. https://doi.org/10.1016/bs.ampbs.2020.07.001

Guo, S. F., Lee, H. P., Chaw, K. C., Miklas, J., Teo, S. L., Dickinson, G. H., Birch, W. R. & Khoo, B. C. (2011). Effect of ultrasound on cyprids and juvenile barnacles. *Biofouling*, *27*, 185–192. https://doi.org/10.1080/08927014.2010.551535

Hata, T., Nishiuchi, Y. & Minagawa, H. (2019). Development of new agriculture and aquaculture technology using fine bubbles. *International Journal of Plasma Environmental Science and Technology*, *12*, 39–43.

Heinemann, Z. E. & Weinhardt, B. E. (2004). *Text book series reservoir fluid* (Vol. 2). Montanuniversitat Leoben, Petroleum Engineering Department. https://pure.unileoben.ac.at/portal/files/561575/Reservoir_Fluids.pdf

Hideki, T. (2014). *Micro- and Nanobubbles: Fundamentals and Applications - 1st Edition*. CRC Press is an imprint of Taylor & Francis Group, an Informa business. https://www.routledge.com/Micro--and-Nanobubbles-Fundamentals-and-Applications/Tsuge/p/book/9789814463102

Hoare, T. & Pelton, R. (2007). Calorimetric Analysis of Thermal Phase Transitions in Functionalized Microgels. *The Journal of Physical Chemistry B*, *111*, 1334–1342. https://doi.org/10.1021/jp066916v

Hu, L. & Xia, Z. (2018). Application of ozone micro-nano-bubbles to groundwater remediation. *Journal of Hazardous Materials*, *342*, 446–453. https://doi.org/10.1016/j.jhazmat.2017.08.030

Inatsu, Y., Kitagawa, T., Nakamura, N., Kawasaki, S., Nei, D., Bari, M. L. & Kawamoto, S. (2011). Effectiveness of stable ozone microbubble water on reducing bacteria on the surface of selected leafy vegetables. *Food Science and Technology Research*, *17*, 479–485. https://doi.org/10.3136/fstr.17.479

James & Tidwell, H. (2012). *Flow-through Raceways*. 173–190. https://doi.org/10.1002/9781118250105.ch9

Jhunkeaw, C., Khongcharoen, N., Rungrueng, N., Sangpo, P., Panphut, W., Thapinta, A., Senapin, S., St-Hilaire, S. & Dong, H. T. (2021). Ozone nanobubble treatment in freshwater effectively reduced pathogenic fish bacteria and is safe for Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, *534*, 736286. https://doi.org/10.1016/j.aquaculture.2020.736286

Kundu, P., Bhattacharya, S., Liu, S. Y., Chen, F. R. & Tseng, F. G. (2018). In-situ tem study of highly stable oxygen nanobubbles in quasi-2D liquid system. *Proceedings of the IEEE International Conference on Micro Electro Mechanical Systems (MEMS)*, *2018-Janua*, 1289–1292. https://doi.org/10.1109/memsys.2018.8346801

Lewis, I. & Lee, S. H. (2007). *Physiology of haemopoiesis*. *25*, 3–9. https://doi.org/10.1007/978-94-011-6558-7

Li, T., Cui, Z., Sun, J., Li, Q., Wang, Y. & Li, G. (2023). Oxidative Capacity of Oxygen Nanobubbles and Their Mechanism for the Catalytic Oxidation of Ferrous Ions with Copper as a Catalyst in Sulfuric Acid Medium. *Langmuir*, *39*, 10112–10121. https://doi.org/10.1021/acs.langmuir.3c01047

Lima, A. F., Oliveira, H. J. B. de, Pereira, A. S. & Sakamoto, S. S. (2020). Effect of density of fingerling and juvenile pirarucu during transportation on water quality and physiological parameters. *Acta Amazonica*, *50*, 223–231. https://doi.org/10.1590/1809-4392202000302

Linh, N. V., Dien, L. T., Sangpo, P., Senapin, S., Thapinta, A., Panphut, W., St-Hilaire, S., Rodkhum, C. & Dong, H. T. (2021). Pre-treatment of Nile tilapia (Oreochromis niloticus) with ozone nanobubbles improve efficacy of heat-killed Streptococcus agalactiae immersion vaccine. *BioRxiv*, 2021.12.13.472363. https://doi.org/10.1101/2021.12.13.472363

Ljunggren, S. & Eriksson, J. C. (1997). The lifetime of a colloid-sized gas bubble in water and the cause of the hydrophobic attraction. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *129–130*, 151–155. https://doi.org/10.1016/s0927-7757(97)00033-2

Mahasri, G., Saskia, A., Apandi, P. S., Dewi, N. N., Rozi & Usuman, N. M. (2018). Development of an aquaculture system using nanobubble technology for the optimation of dissolved oxygen in culture media for nile tilapia (*Oreochromis niloticus)*. *IOP Conference Series: Earth and Environmental Science*, *137*, 12046. https://doi.org/10.1088/1755-1315/137/1/012046

Mallya, Y. J. J. (2007). *The Effect of Dissolved Oxygen on Fish Growth in Aquaculture*. UNU-Fisheries Training Programme.

Marui, T. (2013). An Introduction to Micro / Nano-Bubbles and their Applications. *Systemics, Cybernetics and Informatics*, *11*, 3–7.

Mauladani, S., Rahmawati, A. I., Absirin, M. F., Saputra, R. N., Pratama, A. F., Hidayatullah, A., Dwiarto, A., Syarif, A., Junaedi, H., Cahyadi, D., Saputra, H. K. H., Prabowo, W. T., Kartamiharja, U. K. A., Noviyanto, A. & Rochman, N. T. (2020). Economic feasibility study of Litopenaeus vannamei shrimp farming: nanobubble investment in increasing harvest productivity. *Jurnal Akuakultur Indonesia*, *19*, 30–38. https://doi.org/10.19027/jai.19.1.30-38

Mead, L. E., Sutherl, G. R. & Verrall, E. R. (1976). The effect of ultrasound on water in the presence of dissolved gases. *Canadian Journal of Chemistry*, *54*, 1114–1120. https://doi.org/10.1139/v76-159

Meegoda, N. J., Hewage, A. S. & Batagoda, H. J. (2018). Stability of nanobubbles. *Environmental Engineering Science*, *35*, 1216–1227. https://doi.org/10.1089/ees.2018.0203

Michailidi, E. D., Bomis, G., Varoutoglou, A., Kyzas, G. Z., Mitrikas, G., Mitropoulos, A. C., Efthimiadou, E. K. & Favvas, E. P. (2020). Bulk nanobubbles: Production and investigation of their formation/stability mechanism. *Journal of Colloid and Interface Science*, *564*, 371–380. https://doi.org/10.1016/j.jcis.2019.12.093

Minamikawa, K., Takahashi, M., Makino, T., Tago, K. & Hayatsu, M. (2015). Irrigation with oxygen-nanobubble water can reduce methane emission and arsenic dissolution in a flooded rice paddy. *Environmental Research Letters*, *10*, 84012–84012. https://doi.org/10.1088/1748-9326/10/8/084012

Minible, M. (2020). MiniBle Q Standard - Smallest but The Most Powerful Microbubble Aerator, *News* (pp. 2020–2020). https://miniblemalaysia.com/minible-q-standard-en/

Muthupandian, A. (2016). Encyclopedia of Color Science and Technology. *Handbook of Ultrasonics and Sonochemistry*, 69–98. https://doi.org/10.1007/978-981-287-278-4_74

Muzaddadi, A. U., Ahmad, T., Monika, M. & Nanda, S. K. (2017). Live table fish transportation - a means of innovative value addition in the fish retail markets of Ludhiana, Punjab. *Indian Journal of Fisheries*, *64*, 249–253. https://doi.org/10.21077/ijf.2017.64.special-issue.76296-39

Phan, K. K. T., Truong, T., Wang, Y. & Bhandari, B. (2020). Nanobubbles: Fundamental characteristics and applications in food processing. *Trends in Food Science and Technology*, *95*, 118–130. https://doi.org/10.1016/j.tifs.2019.11.019

Rahmawati, A. I., Saputra, R. N., Hidayatullah, A., Dwiarto, A., Junaedi, H., Cahyadi, D., Saputra, H. K. H., Prabowo, W. T., Kartamiharja, U. K. A., Shafira, H., Noviyanto, A. & Rochman, N. T. (2020). Enhancement of Penaeus vannamei shrimp growth using nanobubble in indoor raceway pond. *Aquaculture and Fisheries*. https://doi.org/10.1016/j.aaf.2020.03.005

Rognerud, M. E., Solemslie, B. W., Islam, H. & Pollet, B. G. (2020). How to Avoid Total Dissolved Gas Supersaturation in Water from Hydropower Plants by Employing Ultrasound. *Journal of Physics: Conference Series*, *1608*, 12004. https://doi.org/10.1088/1742-6596/1608/1/012004

Samuel, L. & Power, J. (2020). *MicroNano bubbles for water treatment*. http://www.rotorualakes.co.nz/vdb/document/1640

Sarkar, B., Mahanty, A., Gupta, S. K., Choudhury, A. R., Daware, A. & Bhattacharjee, S. (2022). Nanotechnology: A next-generation tool for sustainable aquaculture. *Aquaculture*, *546*, 737330–737330. https://doi.org/10.1016/j.aquaculture.2021.737330

Sumpter & J., P. (1997). *Fish Stress and Health in Aquaculture - Kenneth A. Lockridge - Google Books*. 95–95. https://books.google.com.np/books?hl=en&lr=\

Suryadi, I. B. B., Rostini, I., Nariswari, S. & Yustiati, A. (2020). Effect of Stocking Density on Survival Rate and Growth of Tilapia (Oreochromis niloticus Linnaeus, 1758) in Round Container with Water Current Combined with Venturi Aeration System. *Asian Journal of Fisheries and Aquatic Research*, *145*, 52–61. https://doi.org/10.9734/ajfar/2020/v8i130132

Temesgen, T., Bui, T. T., Han, M., Kim, T. I. & Park, H. (2017). Micro and nanobubble technologies as a new horizon for water-treatment techniques: A review. *Adv Colloid Interface Sci*, *246*, 40–51. https://doi.org/10.1016/j.cis.2017.06.011

Thongdon, R., Thonglek, V. & Yoshikawa, K. (2019). Effects of Oxygen Micro Bubble Water on the Recovery Process of Tilapia Fry Transportation at High Stocking Density and Long Distance. *International Journal of Plasma Enironmental Science*, *12*.

Uchida, T., Yoshioka, M. & Horiuchi, R. (2018). Effect of dissolved oxygen level of water on ultrasonic power measured using calorimetry. *Japanese Journal of Applied Physics*, *57*. https://doi.org/10.7567/jjap.57.07lc04

Xiaotong, M., Li, M., Pfeiffer, P., Eisener, J., Ohl, C. D. & Sun, C. (2022). Ion adsorption stabilizes bulk nanobubbles. *Journal of Colloid and Interface Science*, *606*, 1380–1394. https://doi.org/10.1016/j.jcis.2021.08.101

Zhang, Y., Wang, W., Yan, L., Glamuzina, B. & Zhang, X. (2019). Development and evaluation of an intelligent traceability system for waterless live fish transportation. *Food Control*, *95*, 283–297. https://doi.org/10.1016/j.foodcont.2018.08.018

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ECONOMIC AND TECHNOLOGICAL ASPECTS OF HYDROPONIC SYSTEMS IN MUSHROOM CULTIVATION TOWARDS PRECISION AGRICULTURE

Sachin Khaniya[1] and Bidur P. Chaulagain*[2]
[1]Himalayan College of Agricultural Sciences and Technology,
Kirtipur, Kathmandu, Nepal
[2]Science Business Research and Innovation Center (SciBRIC), HICAST
***Corresponding author's email:** bidur@hicast.edu.np

ABSTRACT

In this review, we provide an exhaustive economic and environmental analysis of hydroponic and arenumponic systems within the domain of mushroom cultivation, contrasting these modern methodologies with the traditional substrate-based approaches. Our focus is centered on widely cultivated mushrooms such as Oyster, Button, Shiitake, and Morels. We delve into the inherent challenges posed by conventional cultivation methods, such as variable substrate quality, heightened risks of contamination, and the complexities of environmental control. The study presents hydroponics and arenumponics as innovative, substrate-less cultivation strategies that resolve these issues by employing controlled water solutions and sand as a growth medium, respectively. This review examines a spectrum of hydroponic configurations, including deep flow, nutrient film, and aeroponic systems, demonstrating their effectiveness and potential in mushroom farming. We emphasize the economic feasibility and environmental sustainability of these techniques, considering their cost-effectiveness, resource utilization efficiency, and market prospects. Key objectives encompass a thorough review of hydroponic technologies, an evaluation of growth performance vis-à-vis traditional methods, and an assessment of their economic impact. Our research bridges current knowledge gaps by suggesting the integration of recommended economic models, such as Stochastic Frontier Analysis for measuring efficiency, and Cost-Benefit Analysis for assessing financial viability. The inclusion of case studies enriches our insights into the economic and environmental facets of hydroponic/arenumponic mushroom cultivation. We conclude with policy recommendations and directions for future research, advocating for the adoption of hydroponics/arenumponics as sustainable, efficient, and commercially viable alternatives to conventional practices in mushroom agriculture, thereby aligning with the objectives of modern agricultural sustainability.

Keywords: Hydroponic Mushroom Farming, Arenumponic Cultivation Technique, Soilless Mushroom Production, Economic Viability, Precision Agriculture.

INTRODUCTION

Mushrooms, known for their low-fat content, high protein, metabolites, antioxidants, and fiber, offer a range of health benefits, including boosting immunity, enhancing cognitive health, and regulating blood lipids and glucose levels. As a critical sector in the global agro-industry, mushroom cultivation generates over US $34 billion annually. Common varieties like Oyster (*Pleurotus spp*.), Button (*Agaricus spp*.), Shiitake (*Lentinula edodes*), and Morels (*Morchella spp*.) have traditionally been grown on substrates like straw, composts, and wood logs. However, traditional methods face challenges such as low yields, nutrient deficiencies, and contamination risks, exacerbated by land fragmentation and urbanization.

This paper explores hydroponics and suggests a novel approach called arenumponics as a potential solution to these challenges. Hydroponics, a soilless, substrate-less cultivation technique using nutrient-rich water solutions, offers precise nutrient and moisture control, potentially increasing efficiency, and yield. However, traditional hydroponics still requires some form of organic substrate for mushroom mycelium, which acts as a binding and support medium. To address this, we propose arenumponics, where sand replaces organic substrates, providing both support and an inert medium for nutrient delivery for future research and studies.

Our study aims to fill several gaps in current research. Firstly, we will detail specific challenges and limitations of hydroponics in mushroom cultivation, providing a clearer understanding of why these methods are necessary. We will also place our research within the historical context of mushroom cultivation, tracing its evolution and highlighting how hydroponics emerged as innovative alternatives. Additionally, we will compare this method with other emerging cultivation techniques, offering a comprehensive view of the field's advancements.

The article analyzes hydroponic methods in mushroom farming, comparing them to traditional techniques and also focuses on their environmental and economic

benefits, particularly regarding sustainability, resource efficiency, and cost-effectiveness. The scope includes a thorough review of hydroponic designs, growth performance comparison, and economic viability suggesting the use of models like Stochastic Frontier Analysis and Cost-Benefit Analysis for further research. The study sets out hypotheses aiming to prove that these soilless or inert substrate methods can enhance productivity and offer a viable commercial alternative to conventional cultivation, to contribute to sustainable agricultural practices.

Objectives

Overview of Hydroponic Techniques: Provide a detailed overview of various hydroponic methods, such as deep flow, nutrient film technique, and aeroponics, emphasizing their operational aspects and suitability for cultivating mushrooms like Oyster, Button, Shiitake, and Morels.
Comparative Growth Analysis: Analyze and compare the growth performance between hydroponic (including arenumponics) and traditional substrate-based cultivation methods. This will include assessments of mycelial colonization rate and yield, demonstrating enhanced performance in hydroponic systems.
Advantages of Hydroponics: Discuss the potential benefits of hydroponic systems over conventional cultivation. The article will emphasize improvements in mushroom quality and productivity due to precise control over nutrients and environmental conditions.
Environmental and Economic Impact Assessment: Evaluate the environmental sustainability and economic viability of hydroponic methods based on existing literature.
Empirical Methodology: Suggest implementation of econometric models for financial viability, providing insights into the economic aspects of hydroponic mushroom cultivation.

These objectives will be addressed comprehensively, contributing to a better understanding of the potential of hydroponic methods in enhancing the efficiency and sustainability of mushroom production.

1. MUSHROOM BIOLOGY

In exploring hydroponic and arenumponic methods for mushroom cultivation, it's crucial to understand the mushroom life cycle, comprising the vegetative mycelial and the reproductive fruiting body phases. Mycelial growth depends on key macronutrients such as Carbon (C), Nitrogen (N), Phosphorus (P), Potassium (K),

and Magnesium (Mg), alongside vital micronutrients like Iron (Fe) and Zinc (Zn) (Carrasco et al., 2018). These nutritional needs and environmental factors such as the carbon-to-nitrogen ratio, temperature, pH, and aeration are pivotal in hydroponic systems (Wu et al., 2004; Jayasinghe et al., 2008). This understanding is essential to our research objectives, guiding the optimization of hydroponics and arenumponics for enhanced mushroom growth and yield.

2. CONVENTIONAL CULTIVATION METHODS

Conventional mushroom farming predominantly utilizes organic substrates like rice bran, wheat straw, various cotton wastes, and animal manures, essential for both vegetative and mycelia growth (Fasidi et al., 2016). This traditional method encompasses several steps: substrate preparation, spawn inoculation, and maintaining fruiting room conditions. The entire process, from substrate preparation to harvesting, spans 10 days to 6 months post-spawning (Chang, 2001).

The preparation of substrates involves a meticulous process. Initially, substrates are mixed, hydrated, pasteurized, sterilized, and conditioned. Composting, a critical phase in substrate preparation, typically occurs in two stages. The first phase primarily focuses on reducing the carbon-to-nitrogen (C:N) ratio, while the second phase involves pasteurization, crucial for eliminating competitive microorganisms and maintaining the moisture content of the substrate at approximately 70% (Lim et al., 2013).

Spawn, a vital component in mushroom cultivation, is prepared by inoculating sterilized grains, such as millet or wheat, with mycelium cultures. This spawn provides the necessary nutrition for the mycelium to colonize the substrate. The addition of spawn, typically ranging from 0.5% to 5% of the substrate's weight, is known to enhance yields (Buendia et al., 2016). The inoculated substrate is then placed in growth environments, such as beds, racks, or trays, where controlled conditions are maintained. Ideal temperatures for mycelium colonization range from 22–28°C, with relative humidity kept between 80-90%, ensuring adequate moisture for growth (Flegg, 1979).

Adequate air exchange within the growing environment is essential to remove accumulated CO2, thus providing sufficient oxygen for optimal mushroom growth. Under these conditions, mushrooms typically reach a harvestable size within 10-15 days (González-Fandos et al., 2008, Cheng et al., 2013).

However, recent literature indicates gaps in traditional cultivation methods, particularly regarding the efficient use of resources and environmental sustainability. Innovations in substrate optimization and the development of less resource-intensive cultivation practices are areas needing further exploration.

3. CHALLENGES IN CONVENTIONAL MUSHROOM FARMING

3.1. Substrate Quality Issues: Traditional cultivation often relies on agricultural residues and waste as substrates, which can vary in quality. Poor-quality substrates may lead to nutrient deficiencies, adversely affecting mushroom yields along with contamination risks (Ferdousi et al.)

3.2. Contamination Risks: The process of sterilization is crucial in conventional methods. Such contamination can lead to outbreaks of fungal, viral, and microbial diseases, affecting mushroom growth and development (Ferdousi et al., 2019; Easin et al., 2017).

3.3. Toxicity: In cultivated mushrooms, significant levels of heavy metals were found, with the highest concentrations being: Pb in *Agaricus bitorquis* and *Hypholoma fasciculare*, Cd in *Hydnum repandum*, Fe in *Bovista plumbea*, Cu in *Tricholoma terreum*, Mn in *Laccaria laccata*, and Zn in *Agaricus bitorquis* (Tüzen et al., 1998;Yamaç et al., 2007). Additionally, hydroponics allows precise control of nutrient ratios ensuring safe mushroom cultivation (Asaduzzaman et al., 2022).

3.4. Insufficient Environmental Control: Conventional cultivation often lacks the infrastructure for precise environmental control. These inadequacies like temperature, light quality and periods, humidity, and O_2/CO_2 ratio, essential for optimal mushroom development affect critical growth parameters (Rahman, 2018; Ferdousi et al., 2019, Ferdousi et al., 2019).

3.5. Resource Inefficiency: Post-harvest, a significant portion of the nutrients in the substrate remain unutilized, leading to waste (Grimm et al., 2018). Small-scale farmers, particularly those with limited capital, often cannot fully utilize available resources, including land and infrastructure. Moreover, the reuse of spent compost can carry the risk of disease transmission between crops (Gurung et al., 2020).

4. HYDROPONIC SYSTEMS FOR MUSHROOM CULTIVATION

4.1 Deep Flow Technique (DFT): DFT supports mushrooms on floating rafts in an aerated nutrient solution. This technique has been shown to enhance mycelial colonization by about 25% and increase yields by up to 123% compared to soil-based cultivation, particularly with oyster mushrooms, marking a significant advancement over conventional methods (Gume et al., 2013).

4.2 Nutrient Film Technique (NFT): In NFT, a thin layer of nutrient solution continuously flows over the roots in a slightly inclined channel. This system has proven effective in boosting the total biomass of mushrooms, producing around 427g total weight, with 309g being edible, thus offering a substantial improvement over traditional cultivation practice (Re et al., 2021).

4.3 Aeroponics: Aeroponics involves spraying a fine mist of nutrient-rich water directly onto the suspended mushroom roots. This method promotes optimal growth and development by speeding up mycelial colonization and shortening the cultivation cycle. It also enhances the oxygenation of roots, improving nutrient absorption and overall mushroom health, making it a valuable technique in modern mushroom farming (Narasegowda et al., 2020; Grace 2023).

Additionally, innovative approaches like floating rafts and nutrient-channeled plastic bottle systems have yielded promising results, particularly for oyster mushrooms (Goh et al., 2016).

5. NUTRIENT SOLUTIONS IN HYDROPONIC MUSHROOM CULTIVATION

5.1. Macronutrients: Key carbon sources such as sucrose, glucose, and dextrose are used at optimal concentrations, alongside organic nutrients like yeast extract and peptone. Nitrogen, a crucial macronutrient, is often supplied in the range of 0.1-0.5% using urea, ammonium salts, or other nitrogenous extracts in submerged cultures (Mccoy et al., 1972). The ideal ratio of carbon to nitrogen is critical; for instance, a composition of 3% glucose, 0.072% KNO3, and 0.02% NaH2PO4, maintaining a pH of around 8.5, is found to be effective for mushroom growth (Chang-hong 2008).

5.2. Micronutrients: While required in smaller quantities, micronutrients such as potassium, calcium, magnesium, sulfur, iron, zinc, manganese, and copper play significant roles in the growth and quality of mushrooms (Jung et al., 2010). Calcium supplementation is crucial for maintaining the pH balance and cation exchange in the substrate. Studies have also highlighted the importance of freshly prepared compost, rich in zinc, sulfur, and iron, for the effective growth and yield of mushrooms, indicating the need for balanced micronutrient levels in hydroponic solutions (Sinha et al., 2020). Considering these requirements, it becomes clear that tailoring nutrient solutions to the specific needs of different mushroom varieties is key to successful hydroponic cultivation.

Comparison of Nutrient Solutions

Hydroponic nutrient solutions are formulated to optimize levels of key nutrients like carbon, nitrogen, and phosphorus, along with essential micronutrients, ensuring balanced nutrition for the mycelial growth and fruiting stages of mushrooms (Mccoy et al., 1972; Chang-hong 2008, Sinha et al., 2020,Jung et al., 2010).

6. HYDROPONICALLY TESTED MUSHROOM SPECIES

6.1. Oyster Mushroom (*Pleurotus ostreatus*): Renowned for its rapid growth and high nutritional value, the oyster mushroom has been extensively tested in hydroponic systems like DFT, NFT, and aeroponics. Notably, Nozzi et al. (2018) highlighted the suitability of oyster mushrooms for hydroponic cultivation.

6.2. Shiitake (*Lentinula edodes*) and Reishi (*Ganoderma lucidum*) cultivation: The Shiitake mushroom, another popular variety, has been successfully grown using the NFT system. Sousa et al. (2019) found that while hydroponic cultivation facilitates faster growth and harvesting, resulting in higher yields, there might be concerns regarding nutrient balance affecting quality compared to traditional wood log cultivation. Habijanic et al. (2013) reported the successful cultivation of Reishi mycelium on polyurethane foam, which served as a medium for producing valuable polysaccharides.

7. GROWTH PERFORMANCE COMPARISON BETWEEN HYDROPONIC AND CONVENTIONAL CULTIVATION

7.1. Mycelial Growth Rate: The growth rate of oyster mushroom mycelium has been observed to be 25% higher in the Deep Flow Technique (DFT) compared to traditional soil-based methods (Wenjie Yang et al., 2013). In aeroponic systems, mycelial proliferation saw an 11% increase over manual spraying methods, attributed to improved moisture and dissolved oxygen levels (Sharma et al., 2018).

7.2. Primordia Formation Time: In hydroponic systems using floating rafts, oyster mushroom primordia initiation occurred 2 days earlier compared to ground-based cultivation (Nadir et al., 2016). Shiitake mushrooms also showed a 3-5 day faster primordia development in Nutrient Film Technique (NFT) systems than in traditional soil cultivation (Ohta et al., 1994).

7.3. Fruiting Body Development Duration: The time from pinhead formation to harvest in oyster mushrooms was reduced by 4 days in aeroponic systems compared to manual mist spraying, due to better-controlled moisture (Ray et al., 2013).

8. YIELD

NFT System: Yielded total biomass of 427g, averaging 47.4g per trial, and 309g of edible biomass, averaging 34.3g per trial, demonstrating significant productivity (Re et al., 2021).

Ebb and Flow (E/F) System: Produced a total biomass yield of 424g, averaging 47.1g per trial, and 287g of edible biomass, averaging 31.9g per trial, slightly less than the NFT system.

Commercial Off-The-Shelf (COTS) Kit: Offered lower yields with 365g total mushroom biomass, averaging 40.6g per trial, and 262g of edible mushrooms, averaging 29.1g per trial. The NFT system showed numerically higher total and edible biomass yields compared to the E/F system, and both hydroponic methods outperformed the non-hydroponic COTS kit in terms of mushroom productivity.

9. ADVANTAGES OF HYDROPONICS IN MUSHROOM FARMING

9.1. Optimal Nutrition: Hydroponic systems offer precise control over nutrient levels, enabling customization to meet the specific nutritional needs of mushrooms, leading to improved yields and product quality (Nozzi, V. et al. 2018). This precision helps prevent the nutrient deficiencies often seen in soil-based cultivation, and mushrooms grown hydroponically benefit from a higher bioavailability of essential nutrients (Rashid et al., 2021; Upadhyay et al., 2019).

9.2. Controlled Microclimate: Hydroponics allows for complete control over environmental conditions such as temperature, light, and humidity, optimizing them for enhanced mushroom growth (Pandey et al., 2014). This control also facilitates year-round production, unaffected by external weather changes (Rashid et al., 2021; Upadhyay et al., 2019).

9.3. Reduced Contamination Risk: Hydroponic cultivation significantly reduces the risk of soil-borne diseases, common in traditional farming, and lowers contamination risks from pests and pathogens (Kumar, R. et al., nd; Rashid et al., 2021). Integrated pest management practices are more straightforward to implement in a controlled hydroponic environment (Pandey et al., 2014).

9.4. Increased Productivity: Mushrooms grown in hydroponic systems exhibit faster growth rates due to optimal and stable growing conditions, leading to higher yields per unit area compared to traditional soil-based methods (Rashid et al., 2021; Kumar, R. et al., nd). The ability to maintain continuous production cycles throughout the year further enhances productivity (Upadhyay et al., 2019).

9.5 Reduced Labor Requirements: Hydroponics simplifies cultivation by eliminating labor-intensive soil preparation tasks. Automation of irrigation and lighting reduces labor needs, and the standardized setup facilitates easier harvesting (Rashid et al., 2021; Pandey et al., 2014; Kumar, R. et al., nd).

9.6. **Free from Heavy metals and Toxicity:** The wild edible mushrooms and mushrooms cultivated in conventional substrates system has risks of heavy metals like lead, cadmium, molybdenum, arsenic and mercury. (Mccoy et al., 1972; Chang-hong 2008, Habijanic et al. (2013). The hydroponic and arenumponic system can lower the risks or can be eliminated because of precise and careful choice of inorganic salts and organic nutrients without those toxic metals.

10. CHALLENGES IN HYDROPONIC MUSHROOM FARMING

10.1. Technical Challenges

Moisture Management: Proper moisture level management is crucial to prevent mushroom sogginess, a common issue in hydroponic systems (Re, 2021).

Optimal Conditions for Fruiting: Providing the ideal moisture, nutrient, and gas exchange conditions required for the development of the fruiting body is challenging (Bechara et al., 2006).

Yield Consistency: There is a lack of long-term yield data over multiple harvest cycles, which is necessary to establish the reliability of hydroponic methods (Re, 2021).

Contamination Risks: Inadequate control over moisture and environmental factors can increase the risk of microbial contamination, affecting mushroom growth (Bechara et al., 2006; Re, 2021).

10.2. Economic Analysis:

Return on Investment (ROI): A comprehensive economic analysis, including ROI across the commercial viability of hydroponic mushroom cultivation, is needed (Gurung et al., 2020; Nozzi et al., 2018). Studies should include the cost-benefit analysis of various hydroponic techniques, tailoring nutrient solutions to specific mushroom species, and developing scalable, user-friendly hydroponic system designs.

10.3. Lack of Familiarity and Adoption Challenges:

Grower Exposure: Mushroom growers are often unfamiliar with hydroponic systems and their operation compared to traditional methods (Zhu et al., 2021, Re, 2021; Bechara et al., 2006).

11. PROOF OF CONCEPT

Hydroponic and arenumponic mushroom cultivation system was established at the Science Business Research and Innovation Center (SciBRIC) at HICAST.

11.1. Selection of Mushroom Species: The project involved cultivating various mushroom species, such as oyster mushroom (*Pleurotus ostreatus*), king oyster mushroom (*Pleurotus eryngii*), and Padke chyau (*Schleroderma* spp.). The Padke chyau was collected from the wild at Dandagaun, Patlekhet, Kavrepalnchowk District, Nepal. Padke chyu is edible mushroom popular among Tamang Ethic community in the subtropics and Tharu community of the tropics of Nepal.

11.2 Adaptation of Hydroponic System: Originally designed for plant hydroponics, the system was modified for mushroom cultivation. This involved adding an air diffuser with the help of aquarium air pump to the nutrient water circulation system.

11.3 Nutrient Solutions: A specific nutrient composition was used in the hydroponic system. This included various chemicals and nutrients such as Sucrose, Potassium Phosphate, Ammonium Phosphate, Potassium Nitrate, MgSO4, CaCl2 (substituted with CaCO3 Lime), MnSO4, ZnSO4, FeSO4, NaMoO4, and Thiamine. These nutrients were essential for the growth of mushrooms in a hydroponic setup.

12. ARENUMPONIC SYSTEM DEVELOPMENT AT SCIBRIC LAB

Besides hydroponics, an arenumponic system using sterilized sand as an inert substrate was also developed. This method, known as arenumponic, facilitated uniform moisture distribution, crucial for the mycelium's growth and spread.

13. GROWTH PERFORMANCE IN MUSHROOM HYDROPONICS AND ARENUMPONICS

We cultured and got mycelium growth of oyster and king oyster mushrooms in both hydroponic and arenumponic system. The mycelium growth was better than the traditional methods of cultivation in rice straw for both types of oysters. There is fruiting body formation in one net cup. Because of closures of lab for some reasons the experiment was halted and could not run satisfactorily and the trials are going on. The different figures (1-4) of the photographs show the hydroponic and arenumponic system setup, the growth of mycelium and fruiting stage of oyster and king mushrooms.

Photograph plate-1. Figure-1&2. Hydroponic and arenumponic system setup. Figure-3. Mycelium growth of king oyster in the hydroponic system. Figure-4. Oyster mushroom fruiting.

14. FUTURE PERSPECTIVE ON HYDROPONIC AND ARENUMPONIC MUSHROOM FARMING

14.1. Testing and Refinement of Hydroponic Systems: The exploration of alternative systems such as the Deep Flow Technique should be continued to improve moisture regulation and the quality of mushrooms (Re, 2021). This includes conducting microbiological safety tests over multiple harvests to ensure consistent quality and safety (Re, 2021).

14.2. Economic Analysis and Optimization: Determining the economic viability of hydroponic mushroom cultivation is crucial. This involves optimizing technologies and automation processes to enhance efficiency and reduce costs

(Bechara et al., 2006; Gurung et al., 2020). This research will help quantify the benefits of hydroponic methods over traditional farming (Nozzi et al., 2018).

14.3. Optimization of Hydroponic Formulations: Tailoring nutrient solutions and environmental conditions in hydroponic systems to maximize yields is another important area of research (Bechara et al., 2006). This includes fine-tuning nutrient formulations to meet the specific needs of different mushroom species.

15. ECONOMIC ASPECTS

Gilmour et al. (2019) examined consumer responses and found that while hydroponically grown products didn't garner a price premium, consumer preferences were significantly influenced by the information provided about hydroponic practices. Kholis et al. (2022) discovered that hydroponic ventures, especially small-scale home industries, are quite profitable. The concept of Open Field Hydroponics, despite being traced back to the early '90s, has only begun gaining substantial attention in scientific discourse since the 2000s, as evidenced by the work of Rubio-Asensio et al. (2020, Malik et al. 2018).

In assessing the economic aspects of hydroponic systems in mushroom cultivation, employing robust econometric methods is crucial to quantitatively analyze their financial viability and efficiency. One such approach is the Cost-Benefit Analysis (CBA), which can be used to compare the total costs (including setup, operation, and maintenance) against the benefits (such as increased yield, quality, and market price of mushrooms). Additionally, models like the Cobb-Douglas production function could be applied to understand the relationship between inputs (such as nutrients, water, and labor) and output (mushroom yield), which aids in optimizing resource allocation for maximum economic return. Implementing these econometric analyses will not only offer insights into the economic efficiency of these methods compared to traditional farming but also guide future investments and policy decisions in sustainable mushroom agriculture.

16. EMPIRICAL METHODS

For analyzing the economic aspects of hydroponic systems in mushroom cultivation, an appropriate econometric model should address the specificities of cost structures, revenue streams, and productivity factors associated with this type of agriculture. A suitable model for this context would be the Stochastic Frontier Analysis (SFA). By using Stochastic Frontier Analysis, stakeholders in the hydroponic mushroom industry can gain valuable insights into the efficiency of

their operations, identify areas for improvement, and make data-driven decisions to enhance profitability and sustainability.

17. CONSUMER AWARENESS AND PREFERENCES

Despite these benefits, hydroponic mushroom farming faces challenges such as the need for detailed moisture management and the development of economically viable systems (Re, 2021; Bechara et al., 2006). Furthermore, the unfamiliarity of mushroom growers with hydroponic systems indicates a need for more extensive research and training (Zhu et al., 2021, (Gurung et al., 2020; Rubio-Asensio et al., 2020). By employing econometric models such as Cost-Benefit Analysis (CBA) and the Cobb-Douglas production function, researchers can effectively analyze and optimize the financial viability and efficiency of these systems (Malik et al., 2018; Gilmour et al., 2019). Studies like those by Gilmour et al. (2019) and Kholis et al. (2022) have shown that while hydroponic products may not command a premium price, consumer preferences are highly influenced by information about hydroponic cultivation.

18. CONCLUSION

In conclusion, the study highlights that hydroponic and arenumponic systems in mushroom cultivation provide promising alternatives to traditional farming, addressing issues like inconsistent substrate quality and contamination risks (Ferdousi et al., 2019; Easin et al., 2017). These advanced methods offer precise nutrient control, improved microclimate management, and increased productivity (Gume et al., 2013; Re et al., 2021; Nozzi et al., 2018; Rashid et al., 2021; Kumar et al., nd). However, realizing their full potential in the agricultural sector requires further research into scaling, commercialization, technological innovation, and economic feasibility, including market analysis and regulatory considerations.

REFERENCES

Asaduzzaman, M., Niu, G. and Asao, T., (2022). Nutrients Recycling in Hydroponics: Opportunities and Challenges Toward Sustainable Crop Production Under Controlled Environment Agriculture. *Frontiers in Plant Science*, *13*, p.845472.

Bechara, M.A., et al., (2006). Agaricus bisporus mushroom cultivation in hydroponic systems. *Transactions of the ASABE*, 49(3), pp.825–832.

Buendía, M., Giménez, A., & Valero, J., (2016). Agronomic quantitative assessment of substrates based on spents of Agaricus bisporus and Pleurotus ostreatus. *Acta Agriculturae Slovenica*, 107, pp. 355-371.

Carrasco, J. et al., (2018). Supplementation in Mushroom Crops and its impact on yield and quality, AMB Express.

Chang, S., (2001). Mushrooms and Mushroom Cultivation.Wiley Online Library. https://doi.org/10.1038/npg.els.0000370

Cheng, C., Au, C., Wilke, S., Stajich, J., Zolan, M., Pukkila, P., & Kwan, H., (2013). 5'-Serial Analysis of Gene Expression studies reveal a transcriptomic switch during fruiting body development in Coprinopsis cinerea. *BMC Genomics*, 14, pp. 195 - 195.

Easin, M. A., Hossain, M. I., Saha, S. R., & Roy, S. K. (2017). Techno-economic analysis on mushroom cultivation in Bangladesh. *Bangladesh Journal of Mushroom*, 1(1), 28-36.

Ferdousi, J., Al Riyadh, Z., Hossain, M. I., Saha, S. R., & Zakaria, M. (2019). Mushroom production benefits, status, challenges and opportunities in Bangladesh: A review. *Annual Research & Review in Biology*, 34(6), 1-13.

Flegg, P., (1979). Effects of competition on the development of mycelium, mycelial aggregates and sporophores of Agaricus bisporus. *Scientia Horticulturae*, 11, pp. 141-149.

Gilmour, D.N., Bazzani, C., Nayga Jr, R.M. and Snell, H.A., (2019). Do consumers value hydroponics? Implications for organic certification. *Agricultural Economics*, 50(6), pp.707-721.

González-Fandos, E., Jiménez, A., & Pardo, V., (2008). Quality and shelf life of packaged fresh sliced mushrooms stored at two different temperatures. *Agricultural and Food Science*, 15, pp. 414-422.

Grimm, D., & Wösten, H., (2018). Mushroom cultivation in the circular economy. *Applied Microbiology and Biotechnology*, 102, pp. 7795 - 7803.

Gume, B., Muleta, D., & Abate, D., (2013). Evaluation of locally available substrates for cultivation of oyster mushroom (Pleurotus ostreatus) in Jimma, Ethiopia. African Journal of Microbiology Research, 7, pp. 2228-2237.

Gurung, N., Ray, R. N., & Biswas, R. K. (2020). Aflatoxin contamination in edible mushrooms: Contributing factors, prevention, and future research perspective. Food Control, 114, 107257.

Jayasinghe, C., Imtiaj, A., Hur, H., Lee, G., Lee, T., & Lee, U., (2008). Favorable Culture Conditions for Mycelial Growth of Korean Wild Strains in Ganoderma lucidum. Mycobiology, 36, pp. 28 - 33.

Jung, J., Hong, S., Rinker, D., Choi, M., Lee, B., & Yang, J., (2010). Effects of nutrient composition on yield and quality of mushroom in Lentinula edodes cultivation using softwood sawdust. Journal of Korean wood science and technology, 38, pp. 124-134.

Malik, A.M., Mughal, K.M., Khan, M.A. and Masood, A., (2018). Impact of hydroponics technology in Pakistan's fruits and vegetable sector and global trade: A CGE analysis. FWU Journal of Social Sciences, 12(1), pp.190-202.

McCoy, C., Hill, A., & Kanavel, R., (1972). A liquid medium for the large-scale production of Hirsutella thompsonii in submerged culture. Journal of Invertebrate Pathology, 19, pp. 370-374.

Narasegowda, T., & Kumar, N., (2020). Characteristics of a nozzle spray in relation to its application to aeroponics.

Re, A.M., (2021). The Construction and Development of an NFT System for Mushroom Cultivation in Space: Decreasing Voids in Literature and Demonstrating Technology. Unpublished undergraduate thesis. Virginia Polytechnic Institute and State University.

Sharma, U., Barupal, M., Shekhawat, N., & Kataria, V., 2018. Aeroponics for propagation of horticultural plants: an approach for vertical farming. Horticulture International Journal.

Sheikh, B.A., (2006). Hydroponics: Key to sustain agriculture in water stressed

and urban environment. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, *22*(2), pp.53-57.

Sousa, M., Costa, L., Pereira, T., Zied, D., Rinker, D., & Dias, E., (2019). Enzyme activity and biochemical changes during production of Lentinula edodes (Berk.) Pegler. Food Science and Technology.

Tüzen, M., Özdemir, M. and Demirbaş, A., (1998). Study of heavy metals in some cultivated and uncultivated mushrooms of Turkish origin. *Food Chemistry*, *63*(2), pp.247-251.

Yamaç, M., Yıldız, D., Sarıkürkcü, C., Celikkollu, M. and Solak, M.H., (2007). Heavy metals in some edible mushrooms from the Central Anatolia, Turkey, *Food Chemistry*, *103*(2), pp.263-267.

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