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GENETIC VARIABILITY AND CORRELATION STUDIES FOR SEED COTTON YIELD AND FIBRE QUALITY PARAMETERS IN DIVERSE COTTON GENOTYPES

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ABSTRACT

An experiment was executed at RARS, Lam, Guntur during the *kharif*, 2024 to determine variability and correlation studies across 50 cotton genotypes, including three check varieties (NDLH 2051-1, Sivanandhi, and CICR 23 Bt) for 14 traits in an Augmented Block Design. ANOVA revealed significant differences among the 53 cotton genotypes for all the 14 traits, indicating substantial variability within the experimental material, that could be used for further crop improvement. Genotypic coefficient of variation and phenotypic coefficient of variation were high for number of monopodia per plant, boll weight and seed cotton yield per plant. High heritability coupled with high genetic advance was observed for plant height, number of monopodia per plant, number of bolls per plant, boll weight, lint index, seed index and seed cotton yield per plant rendering the probability of selecting genotypes for these characters which would behave with fidelity being the additive gene action in the inheritance of these attributes. Correlation study demonstrated a significant positive relationship between seed cotton yield per plant and plant height, number of bolls per plant, boll weight, seed index and lint index, indicating direct selection could be preferable for improving the seed cotton yield per plant. The genotypes LHBT 2203, LHBT 9, L 2278 and L 2281 were identified as the best performers for lint index, seed index and seed cotton yield per plant; while Suvin, CCB 29, L 2275, L 2385 and L 2268 for fibre quality traits.

Keywords: Cotton, Correlation, GCV, Genetic Advance, Heritability and PCV

INTRODUCTION

Cotton (*Gossypium* spp.) belongs to the group of oldest domesticated species and it is cultivated as the main source of raw materials for the textile industries. It is a vital commercial cash crop in India, contributing about 20.67% of global cotton production (AICRP on Cotton, 2024-25). Cotton is mainly cultivated in tropical

as well as sub-tropical regions and is mainly grown for fibre and oil purpose. It is crucial for increasing the country's economy and is popularly known as "white gold" (Komala *et al.*, 2018). It is classified under the genus *Gossypium* and the family Malvaceae. India is the only country that cultivates all four cultivated species of cotton that include

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Gossypium arboreum L. and *Gossypium herbaceum* L. which are diploid species ($2n=26$) and are known as old world cotton. *Gossypium barbadense* L. and *Gossypium hirsutum* L. which are tetraploid species ($2n=52$) and are known as new world cotton.

India holds the position of the second largest cotton producer across the globe after China. India ranks as the largest cultivating nation in the world with 11.8 million hectare and produces 25.00 million bales (170 kg/bale) with productivity of 461 kg per hectare (AICRP on Cotton, 2024–25). During 2024-25, the Cotton production in India amounted to produce 299.26 lakh bales from 113.6 lakh hectares with a productivity of 448 kg lint/ha. In comparison of present year (2024-25) to last year (2023-24) the imports were estimated to increase from 15.20 lakh bales (64.47%) to 25.00 lakh bales in 2024-25. Whereas the exports were estimated to decrease from 28.36 (36.53%) to 18.00 lakh bales (AICRP on Cotton, 2024–25). Hence, it becomes crucial to develop high yielding cotton genotypes coupled with superior fibre quality to meet textile industry demands. Climate change further complicates cotton productivity. While many high-yielding cultivars exist, they often lack the desired fibre quality. Over the past decade, a decline in both yield and quality has been observed, largely attributed to a loss of genetic diversity in current cotton genotypes (Sahar *et al.*, 2021).

Genetic variability depends upon numerous morphological and agronomical attributes and their interaction with surrounding biotic influences and abiotic influences. The extent and nature of available genetic variation within germplasm offers significant potential for use in successful breeding programs. This could lead to improvements in various characteristics related to cotton yield alongside with fibre quality (Chapara *et al.*, 2022). To effectively select superior genotypes and

understand the relationships among yield components and fibre characteristics, it is important to know information on the kind and degree of genetic variation, heritability and genetic advance.

MATERIAL AND METHODS

The study was executed at Regional RARS, Lam, Guntur, Andhra Pradesh during *kharif*, 2024-25. The trial comprised of 50 cotton genotypes and three checks (NDLH 2051-1, Sivanandhi and CICR 23 Bt), that were planted in an Augmented Block Design in six blocks. In first five blocks, 12 entries (nine genotypes + three checks) and in the last block eight entries (five genotypes + three checks) were planted randomly in the blocks. Each entry was sown in two rows with a row length of 6.3 m each with a spacing of 105 x 60 cm.

Data was recorded from ten randomly selected plants on various seed cotton yield contributing attributes like days to fifty percent flowering (plot basis), plant height (cm), number of sympodia per plant, number of monopodia per plant, number of bolls per plant, boll weight (g), seed index (g), lint index (g), ginning out turn (%), seed cotton yield per plant (g) and for fibre traits like Upper Half Mean Length (UHML) (mm), uniformity index (%), micronaire ($\mu\text{g}/\text{inch}$) and tenacity (g/tex) data was recorded on plot basis.

The means of 14 traits were assigned to Analysis of Variance (ANOVA). The genotypic, phenotypic and environmental coefficients of variation (GCV, PCV and ECV) along with magnitude of heritability (h^2) and genetic advance. All the analysis were performed using the 'augmented RCBD' package from R Studio software version R.4.4.2. Correlation between character pairs were computed at $p < 0.05$ and $p < 0.01$ in Microsoft Excel using trait averages.

RESULTS AND DISCUSSION

ANOVA indicated notable differences among 50 cotton genotypes and three checks

for all the 14 attributes suggesting substantial genetic variability among the materials (Table 1). As per the mean performance, the genotypes specifically NDLH 3104-4, L 2281, L 2278, LHBT 2203, L 2396, L 2381 and L 2386 exhibited superior characteristics particularly for seed index, lint index, boll weight and seed cotton yield per plant and for fibre quality attributes like Upper Half Mean Length (UHML), tenacity, uniformity index and micronaire the genotypes Suvin, CCB 29, L 2275, L 2385, LHBT 2395, LHBT 26 and Lam Bt 2208 recorded high mean values. Hence, the above genotypes could be suggested for future breeding programs to enhance seed cotton yield and fibre quality traits.

Across all traits analyzed, PCV estimates spanned from 1.83 to 31.27%, while the GCV estimates ranged from 1.61 to 29.67%, demonstrating a close relationship between the two for every trait. The findings also indicated higher heritability (h^2), ranged from 77.63 to 98.79, combined with considerable genetic advance estimates, from 0.71 to 58.49, for all traits examined.

The maximum GCV was observed for the number of monopodia per plant (29.67%), followed by seed cotton yield per plant (23.38%) and boll weight (20.31%). A similar pattern was observed for PCV respectively (Table 2). The environmental coefficients of variation were relatively low compared to the GCV, suggesting minimal environmental impact on these traits. These findings imply substantial genetic variability for these parameters, indicating their suitability for direct selection in breeding programs aimed at enhancing cotton yield and quality. Comparable results have been earlier documented by Sahar *et al.*, (2021), Chapara *et al.*, (2022), Mawblei *et al.*, (2022), Subalakhshmi *et al.*, (2022), Keerthivarman *et al.*, (2023) and Harini *et al.*, (2025).

Plant height, number of sympodia per plant, number of bolls per plant, seed index

and lint index exhibited moderate GCV and PCV values. Rigorous selection could be used for the enhancement of these attributes. These results were in agreement with those of Chapara *et al.*, (2022), Mawblei *et al.*, (2022) and Harini *et al.*, (2025). Low estimates of GCV and PCV were recorded for days to fifty percent flowering, ginning outturn, upper half mean length, uniformity index, micronaire and tenacity, suggesting limited variation among the genotypes evaluated for these traits. Corresponding results were earlier noted by Chapara *et al.* (2022) and Harini *et al.* (2025) (Table 2).

The estimates of heritability, when considered along side genetic advance, offer valuable insights into the nature of gene action governing the expression of polygenic traits, particularly quantitative ones and serve as a dependable criterion for making selection decisions. In the present study, all traits exhibited high heritability values. Notably, high heritability coupled with high genetic advance as a percentage of the mean was observed for plant height, number of monopodia per plant, number of bolls per plant, boll weight, seed index, lint index and seed cotton yield per plant, indicating the predominance of additive gene effects. This suggests that direct phenotypic or simple selection would be effective for improving these traits. Selecting traits that combine high heritability with high genetic advance as a percentage of the mean can therefore be highly beneficial. Comparable results have been reported by Chapara *et al.*, (2022), Mawblei *et al.*, (2022), Keerthivarman *et al.*, (2023) and Harini *et al.*, (2025).

Days to fifty percent flowering, number of sympodia per plant, ginning outturn, upper half mean length, and micronaire displayed high heritability coupled with moderate genetic advance as a percentage of the mean, suggesting the influence of both additive and non-additive gene actions. This indicates that these traits could be more effectively improved

Table 1. Analysis of variance for seed cotton yield attributing traits and fibrequality traits in 53 cotton genotypes

Source	Mean Sum of Squares (MSS)														
	df	DFF	PH (cm)	NMP	NSP	NB	BW (g)	SI (g)	LI (g)	GOT (%)	SCY (g)	UHML (mm)	UI (%)	MIC (μg/inch)	TEN (g/tex)
Blocks	5	14	2114.6**	0.11**	6.36**	240.06**	3.19**	14.01**	1.57**	1.75*	2597.7**	0.90*	3.38**	0.1**	3**
Treatments	52	12.85**	656.86**	0.15**	10.98**	64.11**	0.64**	3.73**	0.90**	5.12**	491.55**	2.77**	2.45**	0.32**	1.29**
Checks	2	3.39**	217.62**	0.12**	121.94**	531.12**	0.07	37.53**	3.62**	19.31**	105.27**	0.62	13.17**	0.07	4.41**
Treatment: Testand Testvs. Check	50	13.23**	674.43**	0.15**	6.54**	45.43**	0.66**	2.38**	0.79**	4.55**	507**	2.85**	2.03**	0.33**	1.17**
Error	10	0.72	18.31	0.01	1.189	2.46	0.02	0.09	0.06	0.42	8.7	0.17	0.5	0.02	0.08

DFF= Days to fifty per cent Flowering; **PH**= Plant Height(cm); **NMP**=Number of Monopodia per Plant;

NSP= Number of Sympodia per Plant; **NB**= Number of Bolls per Plant; **BW**= Boll Weight (g); **SI**= Seed Index(g);

LI= Lint Index (g); **GOT**= Ginning Out Turn (%); **SCY**= Seed Cotton Yield per Plant (g); **UHML**= Upper Half Mean Length(mm);

MIC= Micronaire(μ g/inch); **TEN**=Tenacity (g/tex); **UI**= Uniformity index (%)

df = Degree of Freedom

* Significant at 5% level, ** Significant at 1% level

Table 2. Estimates of genetic parameters for seed cotton yield attributing traits and fibre quality traits in 53 cotton genotypes

Traits	GCV (%)	PCV (%)	ECV (%)	h^2_{bs} (%)	GA	GAM (%)
Days to fifty per cent flowering	6.18	6.34	1.4	95.15	7.57	12.44
Plant height (cm)	19.27	19.48	2.88	97.82	58.49	39.32
Number of monopodia per plant	29.67	31.27	9.87	90.04	0.71	58.09
Number of sympodia per plant	10.39	11.79	5.58	77.63	3.67	18.88
Number of bolls per plant	17.44	17.77	3.37	96.4	16.44	35.34
Boll weight (g)	20.31	20.57	3.28	97.46	1.91	41.36
Seed index (g)	18.61	18.82	2.83	97.75	3.95	37.95
Lint index (%)	15.95	16.61	4.64	92.2	1.64	31.6
Ginning out turn (%)	5.79	6.07	1.84	90.85	4	11.38
Seed cotton yield per plant (g)	23.38	23.52	2.59	98.79	54.64	47.94
Upper half mean length (mm)	5.49	5.67	1.41	93.79	3.16	10.97
Uniformity index (%)	1.61	1.83	0.86	77.93	2.42	2.94
Micronaire	9.49	9.9	2.8	91.99	0.86	18.78
Tenacity (g/tex)	4.1	4.22	1	94.39	2.35	8.21

GCV= Genotypic Coefficient of Variation; **PCV**= Phenotypic Coefficient of Variation;

ECV= Environmental Coefficient of Variation; **GA**= Genetic Advance;

GAM= Genetic Advance Mean: h^2_{bs} = Heritability in broad sense

Table 3. Correlation matrix of seed cotton yield attributing and fibre quality traits in 53 cotton genotypes

Traits	DFF	PH (cm)	NMP	NSP	NB	BW (g)	SI (g)	LI (g)	GOT (%)	SCY (g)	UHML (mm)	MIC (µg/inch)	TEN (g/tex)	UI (%)
DFF	1													
PH (cm)	-0.245	1												
NMP	0.395**	0.041	1											
NSP	-0.055	0.189	0.179	1										
NB	-0.310**	0.387**	-0.119	0.218	1									
BW (g)	-0.202	-0.087	-0.387**	0.180	0.160	1								
SI (g)	-0.057	0.43**	-0.111	0.222	0.569**	0.412**	1							
LI (g)	-0.044	-0.234	-0.262	0.147	0.463**	0.457**	0.714**	1						
GOT (%)	-0.208	0.028	-0.339*	-0.012	-0.02	0.140	-0.231	0.229	1					
SCY (g)	-0.234	0.500**	-0.230	0.174	0.648**	0.519**	0.616**	0.523**	0.065	1				
UHML (mm)	0.594**	-0.015	0.228	0.192	-0.303*	0.087	0.089	0.015	-0.098	-0.049	1			
MIC (µg/inch)	-0.615**	0.155	-0.240	-0.219	0.301*	-0.095	-0.107	-0.09	-0.03	0.003	-0.704**	1		
TEN (g/tex)	0.259	0.013	0.169	0.031	-0.300*	0.198	0.173	0.088	0.006	0.009	0.649**	-0.460**	1	
UI(%)	0.553**	-0.045	0.339*	0.200	-0.224	0.077	0.041	-0.134	-0.254	-0.030	0.569**	-0.389**	0.382**	1

DFF= Days to fifty percent Flowering; **PH**= Plant Height (cm); **NMP**=Number of monopodia per plant;

NSP= Number of sympodia per plant; **NB**= Number of bolls per plant; **BW**= Boll Weight (g); **SI**= Seed Index (g);

LI= Lint Index (g); **GOT**= Ginning Out Turn (%); **SCY**= Seed Cotton Yield per Plant (g);

UHML= Upper Half Mean Length(mm); **MIC**= Micronaire(µg/inch); **TEN**=Tenacity (g/tex) and **UI**= Uniformity index (%).

* Significant at 5% level, ** Significant at 1% level

through hybridization followed by selection. The present results concur with the findings of Chapara *et al.*, (2022), Keerthivarman *et al.*, (2023) and Harini *et al.*, (2025). High heritability combined with low genetic advance as a percent of the mean was recorded for uniformity index and tenacity. The heritability is being exhibited due to favourable influence of environment rather than genotype and implying that these traits could be improved through heterosis breeding as simple selection is ineffective. These results were in consonance with Chapara *et al.*, (2022) and Harini *et al.*, (2025) (Table 2).

Computation of correlation between yield attributing and fibre quality parameters is of considerable importance in plant selection. The correlation coefficients between yield contributing and fibre quality traits were presented in Table 3. Among 14 parameters studied, five traits namely, plant height (0.500**), number of bolls per plant (0.648**), boll weight (0.519**), seed index (0.616**) and lint index (0.523**) exhibited a significant positive correlation with seed cotton yield per plant; therefore, selecting for these traits would facilitate the identification of genotypes with superior seed cotton yield per plant. These results were in consonance with Arunkumar and Murthy (2020), Gnanasekaran *et al.*, (2020), Gauswami Jyoti *et al.*, (2021), Chaudhry *et al.*, (2022), Mawblei *et al.*, (2022) and Chapara *et al.*, (2024).

The principal fibre quality traits demonstrated positive inter-correlations. Upper half mean length, tenacity and uniformity index were positively and significantly associated with one another, while exhibiting a negative correlation with micronaire. Similar trends were reported by Gnanasekaran *et al.*, (2020), Chapara *et al.*, (2022), Gurmesssa *et al.*, (2022) and Harini *et al.*, (2025). Therefore, simultaneous selection for plant height, number of bolls per plant, boll weight, seed index and lint index, along with fibre quality

parameters such as upper half mean length, tenacity and uniformity index, could lead to substantial improvement in both cotton yield and fibre quality.

CONCLUSION

In this investigation, analysis of variance indicated highly significant variation among 50 cotton genotypes and three checks for the 14 yield and fibre parameters indicating the existence of substantial genetic variation. Therefore, a combination of high heritability and high genetic advance was observed for the attributes *viz.*, plant height, number of monopodia per plant, number of bolls per plant, boll weight, seed index, lint index and seed cotton yield per plant rendering the probability of selecting the genotypes for these traits. The genotypes LHBT 2203, LHBT 9, L 2278 and L 2281 were identified to be the best performers for seed index, lint index and seed cotton yield per plant; Suvin, CCB 29, L 2275, L 2385 and L 2268 showed good for fibre quality traits. Association studies indicated that seed cotton yield was positively and significantly correlated with plant height, number of bolls per plant, boll weight, seed index and lint index and would help in direct selection and improving the seed yield of cotton genotypes.

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ANTIDIABETIC POTENTIAL OF *XANTHOSOMA BRASILIENSE* AND *JACQUEMONTIA PENTANTHOS*: A COMPARATIVE STUDY

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ABSTRACT

Diabetes mellitus represents a long-term metabolic disorder that demands effective control strategies. This comparative investigation explored the antidiabetic potential of extracts from *Xanthosoma brasiliense* and *Jacquemontia pentanthos*. The study was conducted during 2024. The extracts were evaluated for their inhibitory activities against alpha-amylase and alpha-glucosidase enzymes. The results showed that *Xanthosoma brasiliense* exhibited potent inhibitory activities against alpha-amylase (IC_{50} : $3.741924 \pm 0.011 \mu\text{g/mL}$) and alpha-glucosidase (IC_{50} : $2.39175 \pm 0.021 \mu\text{g/mL}$). *Jacquemontia pentanthos* demonstrated significant inhibitory activities against alpha-glucosidase (IC_{50} : $3.368435 \pm 0.031 \mu\text{g/mL}$) and moderate activity against alpha-amylase (IC_{50} : $15.38087 \pm 0.027 \mu\text{g/mL}$). The results indicate that extracts of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* could aid in creating natural antidiabetic agents, offering an alternative or supportive option for diabetes management.

Keywords: Alpha-amylase, Alpha-glucosidase, Antidiabetic assays, *Jacquemontia pentanthos* and *Xanthosoma brasiliense*.

INTRODUCTION

Diabetes mellitus consists of various metabolic disorders, all characterized by sustained and abnormal increases in blood glucose concentrations. Its causes are complex, involving problems in insulin release, different levels of resistance to insulin, or most commonly, a complex interplay between both. If left unmanaged, insufficiently treated, or undiagnosed for long periods, diabetes mellitus is closely associated with heightened risks of severe complications such as heart disease, kidney disorders, vision problems and lower-limb amputations (Petersmann *et al.*, 2018 and Schleicher *et al.*, 2022).

At present, standard antidiabetic treatments like oral glucose-lowering medications and insulin can produce side effects such as hypoglycemia, weight gain and greater chances of cardiovascular problems. Furthermore, these therapies may not always be effective in achieving optimal glycemic control. The worldwide increase in diabetes mellitus cases has created the need to explore alternative therapies, including natural products, to support standard treatments. Plant-based treatments are emerging as a promising means of managing diabetes, with many studies showing their ability to regulate

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glucose metabolism, improve insulin sensitivity and minimize oxidative stress.

As the global burden of diabetes continues to escalate, the development of natural antidiabetic agents is now an urgent goal, with the capacity to transform how we manage this debilitating disease. Interest in discovering natural antidiabetic agents has grown rapidly, fueled by the demand for safer, more effective, and affordable treatments capable of enhancing life quality for people with diabetes. (Mechchate *et al.*, 2021).

Xanthosoma brasiliense, a member of the Araceae family, is commonly referred to as Tahitian spinach, tannier spinach, belembé, and Tahitian taro. Unlike some other tannia (*Xanthosoma spp.*), the corms are not consumed as food because they remain small and insufficiently developed. This plant is valued for its medicinal benefits, and its leaves are consumed as a leafy vegetable. *Jacquemontia pentanthes* (Sky blue cluster-vine) is an evergreen, twining vine that produces many small but appealing flowers, ranging in color from sky blue to pinkish-lavender with a white center. Skyblue clustervine is a member of the morning glory family, so flowers open in the morning. The species is recognized for its medicinal qualities, and its tender leaves are also consumed as vegetables. This research aims to examine the inhibitory effects of *Xanthosoma brasiliense* and *Jacquemontia pentanthes* extracts on alpha-amylase and alpha-glucosidase enzymes, as well as their potential role as natural antidiabetic agents.

MATERIAL AND METHODS

Plant material and extraction

Leaf of *Jacquemontia pentanthes* and *Xanthosoma brasiliense* were collected from Achankovil and Kulathupuzha in Kollam district, India. The plant material was shade-

dried, cut into smaller pieces, and ground into coarse powder form. The powdered sample underwent extraction for 10 hours in a Soxhlet apparatus using ethanol as the solvent. Following extraction, the solvent was evaporated using a rotary evaporator, and the crude extracts were kept for further analysis.

Alpha glucosidase inhibition assay

Both the control and extract solutions were prepared using p-Nitrophenyl- α -D-glucopyranoside. Each extract was adjusted to a concentration of 10 μ g/mL, brought to a final volume of 200 μ L and incubated at 37°C. Acarbose served as the positive control. The reaction was started by adding pNPG (p-Nitrophenyl- α -D-glucopyranoside), and the amount of pNP released was measured at 410 nm using a spectrophotometer after a reaction time of 10 minutes. Absorbance from a mixture lacking enzyme was subtracted as a background correction. Higher absorbance values indicated greater enzymatic activity.

Enzyme inhibition % =

$$\frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

The inhibition assay with varying concentration of the inhibitor was also used to determine the concentrations of the extracts resulting in 50 percent inhibition (IC_{50}) compared to the standard.

Alpha amylase inhibition assay

Porcine pancreatic α -amylase (PPA; A05329G191) was dissolved in 9 mL of 20 mM phosphate buffer (pH 6.9). Stock solutions of the extracts were prepared at different concentrations. A 0.5% (w/v) potato starch solution was made in 20 mM phosphate-buffered saline (pH 6.9) and heated in a boiling water bath until clear. Each reaction mixture contained 40 μ L of sample, 160 μ L of distilled water, and 400 μ L of starch solution. The

reaction was initiated by adding 200 μL of enzyme solution, and the mixtures were incubated at 25 $^{\circ}\text{C}$ for 3 minutes. Enzyme solutions were added at one-minute intervals from the start. A 200 μL portion from each reaction was transferred to a separate tube containing 100 μL of DNS reagent (50.68 g sodium potassium tartrate in 70 mL of 2 M NaOH with 0.026 mM 3,5-dinitrosalicylic acid) and heated in a water bath at 85–90 $^{\circ}\text{C}$ for 15 minutes. Each mixture was then diluted with 1 mL of distilled water, and absorbance was measured at 540 nm. A blank was prepared by replacing the enzyme with 200 μL of distilled water. Acarbose, an established α -amylase inhibitor, served as the reference control. All experiments were carried out in triplicate. The α -amylase inhibitory activity was calculated by using following formula:

The α -amylase inhibitory activity =

$$\frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

The concentration of acarbose and the test samples needed to inhibit 50% of α -

amylase activity under the experimental conditions was defined as the IC_{50} value. The α -amylase inhibitory effects of both the extracts and acarbose were calculated, and their respective IC_{50} values were established.

RESULTS AND DISCUSSION

The α -amylase inhibitory activities of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts are shown in Table 1, Fig(1-5). The IC_{50} values recorded for acarbose (Standard), *Xanthosoma brasiliense*, and *Jacquemontia pentanthos* extracts were $2.018457 \pm 0.047 \mu\text{g/mL}$, $3.741924 \pm 0.011 \mu\text{g/mL}$, and $15.38087 \pm 0.027 \mu\text{g/mL}$, respectively.

The α -amylase inhibitory activities of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts

The IC_{50} value was defined as the concentration of acarbose or sample required to achieve 50 percent inhibition of α -amylase activity under the assay conditions. The α -amylase inhibitory effects for both the test

Table 1. The α -amylase inhibitory activities of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts

Concentration ($\mu\text{g/mL}$)	Average absorbance of standard (nm)	Average % inhibition of standard	<i>Jacquemontia pentanthos</i>		<i>Xanthosoma brasiliense</i>	
			Average absor- bance (nm)	Average % inhi- bition	Average absor- bance (nm)	Average % inhi- bition
0.2	0.597	40.06	0.998	0.1	0.891	10.81
0.4	0.514	48.39	0.969	3	0.723	27.63
0.6	0.399	59.94	0.965	3.4	0.675	32.43
0.8	0.274	72.49	0.918	8.11	0.417	58.26
1	0.118	88.15	0.846	15.32	0.325	67.47

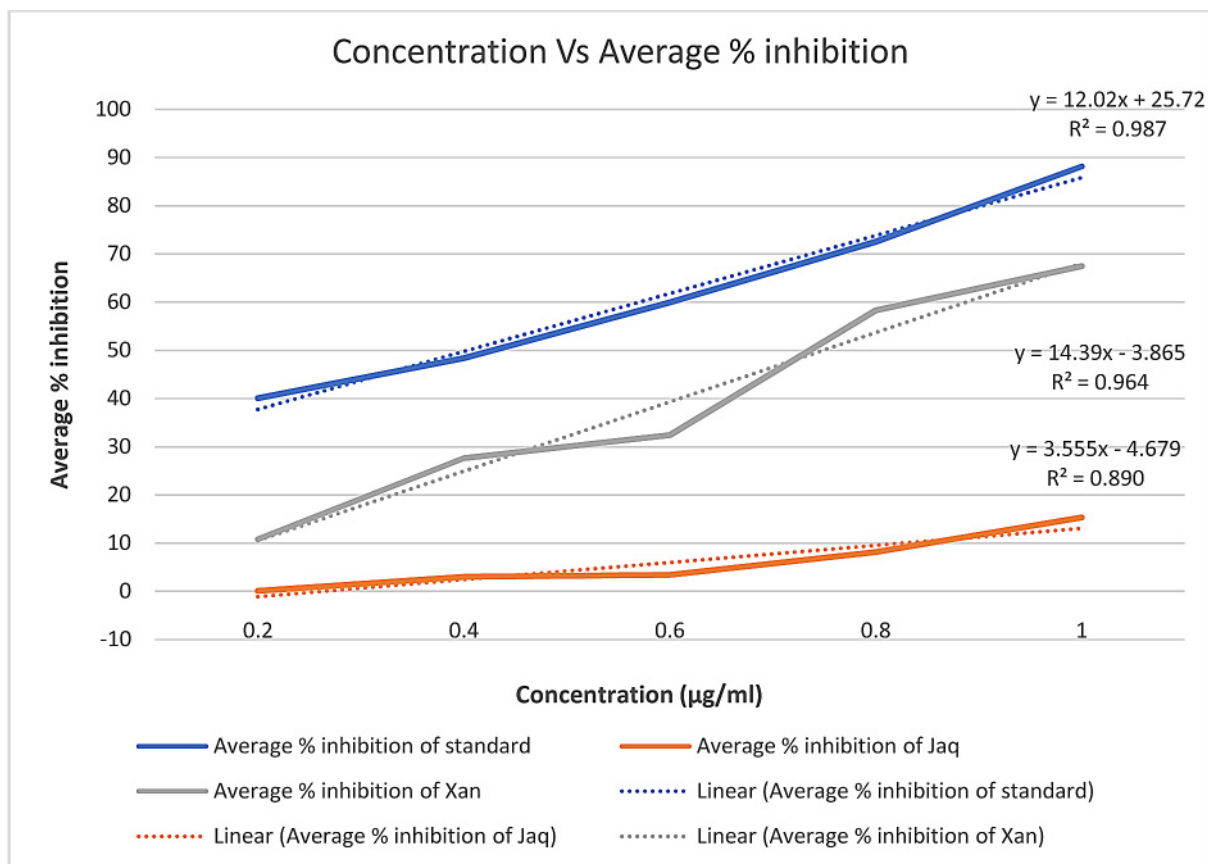


Fig 1. Concentration Vs Average percentage Alpha-amylase inhibitory activities of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts

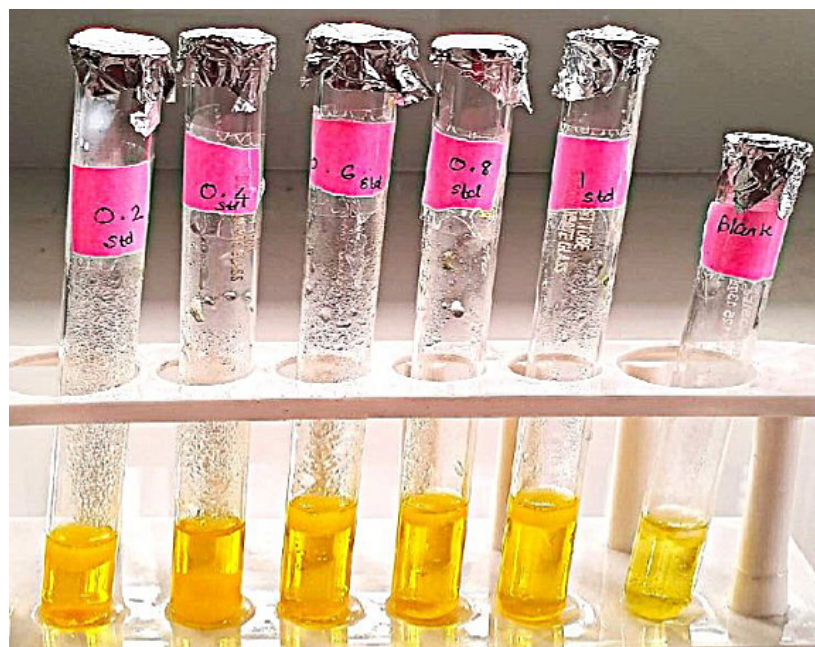


Fig 2. Alpha-Amylase Inhibition Assay of Standard (Acarbose) of *Jacquemontia pentanthos*

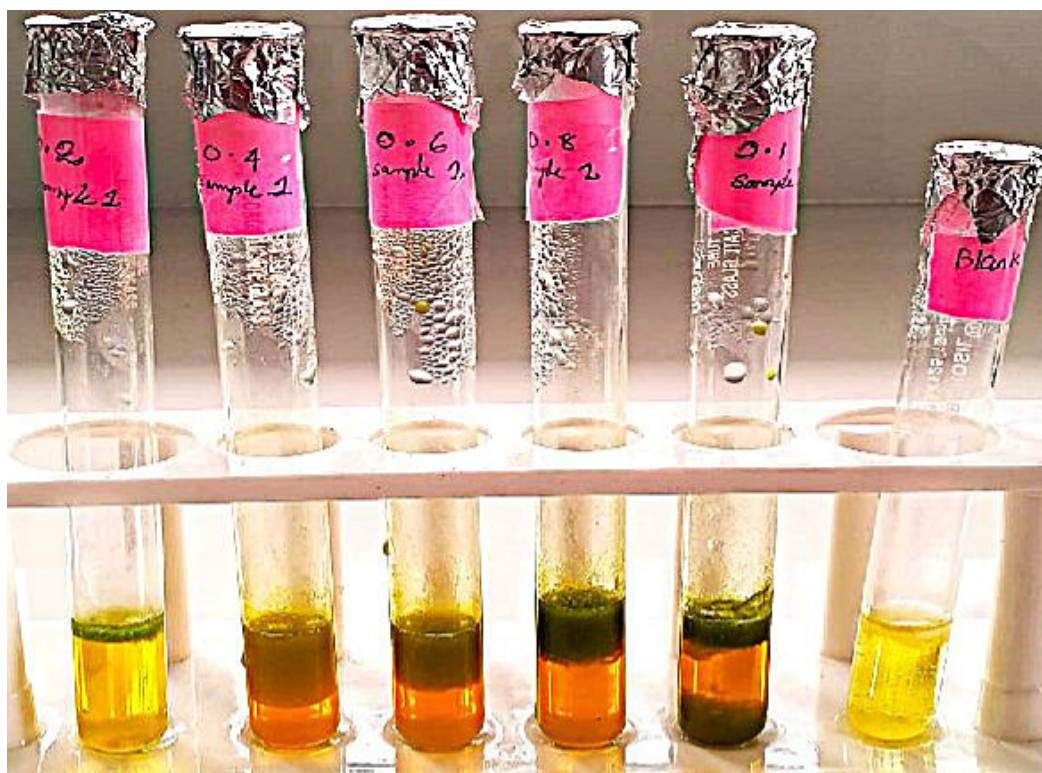


Fig 3. Alpha-Amylase Inhibition Assay of extract of *Jacquemontia pentanthos*

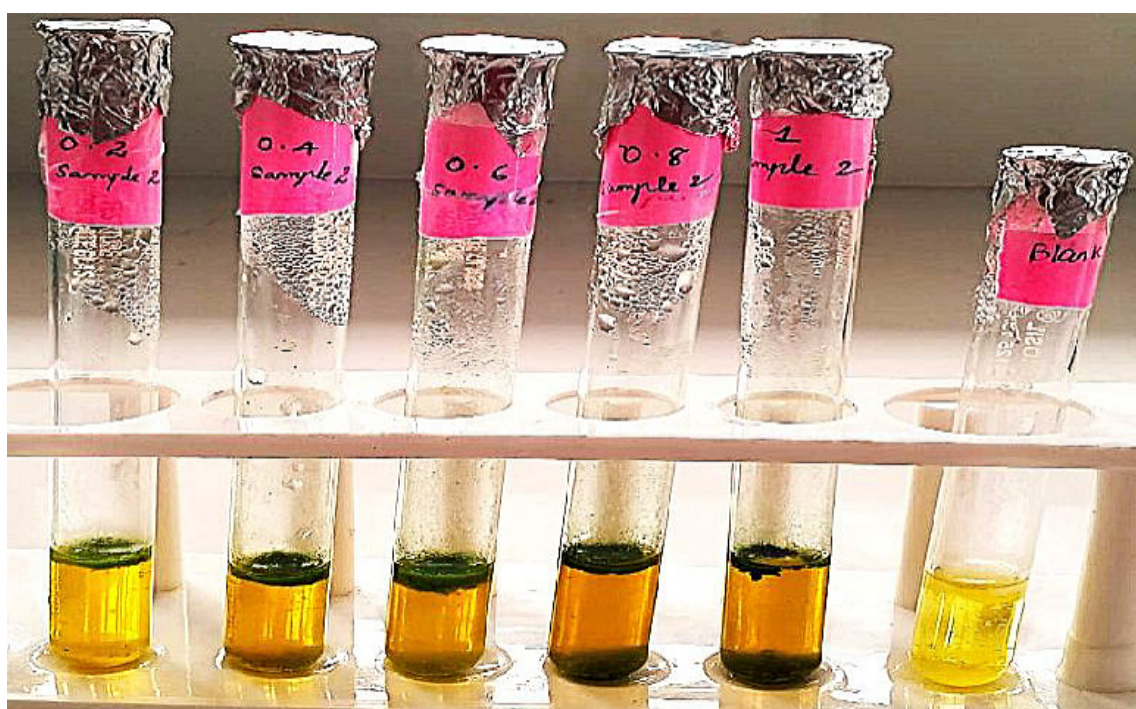


Fig 4. Alpha-Amylase Inhibition Assay of Standard (Acarbose) of *Xanthosoma brasiliense*



Fig 5. Alpha-Amylase Inhibition Assay of Extract of *Xanthosoma brasiliense*

samples and acarbose were determined accordingly.

IC₅₀ of Standard (Acarbose) =
2.018±0.047µg/ml

IC₅₀ of *Xanthosoma brasiliense* =
3.742±0.011µg/ml

IC₅₀ of *Jaquemontia pentanthos* =
15.38±0.027µg/ml

The α -glucosidase inhibitory activities of *Xanthosoma brasiliense* and *Jaquemontia-pentanthos* extracts are presented in Table 2, Fig (6-8). The IC₅₀ values obtained for acarbose (Standard), *Xanthosoma brasiliense*,

Table2. The alpha-glucosidase inhibitory activities of *Xanthosoma brasiliense* and *Jaquemontia pentanthos* extracts

Concentration (µg/ml)	Average absorbance of standard (nm)	Average % inhibition of standard	<i>Jaquemontia pentanthos</i>		<i>Xanthosoma brasiliense</i>	
			Average absor- bance (nm)	Average % inhi- bition	Average absor- bance (nm)	Average % inhi- bition
0.2	0.584	41.37	0.769	22.95	0.654	34.47
0.4	0.471	52.71	0.655	34.37	0.521	47.8
0.6	0.354	64.46	0.532	46.69	0.421	57.82
0.8	0.274	72.49	0.422	57.72	0.374	62.53
1	0.147	85.24	0.324	67.54	0.211	78.86

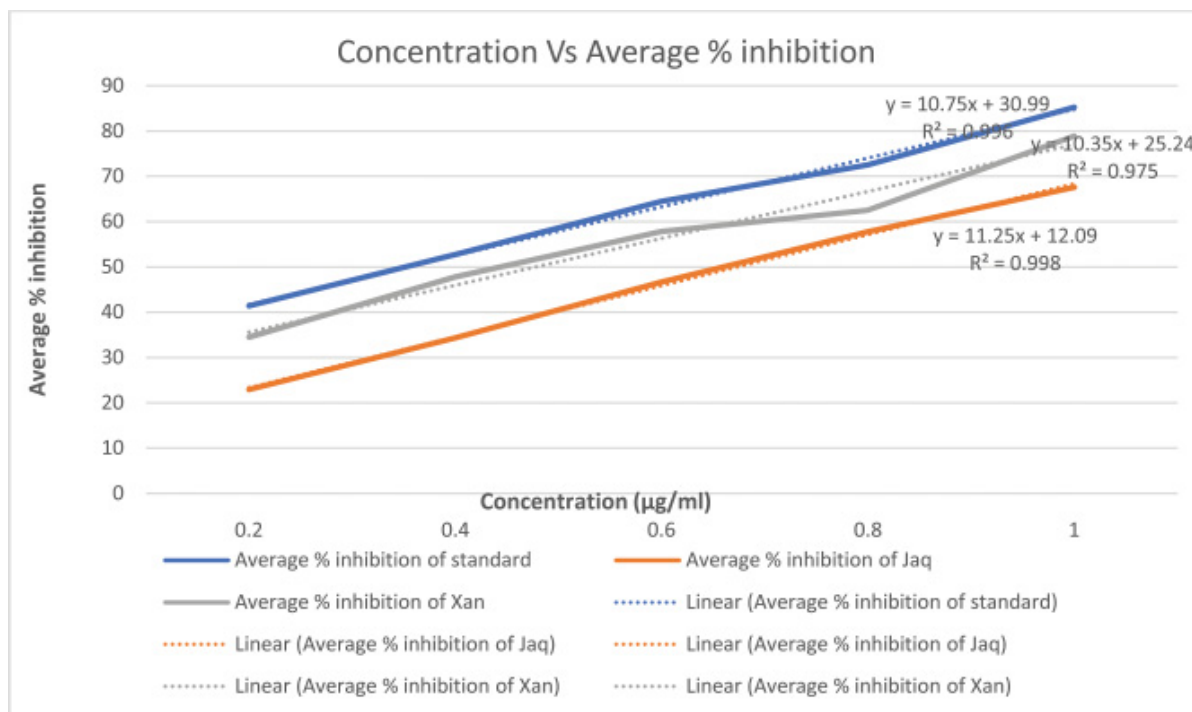


Fig 6. Concentration Vs Average percentage alpha-glucosidase inhibitory activities of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts



Fig 7. Alpha glucosidase Inhibition Assays of *Jacquemontia pentanthos*



**Fig. 8. Alpha glucosidase Inhibition Assays
of *Xanthosoma brasiliense***

and *Jacquemontia pentanthos* extracts were $1.767 \pm 0.011 \mu\text{g/mL}$, $2.392 \pm 0.021 \mu\text{g/mL}$, and $3.368 \pm 0.031 \mu\text{g/mL}$, respectively.

The percentage of α -glucosidase inhibition was calculated using the equation:

$$\text{Enzyme inhibition \%} = \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100\%$$

The assay with varying inhibitor concentrations was used to identify the concentration of extract producing 50% inhibition (IC_{50}) relative to the Standard. The absorbance of the control was recorded as 0.998 nm.

$$\text{IC}_{50} \text{ of Standard (Acarbose)} = 1.767 \pm 0.011 \mu\text{g/ml}$$

$$\text{IC}_{50} \text{ of } Xanthosoma \text{ brasiliense} = 2.392 \pm 0.021 \mu\text{g/ml}$$

$$\text{IC}_{50} \text{ of } Jacquemontia \text{ pentanthos} = 3.368 \pm 0.031 \mu\text{g/ml}$$

Xanthosoma brasiliense demonstrated stronger antidiabetic activity than *Jacquemontia pentanthos* in both α -amylase and α -glucosidase inhibition assays. While *Jacquemontia pentanthos* showed moderate to notable activity, its potency was lower than that of *Xanthosoma brasiliense*. Overall, the findings indicate that both plant extracts possess antidiabetic potential, with *Xanthosoma brasiliense* exhibiting more pronounced inhibitory effects on α -amylase and α -glucosidase. These results highlight the possibility of using these plant extracts as natural antidiabetic agents.

The use of plants in diabetes treatment has a long history, and modern research continues to validate their therapeutic roles. Plant-derived bioactives can exert antidiabetic effects through several mechanisms, including promoting insulin secretion and glucose uptake, suppressing glucose production and intestinal absorption, and alleviating oxidative stress and inflammation.

Diabetes mellitus is a metabolic disorder and a growing global health threat. Insulin plays a central role in regulating carbohydrate, lipid, and protein metabolism, and its deficiency disrupts these essential processes. The enzymes α -amylase and α -glucosidase are key in carbohydrate breakdown to glucose. α -Amylase catalyzes the hydrolysis of starch into simpler sugars, which are then converted to glucose prior to absorption (Abhijit *et al.*, 2014). Inhibiting α -amylase can help lower postprandial hyperglycemia. α -Glucosidase, present in the small intestine, breaks down disaccharides into glucose, thereby facilitating monosaccharide absorption. Its inhibition reduces glucose uptake and can be a valuable strategy in controlling diabetes (Anuradha Devi and Mallikarjuna, 2016).

One effective approach to diabetes management is the suppression of glucose absorption. Targeting digestive enzymes that convert complex carbohydrates into absorbable sugars can help modulate post-meal blood glucose levels. Among these, α -glucosidase and α -amylase are considered primary targets (Mechchate *et al.*, 2021).

The current study assessed the effects of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts on α -amylase and α -glucosidase activity. Both extracts exhibited significant inhibition of these enzymes. Since enzyme inhibition delays carbohydrate digestion and absorption, it can reduce postprandial blood glucose levels, making these extracts promising candidates for natural antidiabetic therapy.

Bioactive constituents such as flavonoids, phenolic acids, and saponins present in the extracts are likely contributors to the observed inhibitory effects. However, further research is needed to isolate and identify the specific active compounds responsible.

This work provides preliminary evidence for the antidiabetic potential of *Xanthosoma brasiliense* and *Jacquemontia pentanthos*. Additional studies are essential to validate these results and explore the feasibility of using these extracts as natural agents for diabetes management.

CONCLUSION

This comparative investigation demonstrated the antidiabetic potential of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* extracts. *Xanthosoma brasiliense* showed strong inhibition of α -amylase (IC_{50} : $3.74 \pm 0.011 \mu\text{g/mL}$) and α -glucosidase (IC_{50} : $2.392 \pm 0.021 \mu\text{g/mL}$), while *Jacquemontia pentanthos* exhibited notable inhibition of α -glucosidase (IC_{50} : $3.368 \pm 0.031 \mu\text{g/mL}$) and moderate inhibition of α -amylase (IC_{50} : $15.38 \pm 0.027 \mu\text{g/mL}$). These results suggest that both plants hold potential as natural antidiabetic agents, offering a possible complementary or alternative strategy for diabetes management. By targeting carbohydrate-hydrolyzing enzymes, the extracts may aid in controlling postprandial blood glucose levels. The outcomes of this study have meaningful implications for translational research, supporting the potential of *Xanthosoma brasiliense* and *Jacquemontia pentanthos* as sources for developing innovative, plant-derived antidiabetic therapeutics.

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ASSESSMENT OF GENETIC VARIABILITY FOR YIELD AND YIELD RELATED TRAITS IN WHEAT

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ABSTRACT

A field study was undertaken at Guru Kashi University, Talwandi Sabo in Bathinda (Punjab) throughout the Rabi season of 2023–2024 to evaluate the genetic variability of 43 wheat genotypes for yield and yield associated characteristics. The experiment used a Randomized Block Design with three replications. Analysis of variance showed considerable variation in all traits except flag leaf width, confirming significant genetic diversity among the genotypes. The maximum genotypic and phenotypic coefficient of variation (GCV and PCV) were noted for each plant's biological yield (GCV: 36.03%, PCV: 39.86%), grain weight per spike (GCV: 29.78%, PCV: 30.18%), and grains per spike (GCV: 22.01%, PCV: 22.23%), indicating their potential for selection. High heritability (>80%) combined with a high genetic advance (>30%) for grains per spike, expressed as a percentage of the mean (heritability: 98.01%, genetic advance: 44.88%), grain weight per spike (heritability: 97.38%, genetic advance: 60.54%), and biological yield per plant (heritability: 81.71%, genetic advance: 67.09%), suggesting these characteristics were mostly controlled by additive genetic effects and could be effectively improved through selection. Traits such as days to flowering (heritability: 87.37%, genetic advance: 8.14%), days to maturity (heritability: 90.97%, genetic advance: 3.58%), and plant height (heritability: 72.87%, genetic advance: 12.77%) displayed high heritability with moderate genetic advance, indicating the impact of both additive and non-additive gene effects. In contrast, traits like tillers per plant (heritability: 17.57%) and flag leaf area (heritability: 21.27%) showed low heritability and genetic advance, implying strong environmental influence and limited potential for direct selection. This study found significant genetic variability within the wheat genotypes, with key yield-related traits showing strong potential for genetic improvement.

Keywords: Genetic advance, Heritability, Variance, Wheat Yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) stands as a cornerstone of global agriculture, renowned as the “Staff of Life” for its vital role in sustaining over 4.5 billion people worldwide. Wheat is cultivated globally on approximately

222 million hectares, producing over 790 million tonnes with an average productivity of 3.56 tonnes per hectare (FAO, 2024). As the second-largest producer of wheat, India plays a crucial part in meeting global demand. In 2023, the country cultivated wheat in 31.76

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million hectares, with a production of 112.74 million tonnes. While the national average productivity is about 3.55 tonnes per hectare, the state of Punjab demonstrates exceptional output, achieving a productivity of 5.1 tonnes per hectare (DES, 2023). This development must occur while addressing both present and future obstacles, such as shrinking land and water supplies, in addition to rising temperatures brought by a climate shift and global warming (Bapela *et al.*, 2022). However, the path to sustainable wheat production faces challenges such as dwindling resources and climate change-induced stresses.

Development of improved genotypes that are capable of producing higher yield under various agro-climatic conditions and various stress condition is always the main objective of wheat breeding programme (Haydar *et al.*, 2020). The presence of genetic variety in the plant population is necessary for the creation of a successful plant breeding program. Hence, the level of significance of variability found in the gene pool of a crop species is of prime importance to a plant breeder for starting a judicious plant breeding program (Farshadfar *et al.*, 2013). Estimating heritability helps plant breeders choose elite genotypes from various genetic groups. Hence, the current investigation was undertaken to estimate the genetic advancement, heritability and variability that can be applied to breeding and crop improvement programme.

MATERIAL AND METHODS

The field test was carried out at Guru Kashi University's farm in Talwandi Sabo, Bathinda (Punjab), located at 29°57'37.5" N latitude, 75°07'16.6" E longitude, and an altitude of 201 m above the average sea level using 43 wheat genotypes in the Rabi season of 2023–2024. The details of genotypes studied is provided in Table-01. The genotypes were seeded in a randomized block design (RBD) with three replications each, with

each row consisting of two-meter-long plots and a line-to-line distance of 25 cm. Observations for all attributes were recorded on five randomly selected individuals per genotype in each replication. The traits recorded were days to 50% flowering (DF), days to maturity (DM), plant height (PH), peduncle length (PL), spike length (SP), number of grains per spike (NGPS), grain weight per spike (GWPS), biological yield per plant (BY), biological yield per plot (BYPP), grain yield per plant (GY), grain yield per plot (GYPP), test weight (TW), flag leaf length (FLL), flag leaf width (FLW), and flag leaf area (FLA) (Fouad, 2020). The mean data of the traits were analysed statistically for variability parameters, using opstat. Wheat plant growth is divided into three stages: vegetative (from seed germination to tillering); reproductive (from stem elongation to flowering) and ripening (from flowering to grain maturity) (Koshraj, 2020; Rao *et al.*, 2021). Vegetative growth lasts around 45-60 days. The optimal temperature for vegetative growth is 15°C to 20°C (Gautam *et al.*, 2018). The temperatures in the months of November and December are suitable for vegetative growth. The rainfall should be around 30-40mm during seedling initiation to ensure adequate moisture content in the soil, which is crucial for seedling emergence. The temperature for the reproductive stage ranges from 20°C to 25°C, making it suitable for stem elongation to flowering. The ripening stage (from flowering to grain maturity) requires temperatures between 25°C to 30°C (Guarin and Asseng, 2022). During the ripening stage, reduced water is needed and the temperature should be higher during the harvesting stage to ensure proper grain drying.

RESULTS AND DISCUSSION

Analysis of Variance

Analysis of variance (ANOVA) of grain yield and yield related traits in wheat genotypes

Table 1. List of wheat genotypes

Sr.No.	Genotypes	Pedigree	Sr. No.	Genotypes	Pedigree
1	WH 1124	MUNIA/CHTO//AMSEL	23	WH 1184	HD2850/WH147
2	WH 1100	PBW 65/2*PASTOR	24	HD 2307	HD-2160/116-1-3
3	WH 1136	NI 5663RAJ 3765	25	HD 2687	CPAN 2009/HD 2329
4	WH 1140	WBLL1*2/VIVITSI	26	HD 3043	PJN/BOW//OPATA*2/3 CROC_ 1/A.SQUARROSA (224)//OPATA
5	WH 1126	WBLL1*2/VIVITSI	27	HD 3386	N/A
6	WH 1202	D67.2/PARANA66.270//AE.SQ. (320)/3/CUNNINGHAM	28	HD 3219	PBW343/HD2879
7	WH 1160	WAXWING*2/VIVITSI	29	HD 3182	N/A
8	WH 715	30/PBW 761	30	PBW 761	PBW 550//Yr15/6* Avocet/3/2* PBW 550
9	WH 542	JUP/BJY"S"//URES	31	PBW 163	N/A
10	WH 522	N/A	32	PBW 706	MINO / 898.97
11	WH 1132	PBW 65/2*PASTOR	33	PBW 769	ATTILA/3*BCN/3/CROC_1/AE.SQUAR ROSA (224)//OPATA/4/CHIBIA//PRLII/ CM65531/3/ SKAUZ/BAV92/4/MUNAL#1
12	WH 1063	BARBET 1 Selection	34	PBW 826	WBLL1*2/KKTS//PASTOR/KUKUNA/3/ KINGBIRD#1//INQALAB 91*2/TUKURU/5/ KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ /4/SAUAL
13	WH 1185	SONALIKA / RAJ 3777	35	PBW 677	PFAU/MILAN/5/CHEN/A.Squa//BCN/3/ VEE#7/BOW/4/PAST

Sr.No.	Genotypes	Pedigree	Sr. No.	Genotypes	Pedigree
14	WH 1270	SHA7//PRL/VEE#6/3/FASAN/ 4/HAAAS8446/2*FASAN/5/CBRD /KAUZ/6/MILAN/AMSE L7/FRET2*2/ KUKUNA/8/2*WHEAR/5OKOLL	36	PBW 681	UP2338/KALYANSONA
15	WH 1105	MILAN/S87230//BABAX	37	PBW 644	PBW-175/HD-2643
16	WH 1182	KLDR/PEWIT1//MILAN/DUCULA	38	PBW 750	TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/ 5/KAUZ/6/FRET2/7/PASTOR//MILAN/ KAUZ/3/BAV92
17	WH 283	1981/RAJ-821	39	PBW 165	N/A
18	WH 1127	RL6043/4/NAC//PASTOR/3/BABAX	40	PBW 475	W4671/PBW54
19	WH 1164	RL 604/4*NAC//2*PASTOR	41	DBW 222	KACHU/SAUAL/8/ATTILA*2/PBW 65/6/ PVN//CAR422/ANA/5/BOW/CROW//BUC/ PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR
20	WH 1134	PRL/2*PASTER	42	DBW 303	WBLL1*2/BRAMBLING/4/BABAX/ LR42//BABAX#2/3/SHAMA*2/5/ PBW343*2/KUKUNA*2//FRTL/PIFED
21	WH 1152	PBW 65/2*PASTOR	43	DBW 187	NAC/TH.AC//3*PVN/3/MIRLO/BUC/ 4/2*PASTOR/5/KACHU/6/KACHU
22	WH 1135	HD29/2* WEAVER	-		

Fig. 1. Meteorological data of temperature and rainfall during rabi season (2023-2024)

showed substantial differences across treatments for the majority of the traits, indicating sufficient variability for effective selection (Table 2). The mean sum of squares for days to flowering (DF), days to maturity (DM), plant height (PH), peduncle length (PL), number of tillers per plant (TPP), grain per spike (GS), grain weight per spike (GWPS), biological yield per plant (BY), grain yield per plant (GY), grain yield per plot (GYPP), biological yield per plot (BYPP), test weight (TW), and flag leaf length (FLL) were highly significant ($p < 0.01$) among treatments, indicating significant genetic variability. Spike length (SL) and flag leaf area (FLA) showed significant differences at $p < 0.05$. This variability suggested potential for selection and improvement of these attributes in wheat breeding programs.

The mean performance of the 43 wheat genotypes across 16 morphological traits, along with estimates of genetic parameters are displayed in Table 3. The average grain yield per plant was 9.02 g, while grain yield per plot ranged from 295.61 to 384.87 g. On average, genotypes took 91.56 days to reach 50 percent flowering and 132.01 days to mature. The average plant height was 98.49 cm. Among yield components, the mean number of grains per spike was 53.72. Additionally, each spike's average grain weight was 2.01 g. The average biological yield per plant was 19.42 g. These mean values provide a baseline understanding of the overall performance of the genotypes under the specific experimental conditions.

Table 3 shows that all attributes had a higher phenotypic coefficient of variation (PCV) than genotypic coefficient of variation (GCV), showing that environmental influences play a role. High heritability and high genetic advance were observed for grain weight per spike ($h^2 = 97.38\%$, $GA = 1.21$, $GAM = 60.54\%$), biological yield per plant ($h^2 = 81.71\%$, $GA = 13.026$, $GAM = 67.08\%$), and grains per spike ($h^2 = 98.00\%$, $GA = 24.11$,

Table 2. Analysis of variance for grain yield and related traits

Source of variation	Mean Sum of Square														
	df	DF	DM	PH	PL	TPP	SL	GS	GWS	BY	GY	GYPP	BYPP	TW	FLL
Replication	2	20.67	6.8	361.66	37.16	2.38	33.59	144.93	0.27	37.52	2.59	740	372	3.56	7.19
Treatments	42	47.11**	17.99**	172.61**	11.81**	0.65*	26.68	422.25**	1.08**	157.	13.175**	318	11602	33.601**	131.56**
Error	84	2.17	0.58	19.06	3.2	0.4	17.81	2.84	0.01	10.95	2.85	597	1922	1.48	26.16
												2.64	5.14	0.71	6.81

**= Significant at 1% and *= Significant at 5% level of significance

Table 3. Genetic components of variance, heritability and genetic advance of different traits

Characters	Genetic components of variance							
	Mean	SE ($\pm$)*	Range (Mean $\pm$ SE)*	h^2 bs (%)	GCV (%)	PCV (%)	GA	GAM (%)
Grain yield per plant	9.02	0.89	8.13-9.91	54.487	20.462	27.721	2.807	31.114
Days to flowering	91.56	0.81	90.75-92.37	87.365	4.227	4.523	7.452	8.139
Days to maturity	132.01	0.43	131.58-132.44	90.971	1.824	1.912	4.734	3.584
Plant Height	98.49	2.42	96.07-100.91	72.865	7.264	8.509	12.580	12.773
Peduncle length	18.73	1.03	17.70-19.76	47.261	9.046	13.158	2.399	12.810
Tillers per plant	4.69	0.37	4.32-5.06	17.567	6.196	14.784	0.251	5.350
Spike length	12.29	2.45	9.84-14.74	14.238	13.992	37.081	1.337	10.876
Grains per spike	53.72	0.97	52.75-54.69	98.008	22.009	22.231	24.113	44.884
Grain weight per spike	2.01	0.07	1.94-2.08	97.379	29.783	30.181	1.215	60.543
Biological yield per plant	19.42	1.92	17.50-21.34	81.710	36.026	39.855	13.026	67.085
Grain yield per plot	340.24	44.63	295.61-384.87	28.691	14.409	26.900	54.090	15.899
Biological yield per plot	868.89	80.05	788.84-948.94	62.664	20.673	26.115	292.924	33.711
Test weight	26.75	0.70	26.05-27.45	87.830	12.222	13.042	6.313	23.596
Flag leaf length	28.11	2.95	25.16-31.06	57.313	21.078	27.842	9.242	32.871
Flag leaf weight	1.73	0.49	1.24-2.22	6.987	13.404	50.711	0.126	7.299
Flag leaf area	35.86	10.11	25.75-45.97	21.266	25.386	55.050	8.648	24.116

GAM = 44.88%), suggesting that these attributes were regulated by additive gene activity and could be effectively improved through selection (Table 3).

Significant genetic variability, high heritability and considerable genetic advancements for improving productivity and quality attributes in wheat genotypes provided a strong basis for selection and breeding programs designed to improve these traits. These findings were consistent with prior investigations by Arya *et al.*, (2017), Kumari *et al.*, (2022), Rani *et al.*, (2018), and Ahmed *et al.*, (2019), which also reported significant genetic variability and potential for improvement in various agronomic traits in wheat.

Grains per spike, grain weight per spike, and biological yield per plant, all showed substantial heritability and genetic advance as a percentage of the mean across environments. Characteristics such as days to flowering ($h^2 = 87.37\%$, GA = 7.452, GAM = 8.14%), days to maturity ($h^2 = 90.97\%$, GA = 4.734, GAM = 3.58%), plant height ($h^2 = 72.87\%$, GA = 12.58, GAM = 12.77%), test weight ($h^2 = 87.83\%$, GA = 6.313, GAM = 23.60%), and flag leaf length ($h^2 = 57.31\%$, GA = 9.242, GAM = 32.87%) also demonstrated strong heritability but with moderate to high level of genetic advance, demonstrating gene effects that are both additive and non-additive. These findings align with previous studies by Koshraj (2020), Kumar *et al.*, (2018), Rani *et al.*, (2018), Dhaliwal *et al.*, (2023), and Raviteja *et al.*, (2023).

CONCLUSION

The analysis of morphological and quality traits in 43 wheat genotypes revealed significant genetic variability, establishing a strong foundation for targeted breeding programs. The ANOVA findings showed significant differences among genotypes for key traits, confirming the existence of enough

genetic variety for selection. Yield-related traits, including biological yield per plant (BY), grains per spike (GS), and grain weight per spike (GWPS), exhibited high heritability (98.01%, 97.38%, and 81.710%, respectively) and genetic advance (44.88%, 60.54%, and 67.08%), suggesting these attributes are predominantly controlled by additive genetic effects and may be effectively improved through selection. Similarly, test weight (TW) and biological yield per plant (BY) showed strong heritability (87.83% and 81.710%) with considerable genetic advance (23.60% and 67.09%, respectively), reinforcing their potential for enhancement through breeding.

Hence, the present study affirmed that wheat genotypes selected for the study possessed considerable genetic variability, providing valuable insights for breeders in selecting superior varieties. Identifying attributes with high heritability and genetic advance led to reliable selection efficiency, resulting in the high-yielding wheat cultivars.

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EFFECT OF PLANT DERIVED NANOPARTICLES ON *SPODOPTERA FRUGIPERDA* (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

The fall army worm (*Spodoptera frugiperda*), a major pest of maize, is responsible for substantial crop losses worldwide. Conventional chemical insecticides are increasingly limited by issues such as pest resistance and concerns about human health. The present study investigates the potential of green-synthesized silver nanoparticles (AgNPs) derived from six different plant extracts as an eco-friendly alternative for managing the *Spodoptera frugiperda*. Larvae were collected from infested maize fields in Nashik district, Maharashtra, India, and subsequently reared under laboratory conditions. Fall armyworms were placed in jars and reared in cages with chickpea, rice and maize flour. Rearing conditions: $27 \pm 3^\circ\text{C}$ temperature and $60 \pm 5\%$ relative humidity. Plant extracts from six plants (datura, neem, ginger, onion, tobacco and mint) were dried, ground, and filtered. 100 grams of powder were dissolved in 500 ml of distilled water, shaken daily for a week, and then filtered. The solution was heated to 78°C to obtain crude extracts. Silver nanoparticles were synthesized by the reduction of silver nitrate using aqueous extracts from six medicinal plants: *Datura stramonium*, *Azadirachta indica* (Neem), *Zingiber officinale* (Ginger), *Allium cepa* (Onion), *Nicotiana tabacum* (Tobacco), and *Mentha arvensis* (Mint). UV-Visible spectroscopy confirmed the formation of polydisperse AgNPs with an average absorbance peak of around 400 nm. Toxicity was assessed through a leaf-dip bioassay method across concentrations ranging from 1 to 60 ppm, with larval mortality recorded at 24 and 48 hours post-treatment. AgNPs synthesized from *Datura* and *Neem* exhibited the highest insecticidal activity, resulting in 96% and 85% mortality at 20 ppm, respectively. AgNPs derived from *Mentha* achieved 88% mortality at 60 ppm, whereas *Zingiber*-based nanoparticles were the least effective, with 73% mortality at the same concentration. The median lethal concentration (LC_{50}) values were lowest for *Datura* (1.88 ppm) and *Neem* (2.61 ppm), indicating superior efficacy, while the highest LC_{50} was observed for *Zingiber* (14.91 ppm). Although one-way ANOVA revealed no statistically significant differences in mortality among treatments ($p > 0.05$), the observed variation in LC_{50} values suggests practical differences in effectiveness. These findings highlight the potential of plant-mediated silver nanoparticles, particularly those synthesized from *Datura stramonium* and *Azadirachta indica*, as promising, sustainable alternatives for managing *Spodoptera frugiperda*.

Keywords: *Datura*, Fall armyworm (FAW), Silver nano particles, *Spodoptera frugiperda*

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INTRODUCTION

The fall armyworm (*Spodoptera frugiperda* J.E. Smith) (Lepidoptera: Noctuidae) is a globally significant agricultural pest known for its extensive host range and high adaptability. Native to the subtropical and tropical regions of the Americas, this pest has emerged as a major threat to global food security (Goergen *et al.*, 2016; Naharki *et al.*, 2020).

This highly migratory and polyphagous insect can feed on more than 350 plant species across 76 plant families, exhibiting a remarkable ability to adapt to diverse agro-ecosystems. Its primary hosts include economically critical crops such as maize, cotton, sorghum, millet, sugarcane, wheat, rice, groundnut, cowpea, potato, and soybean. Maize, however, remains the most vulnerable crop, with yield losses attributed to *Spodoptera frugiperda* infestation estimated to range between 10 and 22 million tons, corresponding to financial losses of approximately USD 6 billion annually. This pest can damage up to 65% of maize crops, severely impacting both smallholder and commercial farming systems (Naharki *et al.*, 2020).

The main food source of *Spodoptera-frugiperda* larvae is the foliage of their host plants, which causes serious tissue damage. Later instar-larvae often eat complete leaf portions, leaving only the midribs intact, whereas early instar larvae usually feed on the outer layers of leaves, producing distinctive “window pane” patterns. The color of larvae changes from greenish to dark as they mature, and they have noticeable longitudinal stripes that help them blend into the plant canopy.

The fall armyworm exhibits remarkable adaptability and proliferation in novel environments, contributing to its designation as an invasive species. The host Maize (*Zea mays* L.), a globally significant diploid annual

cereal crop, serves as a critical food source in many countries. The maize kernel, a nutritious and edible component of the plant, is rich in vitamins, carbohydrates, proteins, fiber, and riboflavin (Kumar and Jhariya, 2013). *Spodoptera frugiperda* is a significant pest affecting maize cultivation in tropical and subtropical regions of the Americas. It poses a substantial threat to maize production in all major maize-growing regions, resulting in significant economic losses and food security challenges.

Recent advances in nanotechnology have further expanded the potential of pest management tools. Nanotechnology, which focuses on the manipulation of materials at the nanoscale, has demonstrated promising applications in pest control, including the development of more efficient pheromone delivery systems, targeted pesticide formulations and innovative monitoring devices. These nanomaterials can enhance the stability, dispersion and controlled release of active compounds, potentially revolutionizing pest management practices in the coming years. The characterization of nanoparticles has been employed to assess their size (Deshmukh, 2019). Nanoparticles (NPs) possess unique physicochemical properties, including high surface area, enhanced reactivity, and specific particle morphology, making them highly effective for a wide range of agricultural applications. Numerous studies have demonstrated the efficacy of different nanoparticles in managing various insect pests and plant diseases (Jabbar *et al.*, 2022; Khan *et al.*, 2021; Nazir *et al.*, 2019; Shahbaz *et al.*, 2022).

One promising alternative is the use of green-synthesized nanoparticles, which have gained attention for their potential to reduce the ecological footprint of pest control while maintaining efficacy. Such nanoparticles, derived from natural plant extracts, offer

several advantages, including lower toxicity to non-target organisms, reduced environmental persistence, and enhanced biodegradability. In this study, we evaluated the toxicological effects of artificially produced, plant-derived silver nanoparticles against fall armyworms (FAWs), assessing their potential as an eco-friendly alternative for pest management.

MATERIAL AND METHODS

Fall armyworm collection and mass-rearing.

Larvae of *Spodoptera frugiperda* were collected from maize plants displaying characteristic infestation symptoms in various villages across the Nashik District, Maharashtra, India. To ensure proper ventilation and containment during transportation, the collected larvae were initially placed in jars covered with fine muslin cloth. Upon arrival at the laboratory, the larvae were transferred to rearing cages measuring 60 × 60 cm. These cages were provisioned with a

nutritionally balanced artificial diet composed of chickpea flour, rice flour, and maize flour, formulated to support the optimal growth and development of *Spodoptera frugiperda*. Mass-rearing was conducted at the Laboratory of the P.G. Department of Zoology and Research Centre, K.R.T. Arts, B.H. Commerce, and A.M. Science College, Nashik (K.T.H.M. College, Nashik), affiliated with Savitribai Phule Pune University, Pune. Rearing conditions were meticulously maintained at a temperature of $27 \pm 3^\circ\text{C}$ and a relative humidity of $60 \pm 5\%$, replicating the natural climate conditions favorable for *Spodoptera frugiperda* development. Following pupation, the pupae were carefully sexed and segregated into separate cages to prevent premature mating and ensure accurate monitoring of adult emergence. Upon enclosure, the adult moths were provided with a 10% (v/v) honey or sugar solution as a carbohydrate source, administered every alternate day to support mating activity and reproductive output. Mating

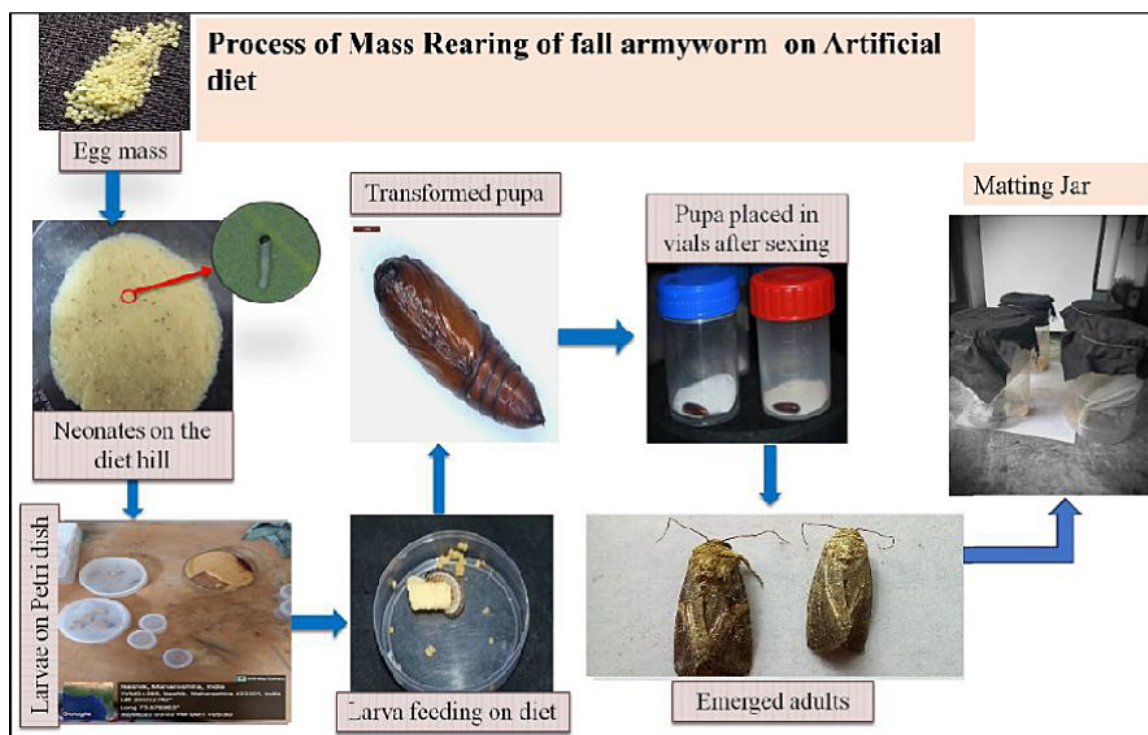


Fig. 1. Mass rearing process of *Spodoptera frugiperda*.

pairs were subsequently introduced into specialized mating cages, designed to promote copulation and oviposition, thereby ensuring a continuous and reliable supply of eggs for ongoing experimental studies.

Preparation of plant extracts

The plant extracts were prepared following the method described by Sarda *et al.*, 1986. Fresh materials from six different plant species were carefully collected, thoroughly cleaned to remove any surface impurities, and then spread on a plastic sheet for shade drying over three weeks to preserve their active phytochemicals. After complete drying, the plant materials were finely ground using an electric grinder and sieved through a 20 μm mesh to ensure a uniform particle size is 20 μm , promoting consistency in subsequent analyses. For extraction, 100 g of the powdered plant material was added to 500 mL of distilled water in a conical flask. The flask was tightly covered with aluminum foil and manually agitated daily for one week to enhance the solubilization of bioactive compounds. After this period, the mixture was filtered to remove residual plant material, and the resulting filtrate was transferred to a fresh conical flask. The filtrate was then concentrated at 78°C to evaporate the solvent (ethanol), yielding the crude plant extract, which served as the final product for subsequent bioassays.

Green synthesis of nanoparticles

Six different botanical extracts, including *Datura stramonium*, *Azadirachta indica*, *Zingiber officinale*, *Allium cepa*, *Nicotiana tabacum* and *Mentha arvensis*, were utilized to synthesize silver nanoparticles (AgNPs) for effective management of fall armyworm infestations. These nanoparticles had an average particle size of 20 nm, providing a high surface area and enhanced bioactivity. The synthesis commenced by gently heating 300 ml of distilled water in a pan for 15 to 20

minutes, just until the formation of small bubbles indicated the onset of boiling. The finely powdered plant extracts were then introduced into the heated water, producing a light green mixture. After cooling and filtering to remove residual plant material, a silver nitrate (AgNO_3) solution was prepared by dissolving a 1mM AgNO_3 (0.085 gm) in 500ml of distilled water. The reduction of the silver nitrate was achieved by gradually adding 15 ml of the prepared plant extract to the boiling AgNO_3 solution, followed by continuous stirring for an additional 10 minutes. This step facilitated the rapid formation of AgNPs, typically indicated by a color change from light green to yellowish-brown, confirming successful nanoparticle synthesis. The final AgNO_3 stock solution had a concentration of 200 ppm, making it suitable for subsequent bioassays and application against fall armyworms.

UV Vis spectral analysis.

The UV Vis absorption spectrum indicated a size of approximately 400 nm. This feature of the silver nanoparticles suggested that the synthesized nanoparticles exhibited polydispersity.

Pesticidal effect of silver nanoparticles

Stock solutions of silver nanoparticles (AgNPs) synthesized from various botanical sources were serially diluted with deionized water to achieve specific concentration ranges tailored to each plant extract: *Azadirachta indica* and *Datura stramonium* at 1, 2, 3, 5, 10, and 20 ppm; *Nicotiana tabacum* and *Allium cepa* at 3, 6, 12, 25, and 50 ppm; and *Mentha arvensis* and *Zingiber officinale* at 4, 8, 15, 30, and 60 ppm. The pesticidal efficacy of these silver nanoparticles (AgNPs) solutions was assessed using a leaf-dip bioassay. Uniform leaf discs (4–5 cm in diameter) were excised from host plants and immersed in the silver nanoparticles (AgNPs) solutions for 30 seconds. The discs were then air-dried under

sterile conditions to remove excess solution. Each treated leaf disc was placed in a sterile petri dish containing moistened filter paper to maintain humidity. To prevent cannibalism, a single 2nd or 3rd instar fall armyworm (*Spodoptera frugiperda*) larva was introduced into each petridish. Each treatment group included three replicates, with ten larvae per replicate. A negative control group was included, consisting of leaf discs treated with deionized water only. Larval mortality was recorded at 24 and 48 hours post-treatment. Larvae were deemed dead if they showed no response to gentle stimulation with a fine brush. Mortality percentages were calculated for each treatment group, and Abbott's formula

was applied to correct for any mortality observed in the control group.

RESULTS AND DISCUSSION

After the silver nanoparticles were applied, mortality was recorded at 24 hour and 48 hour intervals. The data presented in the table highlights the mortality rates of various plant extracts (Neem, Datura, Tobacco, Onion, Mint, and Ginger) at different concentration levels, ranging from control to the highest tested concentration of 60 ppm. Neem extract silver nanoparticles exhibited a significant dose-dependent increase in mortality, starting from 40 percent at 1 ppm and peaking at 85% at 20 ppm. This consistent rise indicates strong

Table 1. Combined mortality of fall armyworms with Abbott's correction.

S.No	Concentration (ppm)	Silver nanoparticle's mortality percentage					
		Neem (%)	Datura (%)	Tobacco (%)	Onion (%)	Mint (%)	Ginger (%)
1	Control	5	7	5	7	6	5
2	1 ppm	40	35	0	0	0	0
3	3 ppm	50	50	30	37	0	0
4	5 ppm	60	70	0	0	0	0
5	10 ppm	70	88	0	0	0	0
6	20 ppm	85	96	0	0	0	0
7	Control	0	0	5	7	0	0
8	3 ppm	0	0	30	37	0	0
9	6 ppm	0	0	35	50	0	0
10	12 ppm	0	0	50	55	0	0
11	25 ppm	0	0	68	60	0	0
12	50 ppm	0	0	75	65	0	0
13	Control	0	0	0	0	6	5
14	4 ppm	0	0	0	0	35	25
15	8 ppm	0	0	0	0	42	38
16	15 ppm	0	0	0	0	68	48
17	30 ppm	0	0	0	0	80	65
18	60 ppm	0	0	0	0	88	73

bioactivity even at lower concentrations, making Neem a promising candidate for nanoparticle-based biopesticide formulations. Datura extract silver nanoparticles showed the highest mortality among all the tested plant extracts, achieving 35% at 1 ppm and reaching a maximum of 96% at 20 ppm. Tobacco and Onion extracts silver nanoparticles exhibited moderate effectiveness, with mortality rates starting at 5% in the control and reaching up to 75% and 65% respectively at 50 ppm. This gradual increase suggests that these extracts may require higher doses to achieve comparable efficacy to Neem and Datura. Mint and Ginger extract silver nanoparticles displayed unique response patterns. Mint showed a significant increase in mortality from 6% (control) to 88% at 60 ppm, reflecting potent insecticidal activity at higher concentrations. Ginger, while effective, demonstrated a slightly lower range, starting at 5% (control) and peaking at 73% at 60 ppm.

Statistical Analysis

The ANOVA analysis yielded an F-statistic of 0.61 with/ a corresponding p-value of 0.6934, indicating that there is no statistically significant difference in the corrected mortality rates among the six plant extracts (Neem, Datura, Tobacco, Onion, Mint, and Ginger) at a 95% confidence level ($p > 0.05$). This result suggests that the observed variations in mortality are likely due to random experimental

variation rather than a true difference in the efficacy of the tested plant extracts.

The LC_{50} (Lethal concentration for 50% mortality) values presented in Table. 2 indicate the relative toxicity of various plant extracts used for pest control. Lower LC_{50} values correspond to higher toxicity, reflecting the potency of each extract against the target organism. With an LC_{50} value of 1.88 ppm, Datura showed the highest toxicity and the lowest concentration needed to reach 50% mortality. With LC_{50} of 2.61 ppm, Neem came up second, demonstrating its well-established insecticidal qualities. With an LC_{50} of 6.63 ppm, Mint demonstrated moderate toxicity and took third place. With LC_{50} levels of 9.43 ppm and 10.55 ppm, respectively, Tobacco and Onion came next. Despite their effectiveness, these extracts probably need larger concentrations to achieve deadly doses, perhaps because they contain less bioactive chemicals than Datura and Neem. Ginger exhibited the lowest toxicity, with an LC_{50} of 14.91 ppm, suggesting a comparatively milder impact on the target organism.

In Fig.2, Datura and Neem silver nanoparticles exhibit the highest insecticidal efficacy at lower concentrations, indicating strong potency. Tobacco and Onion silver nanoparticles demonstrate moderate activity, requiring higher doses for effectiveness. Mint and Ginger silver nanoparticles are less toxic

Table 2. LC_{50} Values of plant extract-synthesized silver nanoparticles against fall armyworm.

Sr.No.	Silver Nanoparticles	LC_{50} (ppm)	Toxicity Rank
1	Datura	1.88	1 st (Highest toxicity)
2	Neem	2.61	2 nd
3	Mint	6.63	3 rd
4	Onion	9.43	4 th
5	Tobacco	10.55	5 th
6	Ginger	14.91	6 th (Lowest toxicity)

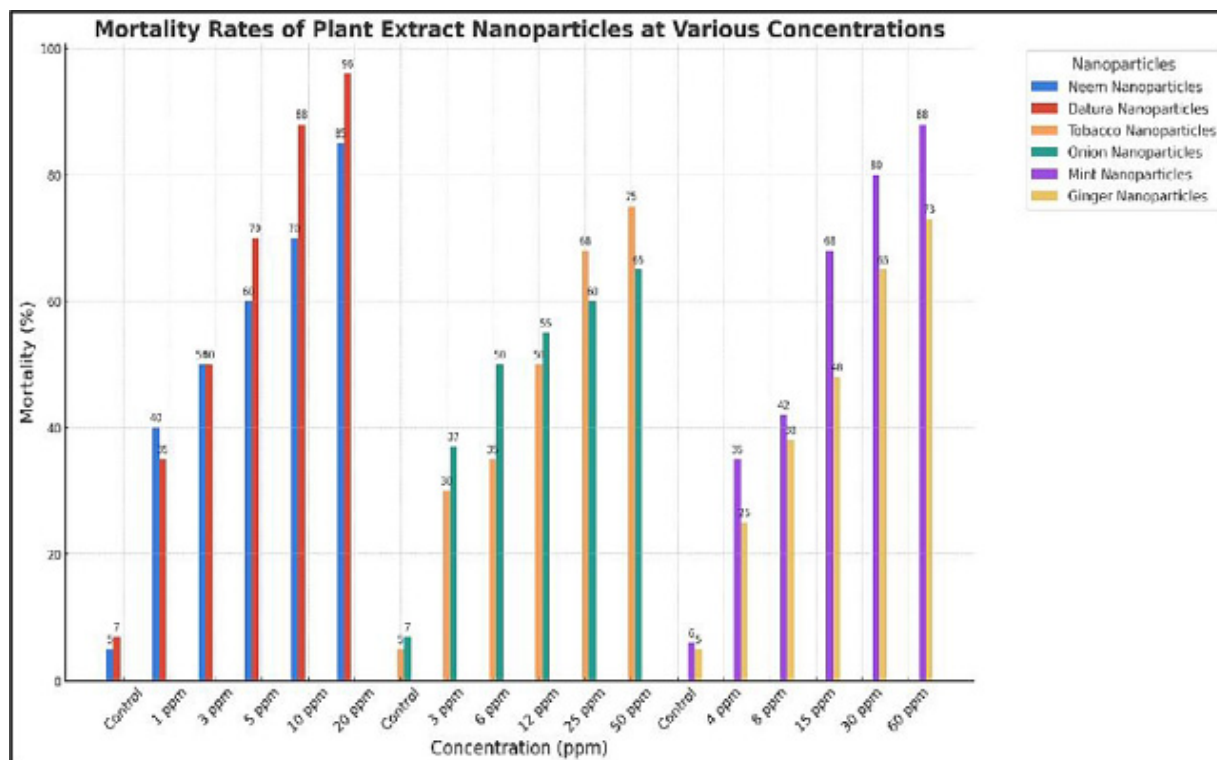


Fig. 2. The mortality rates of six different plant extract nanoparticles (Neem, Datura, Tobacco, Onion, Mint, and Ginger) at various concentrations against the fall armyworm

but remain effective at higher concentrations, making them suitable for use in high-dose biopesticide applications.

Overall, the results indicate that Datura silver nanoparticles possess the most potent insecticidal activity among the tested extracts, closely followed by Neem and Mint silver nanoparticles. The relatively high mortality rates at lower concentrations (e.g., 1 ppm for Neem and Datura) suggest that these silver nanoparticles may be effective even at reduced doses, potentially reducing environmental impact and production costs. In contrast, Ginger and Onion silver nanoparticles, while effective, may require higher doses to achieve comparable mortality rates, potentially limiting their cost-effectiveness in large-scale applications.

These results align with the findings of Sanchis and Bourguet (2008), Pascoli *et al.*,

(2020), and Reed *et al.*, (2001), who reported an 84% mortality rate in Lepidoptera and cotton pests when utilizing Neem silver nanoparticles. Additionally, Gulzar *et al.*, (2020) and Umair *et al.*, (2020) applied Datura plant extracts and silver nanoparticles to *Trogoderma granarium* and observed a mortality rate of 67% within 72 hours. The differences in mortality rates may be linked to the various types of insect species utilized in the studies related to silver nanoparticles.

CONCLUSION

Among the plant-based silver nanoparticles tested, *Datura* and *Neem* exhibited the highest insecticidal potency against the target pest, achieving substantial mortality even at low concentrations (1–20 ppm), with the lowest LC_{50} values of 1.88 ppm and 2.61 ppm, respectively. This indicates strong bioefficacy and high potential for the

development of cost-effective biopesticides. Mint nanoparticles ranked third, demonstrating 88% mortality at 60 ppm and a moderate LC_{50} of 6.63 ppm. In contrast, the silver nanoparticles of Tobacco, Onion, and Ginger displayed comparatively lower toxicity, requiring higher concentrations to elicit similar effects, with LC_{50} values of 9.43 ppm, 10.55 ppm, and 14.91 ppm, respectively. Notably, Ginger was the least potent. Although one-way ANOVA ($p = 0.6934$) did not reveal statistically significant differences in overall mortality across treatments at the 95% confidence level, the consistent trend in LC_{50} values and concentration-dependent mortality supports differential toxic efficacy. The findings of the present study indicated that both the *Datura* and *Neem* silver nanoparticles exhibited notable biocidal effects on the fall armyworm. Additionally, it is advisable to incorporate these nanoparticles in combination with environmentally sustainable methods for the effective management of fall armyworms.

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DETERMINATION OF THE PHYTOCHEMICALS, ANTIOXIDANTS AND ANTIMICROBIAL PROPERTIES OF A RARE AND ENDEMIC PLANT *XANTHOPHYLLUM ARNOTTIANUM* WIGHT OF WESTERN GHATS, INDIA

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ABSTRACT

Xanthophyllum arnottianum Wight is a rare and endemic plant and is having limited distribution in biodiversity hot spot of Western Ghats of India. The study was conducted in the year 2023 to document the phytochemical constitution, antioxidant potential and antimicrobial properties of the leaves of this plant. Study revealed that *Xanthophyllum arnottianum* Wight is a rich source of many of the phytochemicals of which flavonoids composition was found to be 0.08mg/ml-1, tannins 0.57mg/ml-1. Total antioxidant capacity was found to be 0.33mg/ml-1 and enzymatic antioxidants (peroxidase-0.12mg/ml-1). GCMS analysis identified ten principal in the leaf extracts of *X. arnottianum*. This species of plant is recognized for its significant phytochemical profile of importance such as 3,5-Dimethoxyacetophenone, Neophytadiene, Phytol and Acetate. Antimicrobial properties of the methanolic extract of the plant indicated that this plant possesses antibacterial activity against all the three tested microorganisms (*Klebsiella pneumoniae* (8mm), *Staphylococcus aureus* (20mm) and *Escherichia coli* (7mm)). This research serves as an initial endeavour that shed light into the wealth of novel biomolecules that are remained as hidden in the plant kingdom.

Keywords: Antioxidants, Antimicrobial propertles, Endemic plants, Phytochemicals, GCMS

INTRODUCTION

Phytochemicals are the compounds produced by plants as secondary metabolites that may exhibit therapeutic effects and this includes alkaloids, glycosides, terpenoids and phenols. Phytochemicals in plants can be used for their therapeutic purposes or as precursors for the development of new pharmaceuticals. Plants used for the treatment of various

diseases contribute to the discovery of new pharmaceuticals and more than 20,000 plant species used in traditional medicines. Many of the active compounds derived from medicinal plants can be effective in the treatment of various infectious diseases that affects humans and animals. Plants possess many free radical scavenging molecules like phenolics, flavonoids and secondary

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metabolites that possess antioxidant properties. Of the important phytochemicals in plants, the alkaloids exhibit important pharmacological uses such as antibacterial, antimalarial, anticancer properties, tannins which are antiseptics in nature, flavonoids exhibit anti-allergic, anti-inflammatory, antioxidant, antimicrobial properties; saponins help plants against microbial attack. Terpenoids are aromatic and used in foods and pharmaceutical industries while the phenols are precursor to a large array of drugs. Antioxidants that possess free radical scavenging capabilities have role in prevention and therapeutic role in many diseases.

As phytochemicals are secondary metabolites integral to the plant's defence mechanisms. Phytochemicals help the plants to protect it from various microorganisms, insects and herbivores. These constituents occur naturally in all parts of plants such as leaves, stem, and roots. According to WHO, a significant portion (65-80%) of the population still relies on traditional plant-based remedies for the primary healthcare necessities (Shyma *et al.*, 2012). Chemical compounds derived out of plants have wider use in many fields such as agriculture, production of drugs, flavour and fragrances, dyes and pigments, pesticides and food additives. Most of the synthetic drugs that being used in medicines and commercial applications are chemical modifications or copies of naturally obtained substances. The interest to find out more chemical compounds from plants is increasing as a number of infectious agents are becoming more resistant to available antimicrobial compounds. In this context, It is therefore necessary to develop novel drugs derived from plant-based secondary metabolites.

Xanthophyllum arnottianum Wight is one of the 94 species of in the genus *Xanthophyllum* and belongs to the family

Polygalaceae. It is a large shrub up to 8-meter tall, grey, smooth bark with orange blaze. These plants occur in evergreen to semi-evergreen forest up to 1200m. It is endemic to Western Ghats. It is distributed in Kerala, Karnataka, Tamil Nadu. As this plant is having restricted distribution and limited to a certain pockets in Southern Western Ghats, seen in Chooralmala region and Ghast section of Thamarassery. However, there exist a limited understanding of this plant's chemical composition that necessitates further investigation. In this context; the aim of this study was focused on the exploration of the chemical constitution of the plant, antioxidant components and antimicrobial properties.

MATERIAL AND METHODS

Plant Sample Collection and Identification

Fresh leaves of the study material - plant *X. arnottianum* Wight was collected from the Chooralmala region of Wayanad district, Kerala – 673 577 and the GPS reading of the location was N-11.5006 °. E76.1581°. The identity of the specimens was confirmed using regional flowering plant floras and also the voucher materials of the specimens were compared. In addition to that further consultations were also held with specimens deposited at MH (Madaras Herbarium situated at BSI, Coimbatore). In addition to that the taxonomists of the institution authenticated the specimen as *X. arnottianum* Wight. The study was conducted at M.S. Swaminathan Research Foundation Community Agrobiodiversity Centre, Wayanad, Kerala, India.

Sample Preparation and Extraction

The fresh leaf sample of about 1 Kg were collected in polythene bags and taken to the laboratory. The leaves were surface sterilized and washed with clean sterile water. Then the leaves were shade dried. After drying the

leaves were powdered using mechanical blender and then transferred into air tight container. For the extraction, methanol was taken as solvent and the procedures for the same was in line with those mentioned by Jigna and Sumitra (2007).

Qualitative Phytochemical Screening

The chemical composition of the extract was determined through various qualitative chemical tests. For phytoconstituents like Alkaloids two tests were conducted, Mayer's Test and Wagner's Test as mentioned by Raaman, 2006, were taken. For the detection of flavonoids, Alkaline reagent test was employed. The method as mentioned by *Shamaila et al.*, 2009, was employed for the detection of tannins and saponins were tested with Foam test. Ferric chloride test was employed to detect phenols and was described by Raaman, 2006. For the detection of proteins (Millon's Test) and carbohydrates (Molish's Test) methodology mentioned by Sadasivam and Manickam., 1991 were used. For Cardiac glycosides- Keller-Killiani test used that was mentioned by De *et al.*, 2010 was adopted.

Quantitative Estimation of Phytochemicals

The leaves of the plant contained certain phytochemicals that were subsequently quantified using various methods. The total carbohydrate present in the sample was tested using Anthrone method as described in the book by Sadasivam and Manickam, 1991. Flavanoid and tannic acid compositions were determined by the adoption of procedures mentioned by Supratim and Anwar, 2008.

Determination of Antioxidants

As the third step of the study, the antioxidant capabilities of the leaves of *X. arnottianum* were analyzed. Both enzyme

and non-enzymatic antioxidants were studied. The Total Antioxidant capacity was assessed using Phosphomolybdenum method. The enzymatic antioxidants such as Peroxidase were assessed and H₂O₂ Scavenging abilities were also measured using the method mentioned by Supratim *et al.*, 2008.

Screening for the Antibacterial Activity

The antibacterial activity of leaves of *X. arnottianum* Wight was determined against selected cultures of microorganisms kept in the microbial repository of MSSRF Community Agrobiodiversity Centre. The microorganisms collected were *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Escherichia coli*. Disc diffusion method was used to test the effectiveness of the leaf extract (George *et al.*, 2007).

Gas ChromatographyMass Spectrometry (GC-MS)

The Gas chromatography-Mass spectrometry (GCMS) analysis of the sample was performed using a GC-MS (Model; QP 2010 series, Shimadzu, Tokyo, Japan) equipped with a VF-5ms fused silica capillary column of 30m length, 0.25mm diameter, and 0.25mm film thickness. For GC-MS detection, an electron ionization system with ionization energy of 70eV was used. Helium (99.99%) was utilized as the carrier gas at a constant flow rate of 1.51ml/min+. Interpretation of mass spectrum of extracts of the plant were conducted using the database of National Institute of Standard and Technology (NIST) library which is having more than 62,000 spectral patterns. The spectrum of the chemical compounds was matched with the spectrum of National Institute of Standard and Technology (NIST) library database. Procedure followed by Sridharan *et al.*, 2011 was adopted for this study.

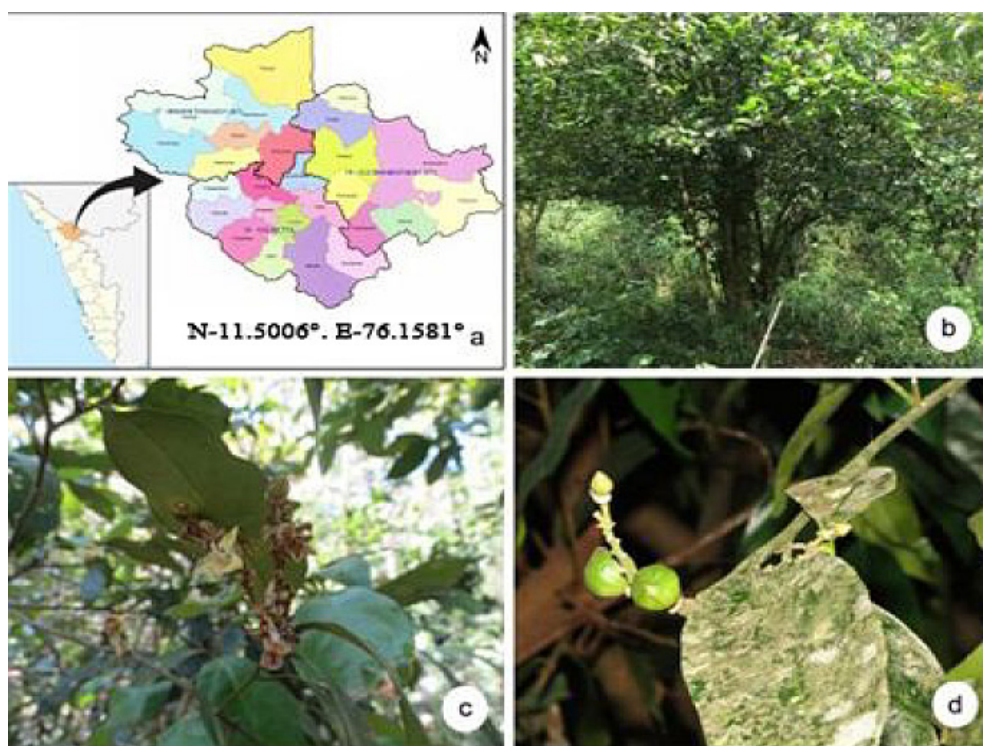


Fig. 1. Map of Kerala with location details and the habitat of the RET plant *X. arnottianum*.

RESULTS AND DISCUSSION

Sample Collection

The fresh leaves of *X. arnottianum* Wight were collected from Chooralmala region of Meppady, Wayanad district and the GPS location details of the place of collection was

as N-11.5006 °. E76.1581° as described in the fig.1, where,

a= Map of Kerala Showing the specific location of Wayanad (not to scale). b= The tree *Xanthophyllum arnottianum* Wight, c= Flower of the plant and d= Fruit of the plant.

Table 1. Qualitative determination of the phytochemicals present in the leaves of *X. arnottianum* Wight.

Sl.No.	Phytochemical component	<i>Xanthophyllum arnottianum</i> Wight
1	Carbohydrates	+
2	Protein	-
3	Alkaloid	-
4	Flavonoid	+
5	Tannin	+
6	Saponin	+
7	Phenol	-
8	Glycosides	+

'+' indicate the presence of the phytoconstituent and '-' indicates the absence of the phytoconstituent.

Table 2. Determination of total carbohydrates, Flavonoids and Tannins

Sl. No.	Sample	Quantity (mg/ml ⁻¹)
1	Total Carbohydrates	0.036±0.0
2	Flavonoids	0.08±0.0
3	Tannins	0.52±0.04

*Mean± standard deviation, n=3.

Qualitative Analysis of Phytochemicals

For the qualitative analysis, sample extracted with solvent methanol of *X. arnottianum* Wight was used. The results showed positive for compounds such as carbohydrates, flavonoids, tannins, saponins, glycosides while protein, alkaloids, phenols gave negative results as given in the table 1.

Quantitative Estimation of Phytochemicals

Methanolic extracts of leaves of *X. arnottianum* Wight showed differences in quantities of phytochemicals present in them.

Determination of Total Carbohydrates

The total carbohydrates content of leaves of *X. arnottianum* was 0.038mg/ml⁻¹. The total carbohydrate content of the sample is shown in Table 2.

The total Flavonoid content of leaves of *X. arnottianum* was 0.08mg/ml⁻¹ and the tannin content in leaves are measured to be 0.57mg/ml⁻¹. *X. arnottianum* possesses significant levels of constituents like carbohydrates, flavonoid, tannin, saponin and glycosides. At the same time, protein, alkaloids and phenol were absent. The total flavonoid content of leaf of *X. arnottianum* was 0.08mg/ml⁻¹. Similar results were reported in *Polygala arillata* Buch-Ham. ex D. Don leaf extract and their total flavonoid content was reported to be 0.04mg/ml⁻¹ (Radhamani and John, 2016). Both of the plants were included in the family Polygalaceae. The total flavonoid content of

leaf extract of *X. arnottianum* was in line with the total flavonoid content of *Polygala arillata*. Flavonoids are chemical compounds reported to have wide range of medicinal properties including anti-viral/bacterial, anti-inflammatory, cardioprotective, anti-diabetic, anti-cancer, anti-aging and these compounds have garnered significant scientific interest and are extensively supported by a substantial body of research. To date, the scientific literature documents over 9,000 distinct flavonoids.

In the current investigation the total tannin content of leaf of *X. arnottianum* was 0.52±0.04mg/ml⁻¹. Similar tannin content was reported in *Polygala arillata* Buch-Ham. ex D. Don, leaf extract and their total tannin content was found to be 0.32mg/ml⁻¹. As these two plants are belonging to the same family Polygalaceae tannin distribution have a relation with the family of plants and its distribution. Indian traditional medicines are well reputed for its knowledge on the use of tannin composition in many of its formulations. The flavonoids and tannin composition of these plants could be better utilized for its pharmaceutical and other industrial applications.

GC-MS Analysis

The GC-MS analysis was conducted to identify various compounds present in the ethanolic leaf extract of *X. arnottianum*. Ten principal compounds were identified from the sample. The main compounds were Tetrakis (2,3-Ditert-Butylphenyl)-4,4'-Biphenylene Diphosphonate (47.54%), 2-tert-Butyl-4,6-

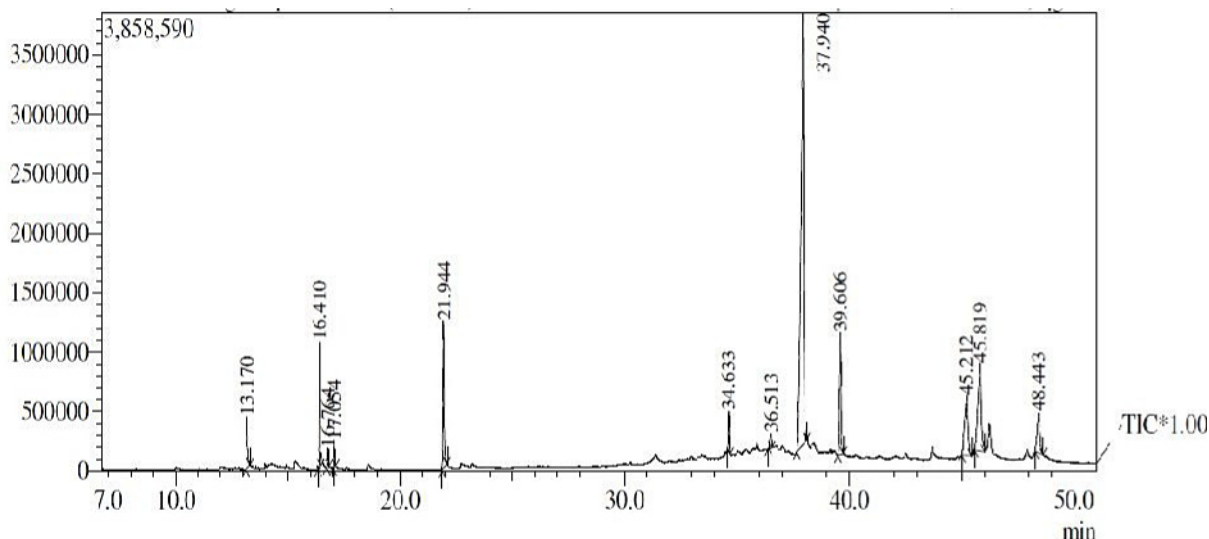


Fig. 2. Chromatogram of the plant extract of GCMS analysis

bis(3,5-di-tert-butyl-4-hydroxybenzyl) Phenol (13.19%), 2-Tert-Butyl-4,6-Bis(3,5-Di-Tert-Butyl-4-Hydroxybenzyl) Phenol (9.09%), Isophytol, acetate (7.35%), Vitamin E (7.18%). The maximum peak showing compound is Tetrakis(2,3-Ditert-Butylphenyl)-4,4'-Biphenylene Diphosphonate (47.54%). The minimum peak showing compound is 3,7,11,15-Tetramethyl-2-hexadecen-1-ol

(0.65%). The chromatogram was given as Fig. 2. and the major compounds present in the sample was given as table 3.

Ten principal compounds were identified in the ethanolic extract of *X. arnottianum* Wight by GC-MS profiling. The major components are Tetrakis (2,3- Ditert- Butylphenyl)- 4,4'-Biphenylene Diphosphonate (47.54%), 2- tert-

Table 3. The major chemical compounds present in the leaf extract (methanol) of *X. arnottianum* Wight

Peak	R.Time	Area	Area%	Height	Height%	Name	Base m/z
1	13.170	1499705	2.48	438333	4.46	3,5'-Dimethoxyacetophenone	180.10
2	16.410	2421680	4.00	1057913	10.77	Neophytadiene	68.05
3	16.764	396647	0.65	159747	1.63	3,7,11,15- Tetramethyl -2- Hexadecen-1-ol	82.05
4	17.054	597666	0.99	228600	2.33	Phytol, Acetate	71.05
5	21.944	4454073	7.35	1235878	12.58	Isophytol, Acetate	71.05
6	34.633	919434	1.52	342050	3.48	Squalene	69.05
7	36.513	660935	1.09	126938	1.29	Beta- Sitosterol	55.05
8	37.940	28790903	47.54	3633482	36.98	Tetrakis (2,3- Ditert- Butylphenyl)-4, 4'Biphenylene Diphosphonate	57.10
9	39.606	4349973	7.18	1022509	10.41	Vitamin E	165.10
10	45.212	5504834	9.09	501934	5.11	2-Tert-Butyl-4,6-Bis (3,5-Ditert- Butyl-4-HydroxyBenzyl) Phenol	57.10

Butyl-4,6-bis(3,5-di-tert-butyl-4-hydroxybenzyl)phenol (13.19%), 2-Tert-Butyl-4,6-Bis(3,5-Di-Tert-Butyl 4-Hydroxybenzyl) Phenol (9.09%), Isophytol, acetate (7.35%), Vitamin E (7.18%), Neophytadiene (4%), 3,5-Dimethoxyacetophenone (2.48%). Among these compounds 4-Biphenylene Diphosphonate can be used as an antioxidant. 2-tert-Butyl-4,6-bis(3,5-di-tert-butyl-4-hydroxybenzyl)phenol can be used as biopesticides and could also be further tested for its pharmacological properties. Isophytol is used in the fragrance industry and used in cosmetics, shampoos, toilet soaps and detergents. The presence of acetate in plant extracts suggests potential applications in various cosmetic and pharmaceutical industries for product processing and preservation. Due to the antioxidant activity of vitamin E in plants have a major role in imparting tolerance to several abiotic stresses. Neophytadiene has good analgesic, antipyretic, anti-inflammatory, antiarthritic and anticancer activities. 3,5-Dimethoxyacetophenone used as anticancer agents. Similar study was reported in *Polygala chinensis* L. Fourteen compounds were identified from ethanolic extract of that plant through GC-MS studies.

Determination of Antioxidants

The leaves of *X. arnottianum* Wight were then taken for testing its antioxidant content. The results obtained are shown in table 4. The total antioxidant capacity was determined. Further investigations were conducted to

assess the plant's enzymatic and non-enzymatic antioxidant components, including peroxidase and hydrogen peroxide (H_2O_2) scavenging activity.

The total antioxidant capacity of *X. arnottianum* is 0.28 ± 0.04 mg/ml. The peroxidase activity is 0.15 ± 0.03 mg/ml-1 and H_2O_2 scavenging activity of *X. arnottianum* is 0.62 ± 0.04 mg/ml-1. The results indicated that plant has antioxidant properties.

The total antioxidant capacity of leaf extract of *X. arnottianum* Wight was measured as 0.28 ± 0.04 mg/ml-1. Antioxidant potential of this plant demonstrated to possess important as many of the life-threatening diseases (cardio vascular and neuro degenerative) preventing medicines could be developed out of this plant specimen. The Hydrogen peroxide scavenging activity of *X. arnottianum* was 0.62 ± 0.04 mg/ml-1. The study also revealed the peroxidase activity of leaf extract of *X. arnottianum* Wight and was measured to be 0.15 ± 0.03 mg/ml-1. Peroxidase have a significant role in the reinforcement of cell wall, enhanced production of reactive oxygen species as signal mediators and antimicrobial agents.

Antimicrobial Activity

The antimicrobial efficacy of the plant extract was assessed against three distinct clinical pathogens namely *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Escherichia coli* and are given in table 5.

Table 4. Antioxidants Composition of the Leaves of *X. arnottianum* Wight

Sl.No.	Test	Quantity (mg/ml ⁻¹)
1	Total antioxidant capacity	0.28 ± 0.04
2	Peroxidase	0.15 ± 0.03
3	H_2O_2 scavenging activity	0.62 ± 0.04

*Mean $\pm$ standard deviation, n=3

Table 5. Antimicrobial properties of crude extract of *X. arnottianum* against selected microorganism.

Sl.No	Name of the organism	Zone of inhibition(mm)			
		Plant extract concentration and Inhibition zone in mm			
		25%	50%	75%	100%
1	<i>Klebsiella pneumoniae</i>	5.3±0.47	7.3±0.16	7.5±0.41	8.3±0.14
2	<i>Staphylococcus aureus</i>	7.2±0.24	9.4±0.47	13.3±0.42	20.4±0.45
3	<i>Escherichia coli</i>	5.4±0.43	6.4±0.28	7.6±0.45	7.4±0.46

*Mean± standard deviation, n=3

The plant extract demonstrated the most potent antimicrobial activity against *Staphylococcus aureus*, with subsequent effectiveness against *Klebsiella pneumoniae* and *Escherichia coli*. The measurements were *Staphylococcus aureus* showed 20mm followed by *Klebsiella pneumoniae* with 8mm and least inhibition was to the *Escherichia coli* with 7mm. These maximal inhibition rates were achieved at the highest tested concentration of the plant extract, which was 100 percent.

The ethanolic extract of *X. arnottianum* Wight demonstrated antimicrobial activity against three clinical pathogens that were evaluated. Methanolic extract showed zone of inhibition against *Klebsiella pneumoniae* was found to be 8mm, against *Staphylococcus aureus* was 20mm and against *Escherichia coli* was 7mm. The observed inhibition values were all attained at the highest tested concentration of the plant extract, i.e., 100 percent. Similar study was reported in *Polygala javana* plant in its petroleum extract against pathogens such as *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Salmonella typhi* (Uthiraselvam et al., 2012).

CONCLUSION

The study revealed the chemical constitution, antioxidants and antimicrobial

properties of the plant *X. arnottianum* Wight is first of its kind attempted to explore its uses and economic values. The study throws light on many aspects of the composition of the plant especially its composition of flavonoids (0.08±0.0mg/ml-1), tannins (0.52±0.04mg/ml-1) and antioxidants like peroxidase (0.15±0.03 mg/ml) and H₂O₂ scavenging activity of 0.62±0.04mg/ml. The plant extract demonstrated inhibitory effects against all microorganisms subjected to testing in which highest inhibition rate was shown by *Staphylococcus aureus* with 20mm followed by *Klebsiella pneumoniae* with 8mm and *E.coli* with 7mm. Detailed analysis with sophisticated equipment like GCMS reveal that as many as 10 important chemicals of importance was present in this plant in which a few has bio pesticidal properties (6- bis(3,5-di-tert-butyl-4-hydroxybenzyl)phenol), antioxidant activities and other compounds of commercial interests.

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Amritha K.V., P.M. Salim, P.J. Jayesh and Joseph John .2025. Determination of the Phytochemicals, Antioxidants and Antimicrobial properties of a Rare and Endemic Plant *Xanthophyllum Arnottianum* Wight of Western Ghats, India. The Journal of Research ANGRAU, 53(2), 36-44.<https://doi.org/10.58537/jorangrau.2025.53.2.05>

SENSORY ATTRIBUTES AND BIOCHEMICAL CHARACTERISTICS OF UNDERUTILIZED FRUIT, *PRUNUS NAPAULENSIS* (SER.) STEUD

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ABSTRACT

This study conducted in 2023, provides a comprehensive analysis of *Prunus napaulensis* (Ser.) Steud, focusing on its physical, biochemical, and sensory attributes. It aims to explore the biochemical composition and sensory profile to provide insights to its nutritional and bioactive compounds and its consumer preferences. Phytochemical screening in aqueous, ethanol and methanol extracts revealed the presence of various bioactive compounds such as flavonoids, tannins, phenols, anthocyanin and alkaloids. Antioxidant activity (DPPH assay) indicated varying degrees of radical scavenging activity in aqueous, ethanol and methanol solvents with IC₅₀ values recorded at 46.90 µg/mL, 144.62 µL/mL and 51.68 µL/mL respectively. The fruit exhibited characteristic physical dimensions and biochemical composition with good amounts of iron (3.03 ± 0.15 mg), calcium (80 ± 2 mg), potassium (371.33 ± 2.52 mg), magnesium (29.33 ± 2.52 mg), zinc (2.6 ± 0.45 mg), vitamin C (49.36 ± 3.92 mg) and significant levels of anthocyanin (244 ± 58.59 mg) highlighting its nutritional value. The Descriptive sensory analysis of the fruit provided an insight into the appearance, colour, aroma, flavour, firmness, taste and juiciness of the fruit contributing to a comprehensive understanding of its sensory attributes and consumer preferences. Thus, the study underscores the significance of the fruit and its potential commercial value and further research and exploration in both the food industry and healthcare sectors.

Keywords: Antioxidant activity, Biochemical composition, Descriptive sensory attributes, Phytochemicals, *Prunus napaulensis*.

INTRODUCTION

Prunus napaulensis (Ser.) Steud, also known as Sohiong, is a flavourful and nutritious fruit indigenous to the eastern Himalayas, including regions of Nepal, Myanmar and China. In India, it thrives in areas such as Meghalaya, Manipur, Assam, Nagaland, and Arunachal Pradesh wherein, this cherry-like fruit is consumed in its raw form or as jam and

wine. The fruit boast high levels of vitamins, minerals and antioxidants. Additionally, it possesses medicinal properties with its leaves having diuretic effects and astringent berries. Despite its nutritional richness and culinary potential, it remains underutilized due to poor or limited storage facilities and processing techniques which lead to significant post-harvest losses. However, *Prunus napaulensis*

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(Ser.) Steud holds a potential for broader consumption and application in food industry for value added products as well as extraction of natural edible colorant. Studies show that the extracted colour when incorporated into squash and jam can remain stable for up to one year. Furthermore, the appealing purple colour of the fruit from the pulp and juice is being utilized in the production of Ready to Serve (RTS) products and cherry wine (Aparna *et al.*, 2018; Rymbai *et al.*, 2016).

This drupe matures between the months of August-November depending on the altitude. They are green to pink during the early stage and turn to dark purple upon ripening and categorized based on variations in size of fruit: big fruit size (7.91g) and small fruit size (3.98g) (Rymbai *et al.*, 2016). Bioactive compounds including naringenin, palmitoleic acid, rutin, quinic acid and quercetin have been extracted from various *Prunus* species found in China (Aparna *et al.*, 2018). Bioactive compounds exhibit potential radical scavenging activity, which can prevent the development and advancement of degenerative diseases. *Prunus napaulensis* (Ser.) Steud. is an excellent source of vitamin C, polyphenols and anthocyanin (Vivek *et al.*, 2018).

This underutilized fruit can be extensively utilised based on the available studies on its bioactive components in addition further needed studies on the sensory attribute and nutritional properties in the support of the utilization of the fruit in the product development and healthy consumption among consumers (Silva *et al.*, 2021). Top of Form. Hence the present study has been attempted at the analysis of sensory attributes and biochemical composition of *Prunus napaulensis* (Ser.) Steud.

MATERIAL AND METHODS

Fresh ripe fruits were collected from Ukhrul, Manipur, India. The fruits were washed

and cleaned to remove any dirt and separate the fruit from its stalk and leaves. The fruits were then kept at room temperature to remove the adhering water. The stone was separated from the fruit pulp; the fruit pulp was pulverized then freeze dried for further analysis. Chemicals used in the study were of analytical grade purchased from Beeline Scientific Company Pvt. Ltd.

Phytochemical Screening

Extract Preparation: The dried fruit sample was subjected to extractions with solvents; aqueous, ethanol and methanol; at ratio of 1:10 at 37°C for 24 h to obtain aqueous, ethanol and methanol extracts. The excess solvents were removed by rotary evaporator; the dried extract was stored at 4°C for further analysis.

The dried extracts were screened for the presence of phytochemicals such as Tannins, Flavonoids, Saponin, Anthraquinone, Anthocyanin, Steroids, Protein, Phenols, Polyphenol, Amino acids and Alkaloid using standard protocol (Balamurugan *et al.*, 2019).

Physicochemical and Nutritional Properties of *Prunus Napaulensis*(Ser.) Steud

Physical properties of fruit namely weight (g); length and diameter (mm), Stone weight (g), Stone length and diameter (mm) were recorded using Vernier calliper. Chemical and nutritional properties like moisture, carbohydrate, protein, crude fat, ash, pH, Total soluble solids, titratable acidity, minerals and ascorbic acid were analysed according to the AOAC methods, 2012. Anthocyanin was analysed according to the method proposed by (Li *et al.* 2017). Energy was calculated by factorial method (protein*4 + carbohydrate*4 + fat*9).

Sensory Attributes

Sensory attributes of *Prunus napaulensis* (Ser.) Steud was analysed by a

panel of 15 semi-trained members using a five point hedonic scale adapted from (Silva *et al.*, 2021). The attributes were classified according to the intensity and scored as 1 for the lowest intensity and 5 for the highest intensity. Descriptive attributes such as smoothness of the Epidermis, Colour intensity, Colour uniformity, Odour intensity, Flavour, taste (Sweetness, Acidic, Bitter, Astringency), Firmness (Force needed to crack the fruit) and Juiciness (Juice extracted from the fruit after chewing) of the fruit were analysed.

Colour Analysis

Colour analysis of a fruit is essential for insight and clarity of the visual appearance and potential applications in food industries as well as other industries such as pharmacy and cosmetics. The fruit colour attributes of *Prunus napaulensis*(Ser.) Steud fruit were quantified by Hunter colorimeter on account of CIELAB (1976) color space, which includes lightness (L*), red-green (a*) and yellow-blue (b*). Colorimeter equipped with D65 illuminant and standard observer at 10° was used to measure the colour parameters.

Antioxidant Activity of *Prunus Napaulensis* (Ser.) Steud

DPPH assay was based on (Bhusal *et al.*, 2020) with slight modifications. Extracts of aqueous, ethanol and methanol with varying concentrations of 10µL/mL, 50µL/mL, 150µL/mL, 250µL/mL, 350µL/mL, 500µL/mL and 750µL/mL were prepared. To ensure accurate measurement within linear range of the spectrophotometer, an aliquot of the extract solution was diluted to 1:4. 0.1 mL of the diluted sample was added to 3.9 ml of 0.1 mM DPPH solution and left to stand in dark for 30 mins at 37°C. Ascorbic acid was used as the standard for this assay. The IC₅₀ value of the extract samples was calculated by the log dose inhibition curve. The absorbance was measured at 517 nm and the DPPH radical

scavenging effect (%) was calculated from the following equation:

$$\% \text{ Inhibitory activity} = \frac{(A1-A2)}{A1} \times 100$$

Where,

A1= absorbance of control

A2= absorbance of testing sample solution

Statistical Analysis

Data were reported and expressed as mean±SD of triplicate observation.

RESULTS AND DISCUSSION

Phytochemical Screening

Aqueous, ethanol and methanol extracts of *Prunus napaulensis* (Ser.) Steud were subjected to qualitative screening of phytochemicals; the test reported the presence of secondary metabolites such as tannins, flavonoids, saponin, anthraquinone, anthocyanin, phenols, polyphenol and alkaloids in all three extracts as presented in the Table 1. This finding was in concurrence with the report stated by (Swier *et al.*, 2016).

Physicochemical and Nutritional Properties of *Prunus Napaulensis* (Ser.) Steud

Physical parameters such as weight, size of fruit and seed were measured using Vernier calliper and depicted in Table 2 revealing that the weight of the fruit was 6.30±1.25g; the size of fruit (length: 20.15±1.91mm and diameter: 20.30±1.39 mm); weight of the stone was 1.79±0.54g with the stone size; 13.73±1.82mm in length and 13.89±1.68mm in diameter. The measurements observed were within the range as reported by (Rymbaiet *al.*,2016; Vivek *et al.*, 2018). The physical parameters of *Prunus napaulensis*(Ser.) Steud fall within the range of dimension typical to plum, peach and cherry fruits evidencing *Prunus napaulensis* (Ser.) Steud belongs to the Rosaceae family (Rymbai *et al.*,2016; Vivek *et al.*,2018).

Table1. Phytochemical screening of extracts of *Prunus napaulensis*(Ser.) Steud

Phytochemicals		Solvents		
		Ethanol	Methanol	Aqueous
1.	Tannins	+	+	+
2.	Flavonoids	+	+	+
3.	Saponin	+	+	+
4.	Anthraquinone	+	+	+
5.	Anthocyanin	+	+	+
6.	Steroids	-	-	-
7.	Protein	-	-	-
8.	Phenol	+	+	+
9.	Polyphenol	+	+	+
10.	Amino acid	-	-	-
11.	Alkaloids	+	+	+

+ Present, - Absent

Table 3 presents the biochemical parameters (mean $\pm$ SD) of *Prunus napaulensis* (Ser.) Steud (*Sohiong*). Acidic pH of 3.73 ± 0.21 , titratable acidity of $0.8 \pm 0.04\%$ and total soluble solids (TSS) content measured at 10.66 ± 0.41 °Brix were recorded. The moisture content of the fruit was $81.51\% \pm 3.50$ indicating high moisture content which is a critical factor for determining the stability of the fruit which in turn aids in the selection of appropriate conditions and storage parameters during the development of new products. However, it was observed to be lower than that of plums and peaches (Rymbai *et al.*,

2016; Vivek *et al.*, 2018). Moderate energy content of 70.58 ± 0.71 Kcal was recorded, It also exhibited moderate amount of carbohydrates (13.2 ± 0.43 g), protein (3.06 ± 0.30 g) and low amount of fat (0.61 ± 0.08 g) and a good source of fibre (2.28 ± 0.59 g).

It nutritionally exhibited low amount of fat (0.61 ± 0.08 g), moderate amount of protein (3.06 ± 0.30 g) and carbohydrates (13.2 ± 0.43 g), and a good source of fibre (2.28 ± 0.59 g) and energy of 70.58 ± 0.71 Kcal. The fruit was notably rich in iron (3.03 ± 0.15 mg), calcium (80 ± 2 mg), potassium (371.33 ± 2.52 mg),

Table 2. Physical parameters of *Prunus napaulensis*(Ser.) Steud

Sl. No.	Physical parameters	Mean $\pm$ SD
1.	Weight of fruit (g)	6.30 ± 1.25
2.	Fruit length (mm)	20.15 ± 1.91
3.	Fruit diameter (mm)	20.30 ± 1.39
4.	Stone weight (g)	1.79 ± 0.54
5.	Stone length (mm)	13.73 ± 1.82
6.	Stone diameter (mm)	13.89 ± 1.68

magnesium (29.33 ± 2.52 mg), zinc (2.6 ± 0.45 mg), and vitamin C (49.36 ± 3.92 mg) and significant levels of anthocyanin (244 ± 58.59 mg) indicating potential properties. Vitamin C as well as minerals values mentioned above was observed to be higher compared to varieties of peach and plum (Rymbai *et al.*, 2016; Vivek *et al.*, 2018). The anthocyanin content was found to be lower than that of blackberries but higher when compared to raspberries (Vivek *et al.*, 2018). These biochemical properties highlight the nutritional and potential health benefits of the fruit, *Prunus napaulensis* (Ser.) Steud.

Descriptive Sensory Profile of *Prunus Napaulensis* (Ser.) Steud

The descriptive sensory analysis of *Prunus napaulensis* (Ser.) Steud was analyzed

by 15 semi-trained panel members using by five point hedonic scales. The descriptive sensory as depicted in Fig. 1 and plate 1 reported a favorable evaluation of its external appearance; smoothness (epidermis) with a score of 4.2 ± 0.86 . The intensity of the dark purple color was reported to be 4.86 ± 0.35 indicating a vibrant and visually appealing hue, however, the colour uniformity scored lower (4.06 ± 0.79) due to the variability in coloration. Colours are a primary indicator for the freshness of a fruit while firmness is recognized as a crucial textural attribute for assessing fruit quality. The odour intensity of the fruit and flavoured garnered a score of 3.13 ± 1.24 and 3.73 ± 1.09 indicating a moderate aroma and a moderate to flavourful taste profile. The sweet taste score was recorded to be lower 1.53 ± 0.83 as compared to acidic taste score

Table 3. Physico chemical and nutritional properties of *Prunus napaulensis*(Ser.) Steud

Sl. No.	Biochemical Parameters	Mean $\pm$ SD
1.	pH	3.73 ± 0.21
2.	Titratable Acidity (%)	0.8 ± 0.04
3.	TSS ($^{\circ}$ Brix)	10.66 ± 0.41
4.	Total Sugar (g)	5.55 ± 1.13
5.	Moisture (%)	81.51 ± 3.50
6.	Energy (Kcal)	70.58 ± 0.71
7.	Carbohydrate (g)	13.2 ± 0.43
8.	Protein (g)	3.06 ± 0.30
9.	Fat (g)	0.61 ± 0.08
10.	Ash (%)	1.00 ± 0.17
11.	Vitamin C (mg)	49.36 ± 3.92
12.	Calcium (mg)	80 ± 2
13.	Iron (mg)	3.03 ± 0.15
14.	Potassium (mg)	371.33 ± 2.51
15.	Magnesium (mg)	29.33 ± 2.5
16.	Zinc (mg)	2.6 ± 0.45
17.	Anthocyanin (mg)	244 ± 58.59
18.	Fiber (g)	2.28 ± 0.59



Fig. 1. Images of the fruit *Prunus napaulensis* (Ser.) Steud

of 3.13 ± 1.12 which due to the low pH of the fruit. The bitter taste and Astringency profile were rated to be 1.93 ± 1.09 and 2.64 ± 1.39 respectively indicating a mild astringent quality. Firmness is the force needed to crack the fruit scored 1.8 ± 0.94 suggesting a relatively soft texture. Juiciness is the amount of juice extracted after chewing scored 3.46 ± 0.99 indicating a moderately juicy fruit. Hence, the findings provide valuable insights on the sensory characteristics of *Prunus napaulensis* (Ser.) Steud, aiding in understanding its quality and consumer preferences.

Color Analysis

The color analysis of *Prunus napaulensis* (Ser.) Steud is essential for understanding and

Table 4. Color values of *Prunus napaulensis* (Ser.) Steud

Sl.No.	Color	Values
1.	L*	23.312
2.	a*	4.385
3.	b*	0.686
4.	ΔL^*	-72.708
5.	Δa^*	4.423
6.	Δb^*	-1.690

analyzing the visual appearance and its potential application as dyes and pigments in food processing industries as well as for use in cosmetics. The color values L*, a*, b*, ΔL^* , Δa^* , Δb^* were measured. The L* value in the CIELAB color space denotes the lightness-darkness of a color ranging from 0 (black) to 100 (white). The higher the value of L* the brighter or lighter the color while a lower value indicates a darker shade. The a* value in the CIELAB color space represents the color range between green (-a) to red (+a) on the Chroma axis. Negative a* value indicates a green tint while a positive value suggest a reddish color. The b* value represents the blue- yellow color. A negative b* value indicates a blue color while a positive b* represents a more yellowish color. The results as shown in table 4 indicates that, the color attribute of *Prunus napaulensis* (Ser.) Steud measured 23.312 for lightness, 4.385 as a* value and 0.686 as the b* value. Thus indicating a reddish color due to the positive a* value however, (Vivek *et al.*, 2018) observed a higher a* value.

Antioxidant Activity of *Prunus Napaulensis* (Ser.) Steud

DPPH assay was used to evaluate the free radical scavenging capacity. The result

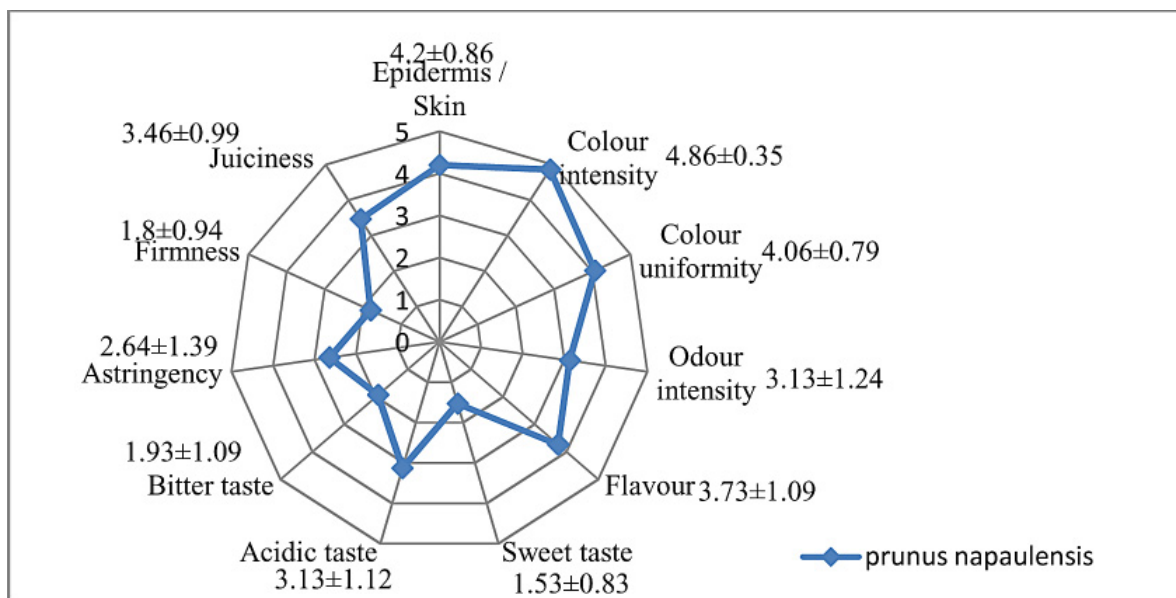


Fig. 2. Radar chart of Descriptive sensory Attributes of *Prunus napaulensis* (Sohiong)

exhibits that various extracts of *Prunus napaulensis* (Ser.) Steud fruit reduced the DPPH concentration indicating that the DPPH activity is also influenced by the type of solvent used. Aqueous extract exhibited the highest antioxidant inhibitory activity (97.44%) at 750 μ L as compared to samples prepared using methanol extract (91.7%) and ethanol extract (86.61%). However, among all extract, methanol extract exhibited the strongest inhibition activity (45.56%) at the lowest concentration (10 μ L). In the present study, samples exhibited concentration dependent DPPH radical scavenging activity (Fig. 3.). With the increase in concentration, the scavenging activity of the sample extracted was increased. The IC_{50} value of extracts (Table 5): aqueous, methanol and ethanol were 46.90 μ g/mL, 51.68 μ L/mL and 144.62 μ L/mL respectively. Ascorbic acid, demonstrated 95.9% radical scavenging activity at a concentration of 15 μ L/mL with an IC_{50} value of 1.530 μ L/mL. The high antioxidant potential stems from the presence of anthocyanin, phenolic acids and phenolic compounds like flavonoids present in *Prunus*

napaulensis (Ser.) Steud. Flavonoids are known for their antioxidant activity. Red and black rice exhibited higher antioxidant activity as compared to white rice owing to the higher content of quercetin and catechin (Chen *et al.*, 2022).

Recent studies by Igwe and Charlton (2016) and Smith *et al.*, (2022) reported the health promoting and nutritional benefits of *Prunus* species, particularly, extracts of prunes (*Prunus domestica* and *Prunus salicina*) due to its rich composition of polyphenols, anthocyanins and flavonoids. These bioactive compounds are known to exhibit physiological benefits such as improved bone density, enhanced gastrointestinal function and protection of the cardiovascular health (Ayub *et al.*, 2023). Additionally, dried plums exhibited protective effects against bone loss due its polyphenolic profile (Smith *et al.*, 2022). Furthermore, experimental studies on anthocyanin-rich extracts of *Prunus* fruits demonstrated significant mitigation of oxidative stress and potential amelioration of

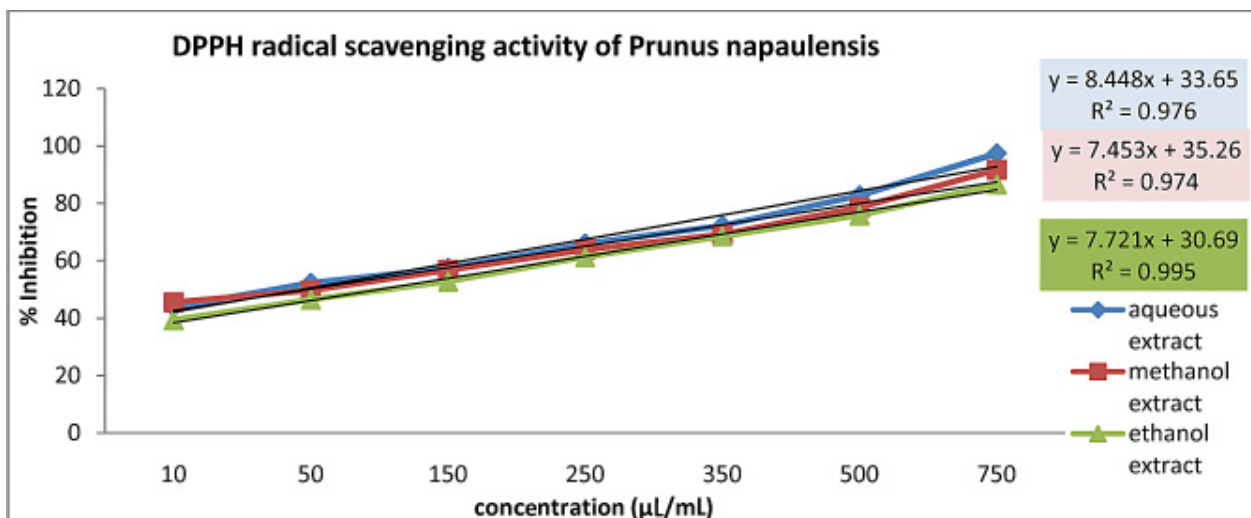


Fig. 3. *In vitro* antioxidant activity (DPPH assay) of aqueous, methanol and ethanol extract of *Prunus napaulensis*(Ser.) Steud.

Table 5. IC₅₀ values of extracts of *Prunus napaulensis*(Ser.) Steud

Fruit extract	IC ₅₀ value (µL/mL)	
1.	Standard ascorbic acid	1.530
2.	Aqueous extract	46.90
3.	Ethanol extract	144.62
4.	Methanol extract	51.68

hyperlipidaemia (Seniuk *et al.*, 2021; Das *et al.*, 2022; Chaudhuri *et al.*, 2015).

CONCLUSION

This study comprehensively evaluated the physical, physicochemical and nutritional characteristics of *Prunus napaulensis*(Ser.) Steud fruit shedding light on its nutritional composition and various bioactive compounds along with the phytochemical screening for secondary metabolites including tannins, flavonoids, saponin, anthocyanin, phenols and polyphenols. The antioxidant activity (DPPH assay) exhibited a radical scavenging activity with IC₅₀ value 46.90µL/mL in aqueous extract. The physical properties showcased the characteristic dimensions of both fruit and seed aligned with Cherry fruit. The nutritional composition highlighted the significant presence of minerals such as iron (3.03 ± 0.15

mg), calcium (80 ± 2 mg), potassium (371.33 ± 2.52 mg),, magnesium (29.33 ± 2.52 mg), and zinc 2.6 ± 0.45 mg), and Vitamin C (49.36 ± 3.92 mg), emphasizing the nutrient density of the fruit. The descriptive sensory analysis of the fruit provided insights into the external appearance, colour, aroma, flavour, taste, firmness, and juiciness, contributing to a comprehensive understanding of sensory attributes of *Prunus napaulensis* (Ser.) Steud towards consumer preferences. The sensory profile indicated a visually appealing dark red to purple hue with moderately juicy texture and lower sweetness score due to the low pH. Overall, this research highlights the nutritional abundance, sensory attributes of *Prunus napaulensis* (Ser.) Steud fruit, suggesting avenues for further exploration for applications in both the food industry and healthcare domains.

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GROWTH PATTERNS OF CHILDREN UNDER FIVE IN URBAN SLUMS IN SAMBALPUR DISTRICT OF ODISHA

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ABSTRACT

A community based cross sectional study was conducted in the years 2022-23 among under-five children living in urban slums of Sambalpur district, Odisha. The proposed study aimed to determine the levels of malnutrition among under-five children and to evaluate the growth of these children by anthropometric measurements. A total sample size of 550 (268 boys and 282 girls) aged between 6 months to 5 years were randomly selected from 20 slums. The data was collected with the help of a predesigned and pretested interview schedule to collect the information on anthropometric measurements and nutritional status of the children. The results of the study revealed that more percentage of actual mean deficits was found in Head Circumference (HC) & Mid-Upper Arm Circumference (MUAC) of the boys. The nutritional status of girls was found to be less in comparison with boys in Grade-I, Grade-II, Grade-III level of malnutrition, both according to Gomez Classification and Indian Academy Pediatrics (IAP) classification.

Keywords: Head Circumference, Height, Malnutrition, Mid-Upper Arm Circumference, Under-Five Children, Weight

INTRODUCTION

The most vulnerable group in a nation is children under the age of five. Their mortality rate and nutritional condition serve as sensitive indicators of nutrition and population health. In India, malnutrition is one of the main public health issues, particularly for children under five. According to National Family Health Survey-5 (NFHS-5, 2019-21) data, 32.1% (Urban-27.3%, Rural-33.8%) under-five children were underweight, 35.5% (Urban-30.1%, Rural-37.3%) were stunted, 19.3% (Urban-18.5%, Rural-19.5%) were wasted and 7.7% (Urban 7.6%, Rural 7.7%) were severely wasted in India. Similarly NFHS-5 data of Odisha revealed 29.7% (Urban-21.5%, Rural-

31.0%) under-five children were underweight, 31.0% (Urban-24.9%, Rural-32.0%) were stunted, 18.1% (Urban-14.9%, Rural-18.6%) were wasted and 6.1% (Urban 3.9%, Rural 6.4%) were severely wasted. NFHS-5 data for Sambalpur District revealed 36.3% under-five children were underweight, 44.8% were stunted, 22.4% were wasted and 7.6% were severely wasted. The substandard housing, overcrowding, bad drinking water, and inadequate sanitation that urban slum inhabitants experience are compounded by their low socioeconomic level, lack of access to basic health care services, ignorance, and illiteracy. According to Panigrahi and Das, (2014), children who live in such situations are always at a significant risk of developing health

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Table 1. Distribution of respondents based on age and gender**n=500**

S.No.	Age (Yrs.)	Boys		Girls	
		n	%	n	%
1	6 months-1	30	46.8	34	53.1
2	>1-2	61	57.5	45	42.4
3	>2-3	43	41.7	60	58.2
4	>3-4	70	54.6	58	45.3
5	>4-5	64	42.9	85	57.0
	Total	268	48.7	282	51.3

and nutritional issues. Slum children have the worst health indices of any urban group and are significantly poorer than the norm for rural areas. According to the 2011 Census, 13.7 million Indians live in slums, making up over 17% of the nation's urban households. The children living in slums are worse affected as not only deprived of the basic services but also not recognized as an important segment, by the urban planners and developer. The prevalence of undernutrition in urban slums is also clearly significantly greater than the national average for both rural and urban areas. Many children in slum areas are susceptible to vicious cycle of malnutrition and infection which contributes to high child mortality and morbidity. Therefore it is highly essential to monitor the growth pattern of children periodically to assess their nutritional status for their proper care and treatment.

MATERIAL AND METHODS

A cross-sectional study was conducted in the years 2022 to 2023 in slum areas of Sambalpur District, Odisha. A total number of 550 (268 boys and 282 girls) children between aged 6 months to 5 years from 20 slum areas of Sambalpur district were selected by simple random sampling method. The data was collected by house to house visit with a pre-designed, pre-tested interview schedule. The World Health Organization's (WHO) Growth Standards-2006 were compared with the anthropometric measurements of the children,

including their height, weight, head circumference (HC), and mid-upper arm circumference (MUAC) (different for boys and girls). Indian Academy of Pediatrics (2015) classification was utilized for assessment of nutritional status of the children to know their severity of malnutrition.

RESULTS AND DISCUSSION

Table 1 shows the information on age and gender of the respondents. Although it was noted that there were more girls (51.3%) than boys (48.7%), the difference was not statistically significant. Additionally, it was noted that a higher proportion of males were in the 1-2 year and 3-4 year age groups, while a higher proportion of girls were in the 6 months–1 year, 2-3 year, and 4-5 year age groups. Similar findings was observed by Gautam *et al.*, (2018), who reported that 51.46% female and 48.46 % male in their study whereas Sharma *et al.*, (2016), reported 51.6% female and 48.6% male in their study which is at par with the findings of the study.

Table 2 depicts that boys were slightly taller than girls. Boys' and girls' heights increased gradually with age, however the observed values fell well short of the WHO growth criterion for height across all age categories (2006). The negative deviation in actual mean height was found from 9.3% to 13.7% in boys whereas it was 8.5% to 12.3% in case of girls. The highest deviation in height

Table 2. Actual mean height of under five children in comparison with WHO standard height (2006)

S.No.	Age (Yrs.)	Height of boys (cm.)					Height of girls (cm.)				
		Actual					Actual				
		Mean Ht. $\pm$ SD	Std. Ht.	%Mean diff.	t value	P value	Mean Ht. $\pm$ SD	Std. Ht.	%Mean diff.	t value	P value
1.	6 months-1	67 $\pm$ 4.8	75.7	-10.5	-9.12	.000*	66.6 $\pm$ 6.3	74	-9.9	-6.76	.000*
2.	>1-2	75.8 $\pm$ 5.7	87.8	-13.7	-16.35	.000*	75.2 $\pm$ 4.9	85.7	-12.3	-14.50	.000*
3.	>2-3	86.1 $\pm$ 5.6	96.1	-10.7	-12.11	.000*	85 $\pm$ 5.9	95.1	-10.7	-13.28	.000*
4.	>3-4	93.4 $\pm$ 5.6	103.3	-9.6	-14.69	.000*	92.1 $\pm$ 5.9	102.7	-10.7	-15.59	.000*
5.	>4-5	100.5 $\pm$ 5.9	110	-9.3	-13.68	.000*	100.1 $\pm$ 5.4	109.4	-8.5	-15.99	.000*

©Ref: As per standard mentioned by WHO - 2006 ; *Significant at 5% level

Table 3. Actual mean weight of children in comparison with WHO standard weight.

S.No.	Age (Yrs.)	Weight of Boys (Kg)					Weight of Girls (Kg)				
		Actual					Actual				
		Mean Ht. $\pm$ SD	Std. Ht.	%Mean diff.	t value	P value	Mean Ht. $\pm$ SD	Std. Ht.	%Mean diff.	t value	P value
1.	6 months-1	9.1 $\pm$ 2.8	9.6	-5.5	-1.01	0.32 ^{NS}	8.3 $\pm$ 2.2	8.9	-7.0	-0.62	.106 ^{NS}
2.	>1-2	9.5 $\pm$ 1.6	12.2	-22.0	-13.02	.000*	9.1 $\pm$ 1.3	11.5	-20.6	-12.32	.000*
3.	>2-3	10.9 $\pm$ 2	14.3	-23.6	-11.30	.000*	10.7 $\pm$ 1.7	13.9	-23.3	-14.55	.000*
4.	>3-4	12.7 $\pm$ 2	16.3	-22.0	-15.08	.000*	12.1 $\pm$ 2.2	16.1	-24.7	-13.83	.000*
5.	>4-5	14.1 $\pm$ 2.2	18.3	-23.0	-15.05	.000*	14.4 $\pm$ 2.3	18.2	-21.0	-15.47	.000*

©Ref: WHO, 2006 *Significant at 5% level NS- Non significant

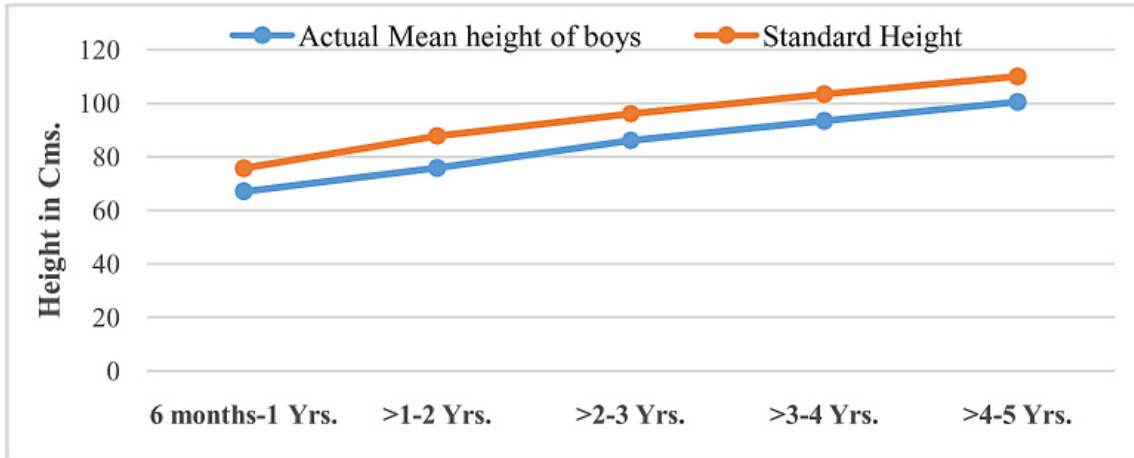


Figure 1 Comparison of actual mean height of boys with WHO growth standards

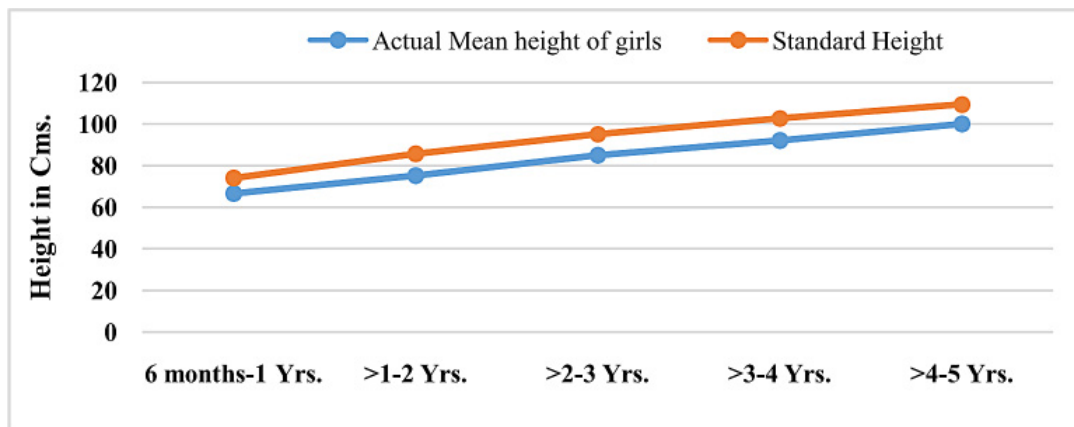


Fig. 2. Comparison of actual mean height of girls with WHO growth standards.

was noted in age group of >1-2 years in both boys & girls. The discrepancy between the respondents' actual mean height and standard height for both boys and girls was highly statistically significant, irrespective of their age when compared (at 95% confidence level, $p < 0.000$). Das *et al.*, (2014) found nearly identical results, reporting that the average height of boys and girls at ages 3, 4, and 5 was 75.2, 97.3, 100.35 and 82.75, 95.4, 101.38, respectively. Another study by Mandal *et al.*, (2020) found that the average height of boys and girls at the ages of 2, 3, and 4 was 78.7, 86.25, 90.8, 97.93 and 75.29, 84, 90.79, and 95.08, respectively, with the exception of the age of 5, which was somewhat lower than the study's findings.

Fig. 1. and 2 shows that the reduced height observed in both boys and girls, as compared to WHO standard values (2006) may be attributed to several factors, including inadequate nutrition, nutrient deficiencies, illnesses, limited access to healthcare, exposure to unsanitary environmental conditions and genetic factors.

The actual mean weight of both boys and girls was found to be lower than the WHO standard values, as shown in Table 3. Additionally, it was noted that the percentage of the actual mean weight difference compared to WHO standard values was lower for both boys and girls between the ages of six months and one year, whereas the mean difference increased as age increased. The prevalence

Table 4. Actual mean Head circumference of children in comparison with WHO standard HC.

S.No.	Age (Yrs.)	Head circumference of boys (cm.)					Head circumference of girls (cm.)				
		Actual		%Mean diff.	t value	P value	Actual		%Mean diff.	t value	P value
		Mean Ht. $\pm$ SD	Std. Ht.				Mean Ht. $\pm$ SD	Std. Ht.			
1.	6 months-1	44.4 $\pm$ 2.2	46.1	-3.7	-4.15	.000*	42.8 $\pm$ 1.9	44.9	-2.1	-6.66	.000*
2.	>1-2	45.2 $\pm$ 1.7	48.3	-6.4	-13.95	.000*	44.7 $\pm$ 1.8	47.2	-2.6	-9.70	.000*
3.	>2-3	46.7 $\pm$ 1.7	49.5	-5.7	-11.23	.000*	45.5 $\pm$ 1.3	48.5	-3.0	-17.65	.000*
4.	>3-4	47.0 $\pm$ 2.0	50.2	-6.3	-13.59	.000*	45.7 $\pm$ 2.2	49.3	-3.6	-12.65	.000*
5.	>4-5	47.7 $\pm$ 2.1	50.7	-5.9	-11.13	.000*	47.3 $\pm$ 1.7	49.9	-2.6	-14.20	.000*

©Ref: WHO, 2006

*Significant at 5% level

of underweight in varying degrees, however, may be caused by poor feeding practices, frequent illnesses, inadequate nutrition, and economic factors like poverty and poor sanitation. The weight deficit was found to be between 5.5% and 23.6% for boys and 7% and 24.7% for girls. For males aged 2-3 years, the gap was greater (23.6%), but for girls, it was greater in the age group of 3-4 years (24.7%). Regardless of age or gender, there was a statistically significant discrepancy between the actual mean weight and the WHO standard values from 2006 in this study, with the exception of the 6–1 year age group. Biswas *et al.*, (2018) conducted a similar study and found that the average weight of boys and girls at ages 3, 4, and 5 was 11.94, 12.9, 14.78, and 11.57, 12.76, 14.35, respectively.

Table 4 depicts that the actual mean head circumference values of both boys and girls which were found to be lower than the WHO standard values (2006). There was a progressive difference in head circumference with increased age in comparison to WHO standard, found in boys & girls from 6 months to 4 year of age. However, the percentage of head circumference deficit was found within the range of 3.7% to 6.4% in boys and 2.1% to 3.6% for girls. Boys aged 1-2 years (6.4%) and girls aged 3-4 years (3.6%) had a greater deficit. Regardless of age or gender, there was a statistically significant discrepancy between the actual mean head circumference and WHO standard values in this investigation. Tigga *et al.*, (2016) observed nearly identical results, with the mean head circumferences of boys and girls at ages 2, 3, 4, and 5 being 48.48, 46.59, 45.53, 46.29 and 45.22, 44.31, 45.37, and 47.57, respectively.

Table 5 reveals both boys' and girls' mean MUAC values, which were found to be below WHO (2006) growth guidelines values. It was intriguing to observe that the mid-upper arm circumference saw a progressive deficit that grew with age and was statistically

Table 5. Actual mean Mid-Upper Arm Circumference of children in comparison with standard MUAC.

S.No.	Age (Yrs.)	MUAC of boys (Cms.)					MUAC of girls (Cms.)				
		Actual					Actual				
		Mean Ht. $\pm$ SD	Std. Ht.	%Mean diff.	t value	P value	Mean Ht. $\pm$ SD	Std. Ht.	%Mean diff.	t value	P value
1.	6 months-1	14 $\pm$ 1.0	14.6	-4.4	-3.34	.002	13.4 $\pm$ 1.1	14.2	-0.9	-4.62	.000*
2.	>1-2	13.8 $\pm$ 1.3	15.2	-9.1	-8.53	.000*	13.4 $\pm$ 1.0	14.9	-1.5	-10.52	.000*
3.	>2-3	14.2 $\pm$ 1.3	15.7	-9.8	-8.07	.000*	13.9 $\pm$ 0.8	15.6	-1.7	-15.79	.000*
4.	>3-4	14.4 $\pm$ 1.0	16.1	-10.7	-13.89	.000*	14.1 $\pm$ 1.2	16.2	-2.1	-13.28	.000*
5.	>4-5	14.6 $\pm$ 1.1	16.5	-11.3	-13.37	.000*	14.6 $\pm$ 1.0	16.9	-2.3	-22.52	.000*

©Ref: WHO, 2006

*Significant at 5% level

significant at both the 5% and 1% levels. However, when compared to WHO standard values (2006), the MUAC deficiency was found to be between 4.4% and 11.3% for males and 6% and 13.8% for girls. In the 4–5 age range, there was a greater deficit in boys (11.3%) and girls (16.9%), respectively. The rise in the percentage of mean difference MUAC between the age groups of 6 months and 5 years may be the result of recurrent episodes of diseases such as respiratory infections and diarrhea, which raise nutrient demands while lowering intake. In the end, this results in muscular atrophy. The discrepancy between the actual mean mid-upper arm circumference and the WHO standard values was statistically significant.

Table 6 describes the deficiency was higher in boys (11.3%) and girls (16.9%) in the 4–5 age group, respectively. Recurrent episodes of illnesses such respiratory infections and diarrhea, which increase nutrient demands while lowering intake, may be the cause of the increase in the percentage of mean difference MUAC between the age groups of 6 months and 5 years. This ultimately leads to muscle atrophy. There was a statistically significant difference between the WHO standard values and the actual mean mid-upper arm circumference. It was found that majority of boys (42.5%) and girls (46.1%) were under Grade I malnutrition, followed by 23.1% boys and 25.9% girls were under Grade II and 3.4% boys and 3.5% girls were under Grade III malnutrition, respectively. Malnutrition was more common in females than in boys, however the differences between the sexes were not statistically significant ($P>0.05$).

Table 7 depicts children's nutritional status according to their IAP classification. The majority of girls (53.5%) and boys (61.6%) were judged to have normal nutritional status. Compared to girls, boys had a superior nutritional state. 25% of boys and 24.5% of girls were found to be suffering from Grade I malnutrition, followed by 10.1% of boys and

Table 6. Nutritional profile of children based on Gomez classification (1956)

S.No.	Gomez classification Nutritional Status	Boys		Girls		P	
		N	%	N	%	÷2	value
1.	Normal (>90%)	83	31.0	69	24.5	2.93	0.402 ^{NS}
2.	Grade I Malnutrition (75-90%)	114	42.5	130	46.1		
3.	Grade II Malnutrition (60-75%)	62	23.1	73	25.9		
4.	Grade III Malnutrition (<60%)	9	3.4	10	3.5		

NS- Non significant

18.1% of girls suffering from Grade II malnutrition, and 3.4% of boys and 3.9% of girls suffering from Grade III malnutrition. It was discovered that none of the responders fell into the grade IV malnutrition level. At the 5% level of significance, the prevalence of malnutrition disparities between boys and girls were determined to be statistically significant ($P < 0.05$). A study carried out by Bhadoria (2023), in rural area of Barabanki District revealed that nutritional status of under five (according to IAP classification of malnutrition) children was as follows *i.e.* 33.3% were normal, 28.3% were mild, 16.7% moderate, 12.2% severe and 9.4% were very severely malnourished.

CONCLUSION

Results revealed that the prevalence of malnutrition was higher in females than in boys, according to the results. Malnutrition was also

seen to be more common as people aged, which could be because of the continued presence of unsanitary environmental variables. The percentage of boys in the 1-2 year age group who had a mean deficit in height was similarly higher (13.7%), but the percentage of boys in the 2-3 year age group who had a mean deficit in weight was higher. Similarly, in case of head circumference, the actual mean difference in comparison to standard was more in the age group of 3-4 years boys *i.e.* 6.3%, whereas the actual mean mid-upper arm circumference was more deficit in case of girls belong to 4-5 years of age group *i.e.* 16.9%. However results on prevalence of malnutrition as per Gomez and IAP classifications showed that more percentage of girls suffers from malnutrition in comparison to boys which might be due to gender disparity in care and availability of health facilities.

Table 7. Nutritional Status of Children based on Indian Academy Pediatrics Classification (2015)

S.No.	Level of Nutritional Status	Boys		Girls		P	
		n	%	n	%	÷2	value
1.	Normal (>80%)	165	61.6	151	53.5	7.883	0.048*
2.	Grade I Malnutrition (70-80%)	67	25.0	69	24.5		
3.	Grade II Malnutrition (60-70%)	27	10.1	51	18.1		
4.	Grade III Malnutrition (50-60%)	9	3.4	11	3.9		
5.	Grade IV Malnutrition (<50%)	0	0.0	0	0.0		

*Significant at 5% level

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DEVELOPMENT OF MILLET-BASED RECIPES UTILISING POTATO STARCH, RICE FLOUR AND ARROWROOT POWDER AS THICKENING AGENTS

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ABSTRACT

The present study aimed to develop value-added products from selected millets by incorporating plant-based, gluten-free starches. Conducted in 2023 at St. Joseph's College for Women, Visakhapatnam, the research focused on four millet varieties: Barnyard, Kodo, Little and Foxtail. Three plant-derived starches—potato starch, arrowroot powder and rice flour were used to enhance the functional and sensory properties of millet-based recipes. The developed products included Barnyard Cutlet, Kodo Steam Cake, Little Millet Soup and Foxtail Papad. Each product was prepared in three variations, using the different starches. Sensory evaluation was conducted using a 9-point hedonic scale. Among the Barnyard Cutlet variations, the rice flour version scored highest for aroma, while the arrowroot-based cutlet was rated best in appearance. Little Millet Soup received consistent ratings across all three starch variations for aroma, aftertaste, and overall acceptability. The Kodo Steam Cake prepared with potato starch received the lowest scores in most parameters, except for appearance, which was rated favourably. In addition to sensory analysis, a line spread test was conducted to assess the viscosity of the starches. The results showed that rice flour had the highest spread ability, indicating lower viscosity, while arrowroot powder showed the least spread, suggesting it is a stronger thickening agent. Moisture content was also analysed, as it plays a critical role in determining the structural and functional properties of food products. Based on loss-on-drying results, arrowroot powder exhibited the highest moisture content among the starches tested.

Keywords- Gluten free, Millets, Starches.

INTRODUCTION

Millets, traditionally known as “Siri Anna,” have been staple grains in India for centuries, consumed regularly by previous generations. However, in recent decades, globalization introduced more refined, gluten-containing cereals such as wheat, oats and rye, which became preferred due to their palatability and

texture. This shift contributed to rising lifestyle and digestive disorders, renewing interest in millets as nutrient-dense, gluten-free alternatives (Makadi *et al.*, 2024).

The year 2023 was declared the International Year of Millets at the G20 summit, led by India, underscoring the importance of these ancient grains in promoting nutrition

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security and sustainable agriculture (Makadi *et al.*, 2024). Millets are gluten-free, which differentiates them from commonly consumed cereals and makes them suitable for gluten-intolerant individuals and those with celiac disease (Aggarwal *et al.*, 2018). However, gluten's absence poses challenges in achieving desirable textures and mouthfeel in cereal-based recipes, such as soft pooris or stretchable naans, which rely on gluten's viscoelastic properties. This limitation was demonstrated by Onyango *et al.*, (2020), where porridges with higher millet content scored lower in sensory evaluations compared to mixed flours containing cassava and cowpea leaf.

Currently, common thickening agents like refined wheat flour (maida) and corn flour are widely used but provide mainly empty calories and, in the case of maida, contain gluten, which is unsuitable for gluten-free diets. To address this, the present study explores the incorporation of lesser-used, nutritionally valuable plant starches-potato, arrowroot and rice starch-to develop millet-based, gluten-free recipes with improved texture and sensory appeal.

Sensory evaluation by semi-trained panellists, alongside instrumental assessments such as the Line Spread Test (LST) and moisture content analysis, were employed to compare the functional and sensory properties of these starches in millet recipes. Previous research has shown that millet-based products can achieve sensory qualities comparable to refined cereals when appropriate formulation strategies are used (Lim, 2024). For instance, millet muffins developed with various millet flours demonstrated good acceptability and nutritional benefits, including higher fiber and mineral content. Similarly, meal preparations using different millet types scored closely to polished white rice in sensory tests, with

barnyard millet and little millet often performing well in taste and texture attributes (Lim, 2024).

Nutritionally, millets are rich in protein with balanced amino acids, dietary fiber, polyphenols, vitamins, and essential minerals such as iron, calcium, zinc, and magnesium, contributing to their functional health benefits including glycaemic control, antioxidant activity, and gut health promotion. Finger millet, in particular, is noted for its exceptionally high calcium content, beneficial for bone health (Bhaduri, 2013).

This study aims to harness the nutritional and functional advantages of millets while overcoming textural limitations by integrating selected plant starches, thereby promoting millet-based foods as viable, gluten-free alternatives with enhanced sensory qualities.

MATERIAL AND METHODS

The present study was carried out in a systematic sequence to develop millet-based value-added recipes utilizing plant-based gluten-free starches. The study started with identification and procurement of raw materials. Four types of millets viz., Barnyard, Kodo, Little, and Foxtail were selected along with three plant-derived starches: potato starch, rice flour and arrowroot powder. The millets were cleaned and ground into flour, and the starches were procured from certified sources to ensure quality and consistency.

The next phase involved the development of recipes, where each millet was incorporated with all three starches to create three different variations per product. The products developed included Barnyard Cutlet, Kodo Steam Cake, Little Millet Soup, and Foxtail Papdas. Physical analysis of the starches was conducted using the line spread test to evaluate viscosity and moisture content analysis to understand their functional properties.



Fig. 1. Research design

Sensory evaluation was carried out using a 9-point hedonic scale to assess organoleptic attributes such as taste, texture, aroma, appearance, and overall acceptability. A panel of semi-trained individuals was employed for the sensory testing under controlled conditions. The data obtained from sensory and physical analyses were subjected to appropriate statistical analysis such as Mean and Standard deviation to interpret the results and identify the most acceptable combinations based on overall performance. Detailed research design is depicted in the form of schematic diagram (Fig.1).

Selection of Ingredients

The study aimed to formulate millet-based recipes using different plant-derived, gluten-free starches. Four varieties of millets—Barnyard, Kodo, Little, and Foxtail were

selected along with three starches: potato starch, arrowroot powder, and rice flour. Each millet was used to develop one recipe, and each recipe was prepared in three variations, incorporating a different starch in each version. The details of millet and starch combinations along with recipes are listed in Table 1.

A total of four value-added recipes were developed, one using each millet. Each recipe was prepared in three versions using the different starches to observe the effect on sensory and physical properties.

The amounts of millet and starch used in these four recipes vary depending on the type of dish and the texture needed. In Little millet soup, 10g of millet and 5g of starch make for a light, easy-to-digest dish—probably warm and soothing. The Barnyard millet recipe uses 50g of millet with 10g of starch, showing millet

Table 1. List of Millets and Starches Used

Sl.No.	Millet	Recipe Name	Starch Variations
1	Barnyard Millet	Barnyard Millet Cutlet	1. Potato Starch 2. Arrowroot Powder 3. Rice Flour
2	Kodo Millet	Kodo Millet Steamed Cake	1. Potato Starch 2. Arrowroot Powder 3. Rice Flour
3	Little Millet	Little Millet Soup	1. Potato Starch 2. Arrowroot Powder 3. Rice Flour
4	Foxtail Millet	Foxtail Millet Papads	1. Potato Starch 2. Arrowroot Powder 3. Rice Flour

Table 2. Millet and Starch composition for value added recipes

Sl. No.	Recipe	Millet (g)	Starch (g)
1	Little millet soup	10	5
2	Barnyard millet	50	10
3	Foxtail papad	80	10
4	Kodo millet cake	25	25

as the main ingredient, while starch adds a bit of thickness. Foxtail millet papad has the highest millet content (80g) along with 10g of starch, which works well for a crispy snack-millet gives the bulk, and starch helps bind and crisp it up. For Kodo millet cake, 25g of millet and 25g of starch are used equally, giving a soft and balanced texture. The starch helps the cake hold its shape and stay moist, while millet adds nutrition.

Line Spread Test

The rheological behaviour of the starches viz., potato starch, arrowroot powder, and rice flour-was assessed using the line spread test. For each sample, readings were recorded at intervals of 5, 15, and 30 minutes.

The results were plotted to compare the viscosity and flow characteristics of each starch.

Moisture Content Analysis

Moisture content of the starches was determined using the hot air oven method. A 5 g sample of each starch was placed in a hot air oven at 210°C for 2 hours. After drying, samples were transferred to a desiccator to cool and then reweighed. Moisture content was calculated using the formula:

$$\text{Moisture Content (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Sensory evaluation of the developed recipes was conducted using a 9-point hedonic scale to assess attributes including taste, aroma, texture, appearance and overall acceptability. A semi-trained panel evaluated all three variations of each recipe. The data obtained was used to identify the most acceptable starch variation for each millet-based product.

RESULTS AND DISCUSSION

Sensory Evaluation

Sensory evaluation was done by a 10 membered semi trained panel for each recipe. They judged the recipes of different attributes like appearance, flavour, aroma, taste, texture, overall acceptability, mouth feel, after taste on a 9- point hedonic scale. Results of sensory evaluations are presented in Table 3.

Kodo Millet Steam Cake

Among the different variations of the Kodo millet steam cake, the rice flour version emerged as the most appreciated. It received the highest scores across nearly all sensory attributes, resulting in an impressive overall

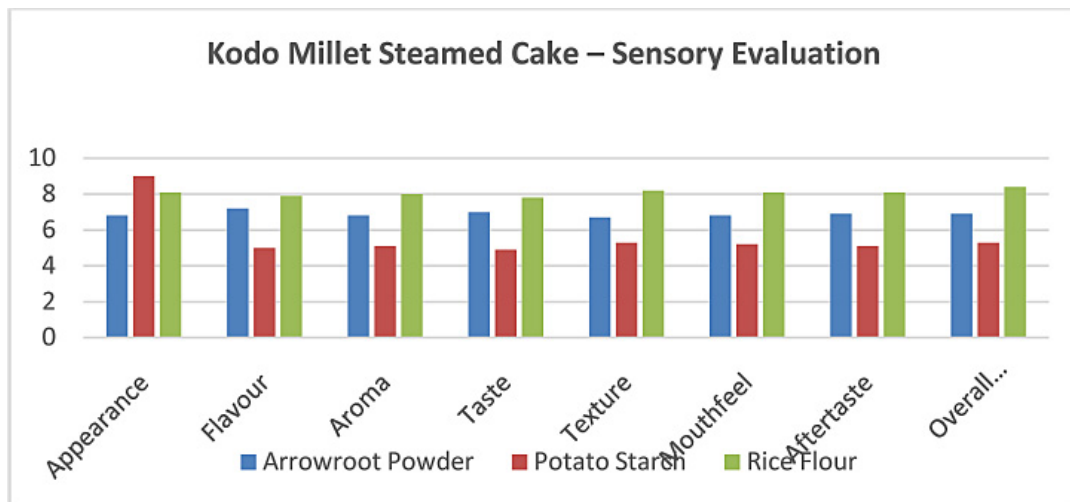


. Plate 1- Kodo millet steam cake

acceptability score of 8.4. This indicates that rice flour contributed positively to the product's texture, taste, and overall sensory appeal, likely due to its neutral flavour profile and familiar mouthfeel.

Table 3. Sensory attributes of Kodo millet steam cake

Attribute	Arrowroot Powder	Potato Starch	Rice Flour
Appearance	6.8±0.82	9±0.08	8.1±0.45
Flavour	7.2±0.71	5±0.58	7.9±0.87
Aroma	6.8±0.47	5.1±34	8±0.78
Taste	7±0.65	4.9±0.16	7.8±0.44
Texture	6.7±0.23	5.3±0.28	8.2±0.77
Mouthfeel	6.8±0.82	5.2±0.55	8.1±0.53
Aftertaste	6.9±0.57	5.1±0.19	8.1±0.56
Overall Acceptability	6.9±0.81	5.3±0.39	8.4±0.18



Graph 1. Sensory attributes of Kodo millet steam cake

Table 4. Sensory attributes of Barnyard millet cutlet.

Attribute	Arrowroot Powder	Potato Starch	Rice Flour
Appearance	8.2±0.17	7.5±0.71	6.2±0.56
Flavour	6.9±0.34	7±0.44	6.8±0.06
Aroma	5.5±0.58	6.8±0.50	7.2±0.33
Taste	6.8±0.29	7.3±0.6	7.2±0.8
Texture	7±0.80	6.9±0.23	6.5±0.9
Mouthfeel	6.9±0.24	6.8±0.13	6.7±0.39
Aftertaste	7±0.33	6.5±0.04	6.8±0.71
Overall Acceptability	7±0.54	6.8±0.9	7.2±0.67

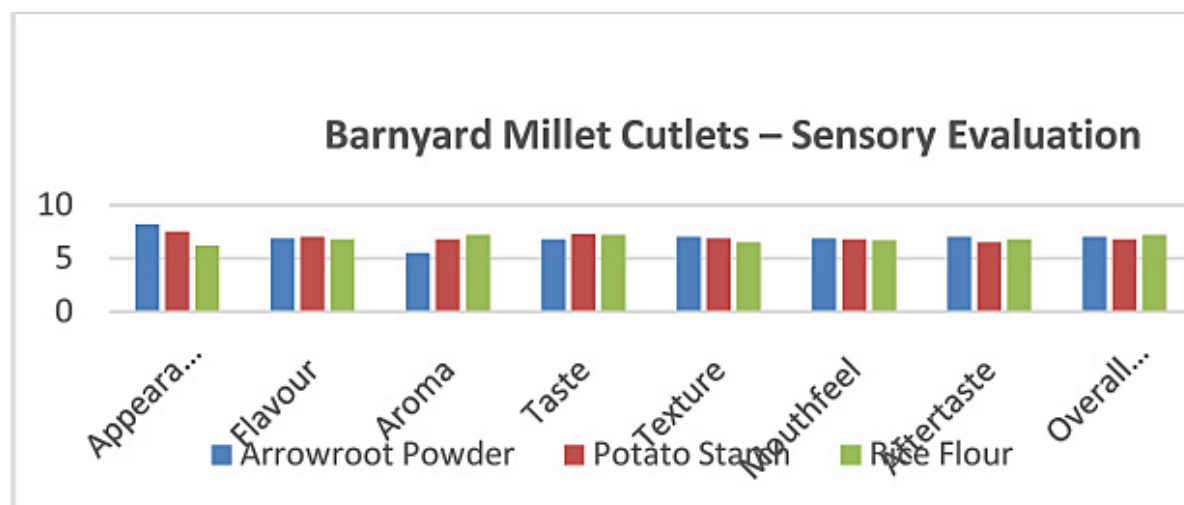
The potato starch variation, although rated the highest for appearance (9.0) was due to its glossy and smooth finish, scored poorly in other attributes such as taste, flavour, and mouthfeel (around 5), bringing down its overall acceptability to just 5.3 this decline in score was possibly due to gummy or dense texture, which did not provide pleasant mouthfeel.

The arrowroot starch version was slightly better than the potato starch one. It achieved decent scores in taste (7.0) and flavour (7.2), suggesting it contributed positively to the sensory profile. However, its overall acceptability score was moderate (6.9),

possibly due to bland flavour of arrowroot powder.

Overall, the findings suggest that while appearance is important, attributes like flavour, texture, and taste play a more crucial role in determining the acceptability of millet-based steam cakes.

A comparative sensory study of millet and rice-based products showed that rice flour-based products scored highest in overall acceptability, taste, and texture, likely due to rice flour's neutral flavour and smooth mouthfeel. This aligns with the present finding that the rice flour version of the steam cake had the highest overall acceptability score (8.4)

**Graph 2. Sensory attributes of Barnyard millet cutlet**

due to its positive sensory profile (Verma *et al.*, 2015).

Rice flour variation cake was better in overall acceptability and moistness. Rice flour had better water binding capacity. This study highlights textural property of rice flour being at par (Kim and Shin, 2009).

In a study conducted where Sensory evaluation of freshly baked gluten-free cookies was carried out using a 9-point hedonic scale. Potato starch showed some improvement, but certain varieties still scored lower in texture and overall acceptability, consistent with the present study's observation that the potato starch steam cake had the highest appearance score (9.0) but low scores (~5) in taste, flavour, and mouthfeel, resulting in a lower overall acceptability (5.3) (Ali *et al.*, 2023).

Barnyard millet cutlet

Barnyard millet cutlet was prepared in 3 variations by incorporating different starches. None of the variation fared extremely well in overall acceptability being 7, 6.8, 7.2 for arrowroot, potato and rice respectively. The arrowroot powder variation showed a more balanced performance, receiving the highest scores for appearance (6.2), texture (7.0), mouthfeel (6.9), and aftertaste (7.0). These results suggest that arrowroot provided a desirable structure and consistency, likely



Plate No. 2 Barnyard Cutlet

contributing to a more cohesive and pleasant eating experience. but its relatively mild taste might have limited its appeal in terms of flavour intensity, keeping the overall acceptability at 7.0.

The potato starch variation, despite being rated highest for taste (7.3) and flavour (7.0)—possibly due to its ability to enhance taste and moisture retention. It was rated the lowest in overall acceptability (6.8).

On the other hand, the rice flour variation scored highest in aroma, suggesting a pleasant smell profile, but it was rated the lowest in appearance, flavour (6.8), texture (6.5), and mouthfeel (6.7). The result shows that while the aroma was inviting, but may be due to a dry or gritty texture it was scored low.

A sensory study conducted by Singh and Iraj, (2023) on products developed using arrowroot powder revealed that formulations with arrowroot scored well in flavour, texture, color, and overall acceptability, with scores around 7.1 to 7.6 on a 9-point hedonic scale, indicating consumer liking. This demonstrates that arrowroot can contribute positively to sensory attributes such as body, texture, and appearance, supporting the above findings of balanced sensory performance in arrowroot cutlets.

A study on gluten-free cookies made from rice flour and green banana flour done by Mouminah and Althaiban, (2025) discusses how rice flour contributes to aroma (mild, pleasant smell) but can result in dry or gritty texture, reducing mouthfeel and overall acceptability. These results are at par with present study's results where rice flour cutlet variations score well only in aroma but other attributes were not appreciated well.

Little millet soup.

Among the three starch variations used in the preparation, arrowroot powder was rated

Table 5. Sensory attributes of Little millet soup.

Attribute	Arrowroot Powder	Potato Starch	Rice Flour
Appearance	7.8±0.09	7.3±0.43	7.5±0.75
Flavour	7.1±0.89	7.4±0.0.7	7.6±0.48
Aroma	6.5±0.85	6.8±0.92	7.1±0.28
Taste	7.4±0.70	7±0.25	7.5±0.03
Texture	7±0.58	7.9±0.72	7.4±0.63
Mouthfeel	7.1±0.40	7.8±0.13	7.6±0.24
Aftertaste	6.5±0.68	6.7±0.55	6.6±0.71
Overall Acceptability	7.1±0.35	7.2±0.60	7.3±0.62s

**Plate 2- Three variations of little millet soup**

the highest in appearance (7.8), possibly due to its ability to produce a clean, smooth surface and appealing structure. However, it received the lowest scores in aroma (6.5), mouthfeel (7.1), and aftertaste (6.5), indicating that while

visually appealing, it may have lacked the sensory depth and lingering flavour profile desired in the product. Consequently, its overall acceptability remained moderate at (7.1).

The potato starch variation performed best in terms of aftertaste (6.7), mouthfeel (7.9), and texture (7.8). These findings suggest that potato starch contributed to a creamy consistency and pleasant tactile quality, enhancing the eating experience. However, it was rated lowest in appearance (7.3) and taste (7.0), possibly due to a slightly dull look and a neutral or bland flavour.

On the other hand, the rice flour variation stood out by scoring the highest in

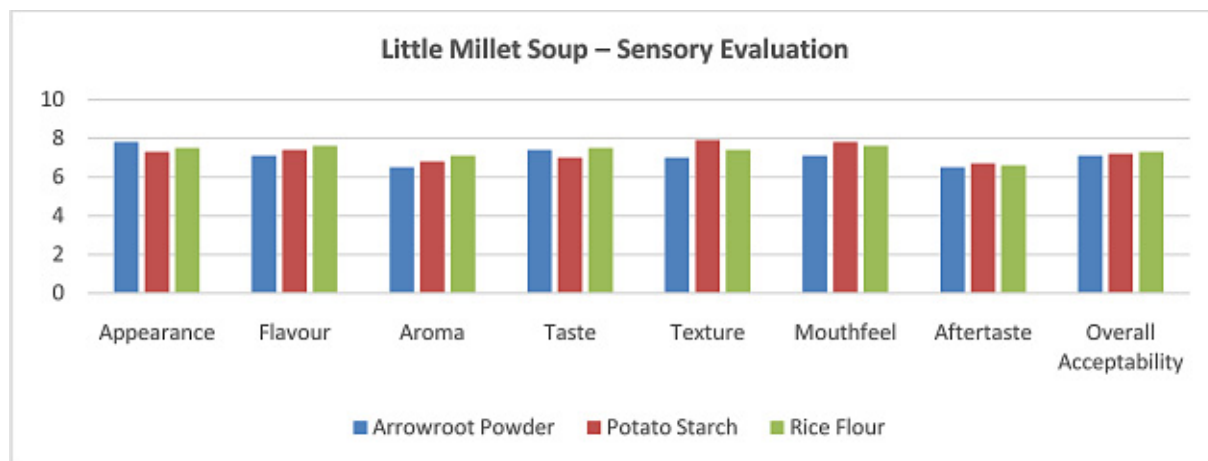
**Graph 3. Sensory attributes of Little millet soup.**

Table 6. Sensory attributes of Foxtail millet papad

Attribute	Arrowroot Powder	Potato Starch	Rice Flour
Appearance	8±0.54	8.2±0.73	8.3±0.26
Flavour	7.2±0.64	7.4±0.80	7.3±0.06
Aroma	7.1±0.05	7.3±0.32	7.5±0.67
Taste	7.3±0.68	7.5±0.56	7.2±0.31
Texture	7.4±0.40	7.6±0.27	7.1±0.41
Mouthfeel	7.3±0.26	7.5±0.46	7.2±0.50
Aftertaste	7.3±0.76	7.4±0.5	7.1±0.11
Overall Acceptability	7.4±0.22	7.5±0.54	7.3±0.52

flavour (7.6), aroma (7.1), taste (7.5), and overall acceptability (7.3). This indicates that rice flour enhanced the sensory appeal of the product through a more balanced and familiar flavour profile, as well as a pleasing aroma.

Texture of arrowroot powder was also well-appreciated; taste of the soups was almost rated alike in all variations. In a review study conducted by Amante *et al.*, (2021) mentioned that arrowroot starch is rich in minerals. It showed great rheological properties on gelatinization and many food products like ice cream stabilizers, breads and infant formulas were developed. Rheological properties of the plant present negative synergesis, stability during cooking, higher solubility, and absorption index.

A study characterized native and partially gelatinized potato starch, showing that partially gelatinized potato starch forms stable pastes with shear-thinning (pseudoplastic) behaviour ideal for thickening applications. The apparent viscosity increases with gelatinization degree, contributing to creamy, smooth textures in soups and sauces. These results are at par with the sensory results of Little millet soup which was showed good sensory scores for mouthfeel and texture(Xu *et al.*, 2021).

Foxtail millet papads

Millet papad, a novel and nutritious recipe, was developed in three different variations using arrowroot powder, potato starch, and rice flour as binding agents. Among

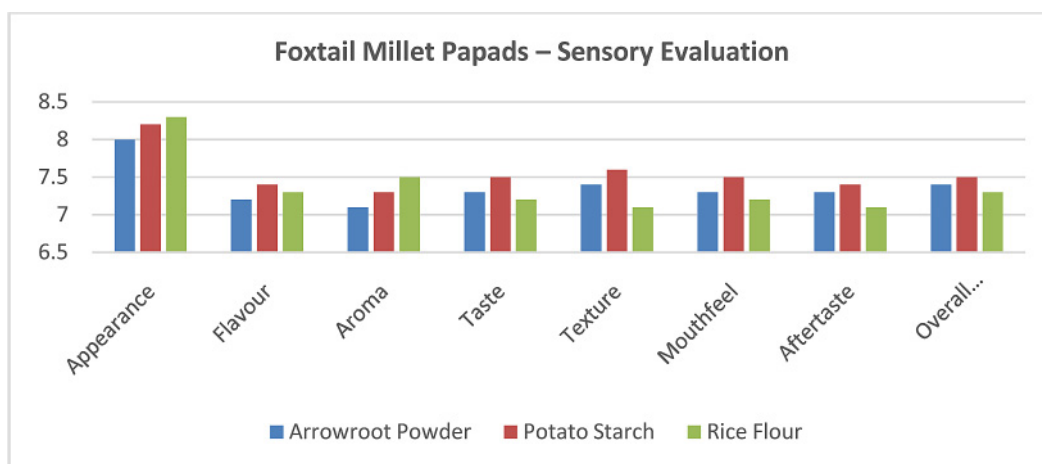
**Graph 4. Sensory attributes of Foxtail millet papad**

Table 7. Line spread test

Time	Rice Flour	Potato Starch	Arrowroot
5 mins	23	20	10
15 mins	25	23	12
30 mins	28	24	16

these, the arrowroot-based variation did not perform well across most sensory attributes, likely due to its neutral flavour profile and less appealing mouthfeel and less desirable texture required for papad preparation resulting in a moderate overall acceptability score of 7.4.

In contrast, the potato starch variation emerged as the most palatable, receiving the highest scores in flavour (7.4), taste (7.3), and overall acceptability (7.5). This can be due to potato starch's ability to enhance the crispness and flavour absorption of the papad.

The rice flour variation stood out in terms of aroma (7.5) and appearance (8.3). However, it scored the lowest in taste (7.2), texture (7.1), mouthfeel (7.2), and aftertaste (7.1). This could be due to rice flour's tendency to harden on frying and imparting bland flavour, which may have resulted the overall acceptability, scoring slightly lower at 7.3.

The same results were seen in studies conducted by Thapa and Thapa (2019), where potato starch stood out among other starch

sources due to its exceptional qualities. With its notable attributes including high swelling power and viscosity, it surpasses other starch varieties. Distinguished by its larger granule size and a low glass transition temperature, potato starch offers clear pastes and a neutral taste profile. A study revealed that Potato flour serves as a versatile ingredient, functioning as both a thickener and flavour enhancer. Its unique and pleasant taste enhances a variety of dishes when combined with cereal and pulse flours. This combination creates a delightful array of products, including biscuits, cakes, parathas, and bread (Thapa and Thapa, 2019).

In a study conducted by Aggarwal (2018), where sensory evaluation of masala khakhra made with arrowroot, were assessed for the following parameters, appearance, colour, flavour, texture, taste, and overall acceptability using trained panellists. The results showed variation with arrowroot starch had improved sensory characters and was

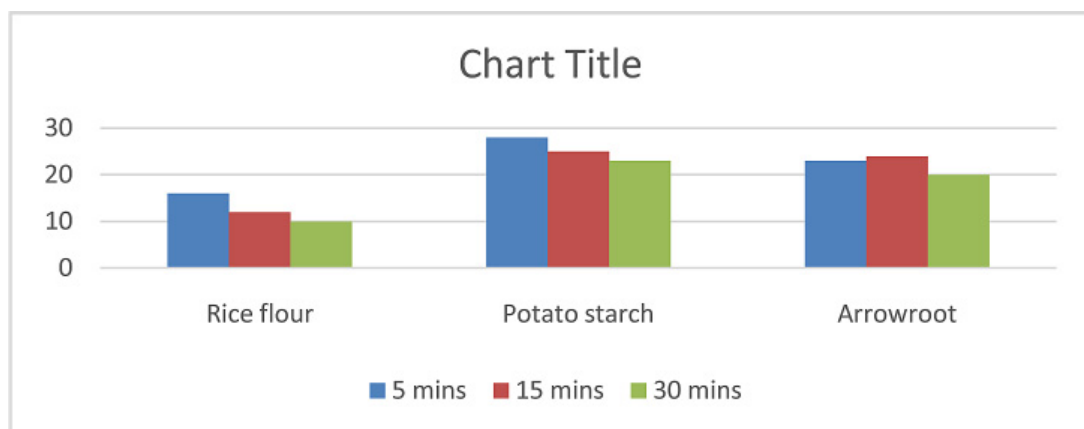
**Graph 5. Line spread test**

Table 8. Mean moisture content in thickening agents

Thickening agents	Weight of the sample (g)	Mean (D)	Moisture content (%)
Rice flour	5	0.1046	10.46%
Arrow root powder	5	0.1196	11.96%
Potato starch	5	0.1038	10.38%

scored best for texture and taste in contrast to the present study.

II. Physical Analysis

The physical analysis was tested by line spread test and moisture content analysis among three thickening agents arrow root powder, potato starch and rice flour and here is the view of the results in Table 8.

Line spread test

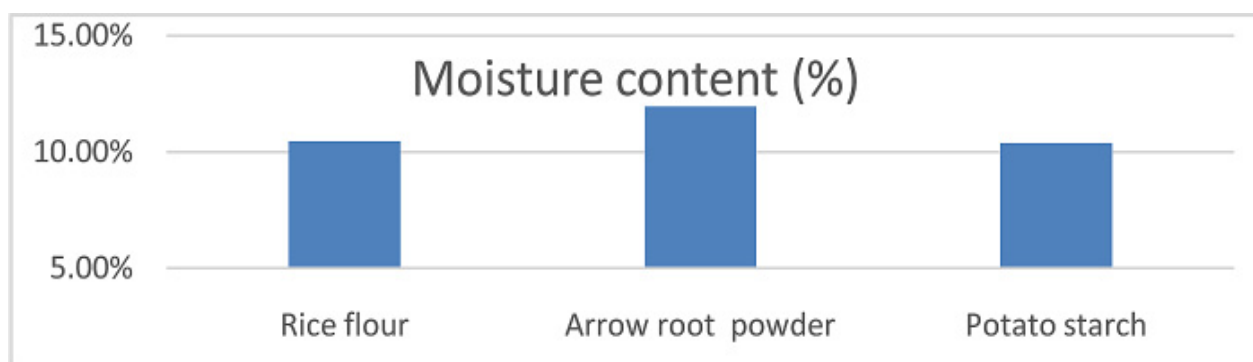
The Line Spread Test results indicate the flow behaviour of rice flour, potato starch, and arrowroot at different time intervals. At 5 minutes, arrowroot shows the lowest spread (10), meaning it forms the thickest gel, while rice flour spreads the most (23), indicating a thinner consistency. Potato starch lies in between with a spread of 20. As time progresses, the spread increases slightly for all samples. By 30 minutes, rice flour has the highest spread 28, suggesting it remains the most fluid, while arrowroot, with a spread of 16, continues to form the most stable and thickest gel. Potato starch remains

intermediate at 24. Overall, arrowroot produces the most viscous and stable gel, while rice flour shows the least resistance to flow, making it the thinnest among the three.

A study conducted by Katayama *et al.*, (2023) showed same results as the present study i.e potato starch being more viscous than rice flour. LST measurements were taken at 30 seconds and 5 minutes on starch-thickened foods including potato starch and rice flour-based samples. The results showed that potato starch samples exhibited minimal increase in spread distance over time, indicating stable viscosity and thickening properties. In contrast, rice flour samples showed a greater increase in spread distance, reflecting lower viscosity stability and faster texture deterioration likely due to moisture absorption.

Moisture Analysis

The moisture content analysis of millet papad prepared with different thickening agents revealed slight variations in their ability to retain water. Among the three, arrowroot

**Graph 6. Mean moisture content in thickening agents**

powder showed the highest moisture content at 11.96%, indicating a greater tendency to retain moisture, which could contribute to a softer texture or reduced crispness after frying. Rice flour recorded a moisture content of 10.46%, while potato starch had the lowest at 10.38%, suggesting better moisture control and potentially crisper texture in the final product. All samples were of equal weight (5g).

The moisture content of arrowroot starch in the present study was found to be 11.96%, which aligns well with scientifically reported values. According to Malki *et al.*, (2023) arrowroot starch typically exhibits a moisture content of $10.87\% \pm 1.30\%$, which falls within the acceptable range of less than 15% for starch powders. This consistency indicates that the arrowroot starch used in the current study possesses good stability and quality for food applications, as higher moisture content beyond 15% can lead to microbial growth and reduced shelf life. Therefore, the result of 11.96% not only validates the quality of the sample used but also supports its suitability for safe storage and use in various food formulations.

In the present study, the moisture content of potato starch was found to be 10.38%, which is in close agreement with values reported in earlier scientific research. According to Bao *et al.*, (2021) potato starch samples dried using standard laboratory hot oven methods show moisture content ranging from 8.7% to 10.5%, depending on the drying conditions. Since sample falls well within this range, it confirms the accuracy of the drying process and indicates that the potato starch used is of acceptable quality and suitable for food applications. Maintaining moisture content below 12–14% is crucial for the safe storage and stability of starch powders, and result of present study 10.38% suggests good shelf life and reduced risk of microbial spoilage.

CONCLUSION

In this study, four different millet grains viz., barnyard, little, foxtail, and kodo were taken to create new products by adding non-glutinous starches such as potato starch, arrowroot powder, and rice flour. Three recipes for each type of millet by using these three starches were developed. A panel of 10 semi-trained individuals evaluated the taste and quality of these recipes. Arrowroot powder received the highest scores in most recipes, while potato starch was not well-received. The viscosity of the starches was tested using the line spread test at specific time intervals and found that the rheological properties of the starches increased over time. We also analyzed the moisture content of the starches using the Loss on Drying method. The results suggest that these starches can be a suitable substitute for wheat flour and cornflour for individuals with digestive issues such as celiac disease and gluten allergies.

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DEVELOPMENT AND EVALUATION OF NUTRILADDU FOR COMBATING ANAEMIA AND UNDERWEIGHT

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ABSTRACT

This study conducted in 2023 aimed to develop iron and calorie rich nutritious recipe from inexpensive and indigenous ingredients, to be used as food supplement to prevent anaemia and enhance weight among undernourished and anaemic individuals. Iron rich ingredients such as Bajra, Amaranth seeds, Rice flakes, Black gram, Roasted Bengal gram, Groundnuts Sesame, Garden cress seeds, Cauliflower leaves powder, Amla powder were used to formulate nutrimix at three different proportions as variations V1, V2 and V3 along with Jaggery and Ghee to prepare Nutriladdu. Organoleptic evaluation was done by a panel of 30 semi trained members using 9 - point hedonic scale to assess the sensory attributes of the prepared laddus. Nutritional analysis was conducted to estimate energy, protein, carbohydrate, fat, iron, and beta carotene, along with a microbiological analysis to assess shelf life. The results showed that the laddu prepared with nutrimix V1 was selected as food supplement, due to its highest average sensory score as determined by one-way ANOVA compared to the other compositions. The nutritional analysis indicated that the Nutriladdu (V1) per 100g contains 412 kcal, 12.93g of protein, 47.78g of carbohydrates, 18.36g of fat, 7.324mg of iron, 65.93mg of calcium, and 30.07µg (8.42 IU) of vitamin A. Shelf-life analysis showed acceptability for up to 15 days of storage at room temperature. The findings indicate a potential enhancement of nutrient content in recipes by integrating cauliflower leaves, garden cress seeds, and amla at a 10 percent level, without adversely affecting sensory quality. Fortifying the menu with nutriladdu as a snack would serve as an effective food-based strategy to prevent or ameliorate anemia and promote weight gain among undernourished individuals.

Keywords: Iron Deficiency Anaemia (IDA), Nutrient analysis, Nutriladdu, Nutrimix, Organoleptic evaluation, Underweight

INTRODUCTION

Despite being one of the first countries in the world to initiate the National Nutritional Anemia Prophylaxis Programme in 1970, Iron Deficiency Anaemia (IDA) is still an unresolved nutritional problem in India. According to the National Family Health Survey (NFHS-5, 2019-

21), the prevalence of anemia among Indian women aged 15-49 years is still high (>50%). Among children aged 6-59 months, 67.1% were affected, with 52 percent of pregnant women were reported to be anaemic. Despite the complexity of anaemia's causes, it is believed that iron deficiency accounts for roughly 50%

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of instances. Underweight remains a significant public health concern, affecting various demographic groups, particularly children and women. According to a pooled analysis of 2146 population-based studies involving 128.9 million children, adolescents, and adults worldwide (Lancet, 2017), approximately one-third of male peers and one fifth of girls aged 5-19 are underweight, making South Asia as the region with the highest occurrence of moderate to severe underweight. South Asia, including India, had exhibited the lowest BMIs among both male and female adolescents. The National Family Health Survey-5 (NFHS 2019-2021) reported that 24% of adolescent girls aged 15-19 years were underweight (BMI < 18.5 kg/m²) with high rates in rural and tribal populations. Malnutrition during adolescence profoundly impacts the developmental processes. Underweight among adolescent girls is nutritional issues perpetuating inter-generational impacts. Anaemia is more common in adolescents in developing countries due to their rapid growth, development, menstruation, plant diets, and limited consumption of animal-based foods that provide bioavailable heme iron (Petry *et al.*, 2016). Due to the growth spurt and menstrual loss, teenage girls have higher iron needs. If their diet is undiversified and does not include foods high in iron in their daily meals, they may be more susceptible to iron deficiency anaemia (IDA), chronic nutritional deficiencies, and undernutrition. Various approaches yield positive outcomes in tackling anaemia such as ensuring dietary variety, incorporating iron-rich foods into daily meals providing iron tablets supplements, fortifying foods with iron and educating the community on Nutrition. (Shikha and Shalini, 2021).

Strategy to resolve anaemia involves enhancing diet to increase iron consumption by choosing foods rich in iron including meat, fish, legumes and green leafy vegetables. This

approach emphasizes iron bioavailability to optimize its absorption through incorporating significant quantities of iron absorption enhancers in meals like vitamin C and meat while minimizing the ingestion of iron inhibitors such as phytates, polyphenols and calcium. Additionally, it involves the fortification of staple foods, including wheat, maize, and rice, alongside the enhancement of knowledge through nutrition education and counselling.

Eating patterns have changed and snacking has become more common. As having snacks in between meals contribute to nutrient intake, help to meet the nutritional recommendations, nutritional quality of the snack needs to be focused. Laddu a traditional Indian sweet snack, is typically made from multiple ingredients. Its widespread consumption across diverse socioeconomic strata, considered as a potential vehicle for nutritional interventions particularly addressing iron deficiency anaemia. Development of nutrient dense iron rich laddu from multiple ingredients addresses a significant dietary need for anaemia prevention and promote weight gain among individuals who have the habit of consuming snacks in between the meal. This study was carried out with the objective to develop a nutritious snack-laddu using iron rich ingredients from different food groups, assessing the sensory attributes and nutrient composition of the developed laddu.

MATERIAL AND METHODS

Product formulation

Procurement and Processing of Ingredients

The formulation used for the development of Iron rich snack was based on the ICMR recommendations of the basic five food groups. Thus, cost effective, convenient and seasonally available iron rich sources were chosen. Foods from various groups were

chosen based on their nutritive value given in Food Composition Table (Longvah *et al.*, 2017). Accordingly, Rice Flakes, Bajra from cereal and nutri-cereals group, Amaranth seeds from pseudo-cereals, dehusked Black gram, roasted Bengal gram from pulse group, Groundnut, Sesame and Garden cress seeds (halim) from oil seeds group and cauliflower leaf powder from leafy vegetable group and Amla powder from special food or fruit group were selected for nutrimix flour. The ingredients Rice flakes, Pearl millet, Amaranth seeds, Black gram, Roasted Bengal gram, Groundnut, and Sesame were purchased from the local market of Puducherry and were cleaned thoroughly and subjected to suitable processing methods - dry roasting and made into powder/flour slightly coarse in consistency. Dark green Cauliflower leaves were procured from the market, where the daily market has wholesale and retail sale of cauliflower, trimming the leaves aside and leaving it as

waste or given as feed for cattle. The leaves were chosen properly and pale or yellow coloured were not chosen. The leaves were sorted; stalks were removed, washed and dried in an hot air oven and the dried leaves were made into powder. Amla powder, Roasted Bengal gram, roasted peanuts, ghee and jaggery were procured from the market. As per the composition decided, dry roasted the bajra, rice flakes, dehusked black gram, sesame seeds, amaranth seeds and halim seeds on a heavy bottom pan on low heat till golden brown. Once cooled was transferred into powerful blender and was fine powdered. Thus, powdered form of all selected ingredients was made ready for making nutrimix of different proportions.

Formulation of the mix and product

The powder made from the ingredients were mixed in three different compositions each consisting of 100gm of mix. To the

Table 1. The proportion of ingredients used to prepare the Nutriladdu

Ingredients for Nutrimix (Laddu)	Nutriladdu Composition (V1) (g)	Nutriladdu Composition (V2) (g)	Nutriladdu Composition (V3) (g)
Bajra	15	10	5
Amaranth seeds	10	10	5
Rice flakes	15	10	5
Black gram	15	10	5
Roasted Bengal gram	15	10	5
Groundnuts	5	10	15
Sesame	5	10	15
Garden cress seed	10	10	15
Cauliflower leaves powder	5	10	15
Amla powder	5	10	15
Total	100	100	100
Jaggery	30	30	30
Ghee	15	15	15
Total	145	145	145

formulated flour mix, powdered palm jaggery(30gm) was added and by using melted ghee (15gm) the laddu was prepared. Thus, three different variations of laddu were made (Table 1) and accordingly named as V1, V2 and V3.

Sensory evaluation of the Nutriladdu

The sensory evaluation aims to determine the final selected product from three formulations made. Organoleptic evaluation was done using a panel of 30 members which included trained, semi trained and untrained panelists (school girls, post graduate students, research scholars, and staff members and homemakers). The 9-point hedonic scale is a widely used method in organoleptic evaluation to assess and quantify individuals' subjective responses to a product's overall liking or preference. It allows consumers to express their feelings toward a particular item, often a food product, on a scale ranging from 1 to 9. Each point on the scale represents a specific level of liking or disliking, and the scale is typically anchored with verbal descriptors to guide the participants in their evaluation. Minimum score '1' is intensely disliked, and there may be a strong aversion to its organoleptic characteristics. Maximum score of '9' is liked intensely, and there is a strong preference for its organoleptic attributes. This score represents the highest level of liking. Sensory aspects such as appearance, colour, taste, flavour, texture and overall acceptability was evaluated for all the three laddu made with V1, V2 and V3 nutrimix respectively by the panelists using 9 – point hedonic scale. The overall rating was obtained by averaging the scores given by the panelists. The laddu with the highest overall acceptability score was selected for further analysis.

Nutritional analysis of the selected laddu

The samples, designated for supplementation, underwent macronutrient

and micronutrient testing at the Food Quality Testing Laboratory.

Chemical analysis of the selected laddu

Physicochemical analysis of the developed laddu was done. The Appearance, Odour, Acidity, Moisture, Ash, Acid insoluble Ash, other extraneous matter were the chemical parameters analyzed. Heavy metals like Lead, Mercury, Cadmium, Nickel, and Arsenic were also analyzed.

Microbiological analysis of the laddu

Microbiological analysis of the laddu was done on day one and on day 15 which included Total Plate Count, E-Coli, Coliform, Salmonella, Yeast and Mould.

Statistical analysis

The sensory data obtained was subjected to analysis of variance (ANOVA) using SPSS version 21.0. The data was expressed as mean $\pm$ standard deviation and the difference between samples was considered significant if its level of significance $p < 0.05$.

RESULTS AND DISCUSSION

The laddus prepared with various composition along with standard were subjected to sensory evaluation. Table 2 shows the comparison of the scores of three different variations with regard to organoleptic properties.

Duncan Multiple Range Test (DMRT) was conducted to find which two variations differ significantly. It is seen from the above table that except texture all the variations differ significantly with respect to all the attributes as well as overall acceptability. Sensory evaluation confirms incorporation of cauliflower leaves powder had significant effect on sensory properties of the laddu. The mean score of V1 (7.0) was found to be more than V2 (4.0) and V3(3.2) for overall acceptability.

Table 2. ANOVA for significant difference among the prepared food supplements with respect to organoleptic properties

Organoleptic properties of the supplement	Group				F value	P value
	Standard	V1	V2	V3		
Appearance	7.933 ^d (.254)	6.767 ^c (.504)	6.000 ^b (.371)	4.033 ^a (.414)	513.643	<0.001**
Colour	7.667 ^d (.711)	6.933 ^c (.365)	5.767 ^b (.504)	5.033 ^a (.414)	155.878	<0.001**
Flavour	7.767 ^d (.568)	7.067 ^c (.365)	5.133 ^b (.346)	5.867 ^a (.507)	201.000	<0.001**
Texture	7.833 ^d (.379)	7.867 ^d (.346)	4.967 ^b (.414)	6.800 ^a (.484)	331.789	<0.001**
Taste	7.900 ^d (.305)	6.967 ^c (.490)	4.100 ^b (.403)	2.167 ^a (.379)	1301.523	<0.001**
Overall Acceptability	7.767 ^d (.504)	7.000 ^c (.455)	4.033 ^b (.414)	3.167 ^a (.531)	655.862	<0.001**

1. The value within bracket refers to SD
2. ** denotes significant at 1% level.
3. * denotes significant at 5% level.
4. Different alphabet among products denotes significant difference at 5% level using Duncan Multiple Range Test (DMRT)

Incorporation of cauliflower leaves powder was found to reduce the sensory attributes of the laddu with the increase in the level of incorporation, which is similar to the study reported by Roshini Singh & Nidhi Verma (2022). Similarly, inclusion of Garden cress seed powder at 10% level was found to be acceptable which is in consistent with study by Tanu Jain *et al.*, (2016). The quality of taste received the lowest score of 2.6 for 15% of cauliflower, garden cress seed and amla incorporated product. Duncan's multiple range tests applied to check for differences in between the samples, revealed that they were not similar in any of the sensory attributes. However, the 10% cauliflower garden cress, and amla incorporated product was found to be similar to control in terms of texture, flavour and overall quality although significant

difference was seen in appearance and colour. Laddu prepared with nutrimix V1 was chosen as food supplement based on the average perception and overall acceptability.

Nutritional analysis of the laddu

The nutrient composition of the laddu prepared with the nutrimix V1 was analyzed by appropriate methods and is given in table 3.

The nutrient composition of Nutri laddu shows that 100g of laddu provides 412.58 kcal, 47.78g of carbohydrates, 12.93 g of protein, 18.36 g of fat, 2.54 g of crude fibre. The mineral composition level indicated 655.93 mg of calcium, 7.32 mg of iron, and the vitamins A and C were 8.42IU and 19.25 mg respectively. In a study by Padma *et al.*, (2019) laddu made of health mix provided protein 13.90g, fat 5.46g, carbohydrates 71.54g, energy 348.16

Table 3. Nutritional composition of the Laddu(V1)

Nutrients	Formulated product-Laddu (V1) per 100g
Calories (kcal)	412.58
Carbohydrate(g)	47.78
Protein(g)	12.93
Fat(g)	18.36
Crude Fiber(g)	2.54
Calcium(mg)	655.93
Iron(mg)	7.32
Vitamin A (IU)	8.42
Vitamin C(mg)	19.25

kcal, iron 9.10mg, calcium 210mg per 100 gm. The nutrilladdu developed had nearly the same nutritional composition as that of the millet laddu developed by Subbaiyan *et al.*, (2024) which was found to have 11.13 g of protein, 64.47 g of carbohydrate, and 15.13 g of fat per

100 g of the product. The protein, fat and iron content of the nutrilladdu is higher than that of the pearl millet laddu formulated by Rubavathi *et al.*, (2022), which showed that the protein 9.9 ± 2.8 g, fat 4.2 ± 0.5 g carbohydrate 69 g per 100g. Laddu produced solely with ragi by Shazia *et al.*, (2023) had a total protein value of only 3.18g/100, but nutrilladdu formulated with ingredients from various food groups had a protein content of 12.93g/100g, suggesting that it not only offers diversity but also enhances the nutritional composition overall.

Chemical analysis of the laddu

Physicochemical properties and heavy metal analysis of the laddu prepared with the nutrilmix V1 are provided in Table 4 and it depicts that the results meet the acceptance criteria.

The results for physicochemical analysis revealed that appearance was good and odour was agreeable and there was no extraneous matter present thus making the laddu acceptable for consumption. Other attributes

Table 4. Physicochemical and Heavy Metal analysis of laddu (V1)

Physicochemical analysis		
Parameter	Specification	Result
Appearance	Good	Good
Odour	Agreeable	Agreeable
Acidity	Max 0.2%	0.08%
Moisture	Max 7.0%	4.0%
Ash	Max 5.0%	1.5%
Acid insoluble ash	Max 0.1%	0.02%
Other extraneous matter	To be absent	Absent
Heavy metals analysis		
Lead	Max 5.0 mg/Kg	0.5 mg/kg
Mercury	Max 0.25 mg/Kg	<0.01mg/kg
Cadmium	Max 1.0 mg/Kg	<0.01mg/kg
Nickel	Max 0.5 mg/Kg	<0.01mg/kg
Arsenic	Max 0.5 mg/Kg	<0.01mg/kg

Table 5. Microbiological analysis of the Laddu (V1)

Parameter	Specification	Result	
		First day	After 15 days
Total plate count	Max10 x 10 ³ CFU/g	200 x 10 ¹ CFU/g	270 x 10 ¹ CFU/g
E.Coli	Absent	Absent	Absent
Coliform	<10CFU/g	0 CFU/g	0 CFU/g
Salmonella	Absent	Absent	Absent
Yeast and Mould	<10CFU/g	0 CFU/g	0 CFU/g

like acidity, moisture and ash were within the permissible limit. The heavy metal analysis to measure the level of toxic metals like lead, mercury, cadmium, nickel, arsenic present in laddu by Inductively Coupled Plasma Spectrometry (ICP-MS) proved that the detected concentrations were within the regulatory standards recommended by FSSAI (Food Safety and Standards Authority of India).

Microbiological analysis

The storage stability results of the microbiological analysis of Nutriladdu prepared with the nutrimix V1 are given in table 5 and are in compliance to specification thus making it acceptable for consumption.

Microbial testing on first day and after fortnight to identify food borne pathogens and storage organisms to ensure food safety. The total plate count in the laddu was 200CFU/g on the first day and 270 CFU/g after 15 days. There was no growth observed for Coliform, Yeast, and Mould, and E. coli and Salmonella were not present at any point during the storage period. Thus, the Microbial analysis proved that the Nutri laddu was free of biological hazards and safe for consumption.

CONCLUSION

The result signifies that incorporating energy rich ingredients such as jaggery, ghee along with inexpensive and indigenous iron rich ingredients such as cauliflower leaves, garden cress seeds as functional ingredients

from different dietary groups in the-nutritious snack provided 412.58 kcal, 12.93 g of protein, 655.93 mg of calcium, 7.32 mg of iron per 100gm of laddu. The Nutriladdu prepared with 10 % incorporation of cauliflower leaves, garden cress seeds and amla powder was found to have better overall acceptability. The results of physicochemical analysis confirm that the appearance was good, odour was agreeable, heavy metals and other attributes were within the permissible limits, and no extraneous matter was present. Thus, the nutritional composition, sensory attributes and the storage stability of the laddu makes it suitable for consumption as well as more comprehensive understanding of utilizing iron rich food sources in traditional food preparation, potentially paving the way for food-based approach for preventing iron deficiency anaemia. Further the study can be extended to assess the phytochemicals, bio accessibility and bioavailability of nutrients present in the developed Nutriladdu.

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INFLUENCE OF PARENTAL INVOLVEMENT ON EARLY CHILDHOOD CARE AND EDUCATION (ECCE): THE TEACHERS' PERSPECTIVES

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ABSTRACT

This study conducted in the year 2022, investigates Anganwadi teachers' perceptions of parental involvement in Early Childhood Care and Education (ECCE) in Kerala, India, focusing on the influence of teachers' age and years of experience on parental involvement. Using a self-designed rating scale, responses from 225 teachers were analysed through one-sample Z-tests and ANOVA to evaluate perceptions and demographic variations. The findings revealed a generally positive perception of parental involvement, with a mean perception score of 71.7% ($z = 36.005$, $p < 0.001$). Older teachers (mean = 22.25, SD = 2.70) and those with more experience (mean = 22.81, SD = 2.63 for 25-35 years) exhibited significantly more favourable attitudes toward parental involvement ($p < 0.05$). While most teachers (96.5%) agreed or strongly agreed that both parents and teachers should collaborate to enhance children's readiness skills. Gaps in parental awareness were evident, with 73.3% of teachers perceiving a lack of awareness about ECCE. The study emphasises the need of professional development programs to strengthen teacher-parent collaboration, including training sessions, enhanced communication tactics, and active parental participation in decision-making.

Keywords: ECCE, ICDS, Parental Involvement, Teaching experience, Teachers Perceptions

INTRODUCTION

Parental involvement is key to children's growth in education, both academically and emotionally. While its importance is well known, little attention has been given to how teachers see and experience parental participation, especially in varied cultural settings. Recent research emphasises the significance of active parental involvement in preparing children for formal schooling. Trivedi (2023) in his study showed that a loving home atmosphere rich in activities such as reading and interactive play considerably improves children's school readiness. Similarly, the COVID-19 pandemic highlighted the importance of structured

parental assistance, as parents became more involved in their children's education amid school closures. Vernekar *et al.*, (2022) found that structured programs meant to empower parents significantly reduced possible learning deficits in early childhood settings.

Understanding the dynamics of parental involvement is critical in developing effective ECCE programs in India. Cultural and social influences have a significant impact on parental attitudes and practices, affecting their level of engagement. Swargiary and Roy (2023) performed a survey and discovered that parents' views and opinions about preschool

education strongly influence their involvement in their children's early learning experiences. These findings indicate that culturally sensitive practices are critical to developing effective parent-teacher relationships. For instance, a meta-analysis by Castro *et al.*, (2015) demonstrated that parental involvement is positively associated with children's academic achievement, social skills, and self-esteem.

Socio-economic status (SES) affects how much parents can be involved in early education. Families with higher SES often have more time, resources and awareness to support their children. In contrast, those with lower SES may face challenges like busy work schedules or limited access to information, making it harder to participate in ECCE (Gokturk and Dinckal, 2017). When parents are involved in early childhood education, a child's classroom experiences can extend to incorporate real-world activities that occur within the home environment. A parent can better assess their child's competency and identify areas for improvement to boost confidence and ability if aware of what their preschooler activity (Spreeuwenberg, 2022). This research explores teachers' perspectives on the influence of parental engagement in ECCE.

HYPOTHESIS

H_0 : The level of Perception on ECCE and parents is = 50 percent of total score (H_0 :MPS=50%)

H_1 : The level of Perception on ECCE and parents is > 50 percent of total score (H_1 :MPS>50%)

H_2 : The mean Score of Perception on ECCE and parents is consistent across different age groups.

H_3 : mean Score of Perception on ECCE and parents is the same for different years of experience

MATERIAL AND METHODS

The study conducted in 2022 employed a straightforward yet effective approach to explore Anganwadi teachers' perceptions of parental involvement in Early Childhood Care and Education (ECCE) in Kerala, India. The aim of the study was to understand the influence of factors like age and years of experience influence these perceptions.

The research used a cross-sectional survey design, targeting 225 Anganwadi teachers working in both urban and rural areas under the Integrated Child Development Services (ICDS) scheme. A stratified sampling method was adopted to ensure the inclusion of teachers across diverse age groups and varying levels of experience. The data collection tool consisted of a self-designed questionnaire divided into two sections. The first section gathered basic demographic details such as age and years of teaching experience. The second section focused on teachers' perceptions of parental involvement, utilizing a five-point Likert scale. The questions addressed critical aspects like the quality of teacher-parent collaboration, communication practices and the role of parents in supporting their children's education.

The collected data were analysed using various statistical methods to answer the research questions. Descriptive statistics, including mean, standard deviation, and percentage scores, were calculated to gauge teachers' perceptions. A one-sample Z-test was employed to determine whether the overall perception score exceeded the hypothesized threshold of 50%. Additionally, one-way ANOVA tests were conducted to compare perception scores across different age groups and years of experience.

RESULTS AND DISCUSSION

Teachers Perception on Parental Involvement on ECCE

To gauge teachers' perception of early childhood care and education (ECCE) and

Table 1. Descriptive Statistics and Z-Test for Perception on ECCE and Parents

Sl.No	Variable	N	SD	Mean	Mean %	CV	z	p
1	Perception on ECCE and parents	225	2.71	21.51	71.70	12.61	36.005	<0.001

parental involvement, questions were asked using a five-point Likert scale. Responses were scored from 1 to 5. The combined score of all questions for the 225 respondents was calculated. Subsequently, the mean percentage score for extent of teachers' perception on ECCE and parents was determined.

The mean percentage score of 71.70% for perception on ECCE and parents suggests that the extent of perception falls within the range of good to medium. The coefficient of variation indicates stability since its value is below 20%. To determine if the observed sample information accurately represents the population and to confirm whether the extent of perception on ECCE and parental involvement is indeed medium, hypothesis H_0 and H_1 has developed.

The hypothesis was evaluated using a one-sample Z test, the results are illustrated

in Table 1. The p-value obtained using the table 1 was lower than 0.05, and the z-value is positive, indicating statistical significance. Consequently, the rejection of the null hypothesis led to the inference that the level of perception on ECCE and parents exceeds 50%, suggesting a good level. The results show that Anganwadi teachers perceive parental involvement as crucial to early childhood education.

According to Gokturk and Dinckal (2017), teachers define parental involvement as the support parents offer their children during homework or project work at home, whereas parents desire involvement in decisions regarding their children's education. They suggest that when there's a discrepancy between parents' and teachers' viewpoints, collaboration becomes less effective. Wu and Hindman (2024) emphasised the importance

Table 2. Teachers' perception on parents involvement in ECCE

n=225						
Sl.No	Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1	Parents prefer Anganwadi	6.7	30.2	4.9	44	14.2
2	Preschools should discuss readiness	0.9	0	0	56	43.1
3	Parents have no influence on readiness	17.3	73.3	2.2	4.9	2.2
4	Parents and teachers should collaborate on readiness	0.4	2.7	0.4	42.7	53.8
5	Parental education impacts readiness	5.3	40	2.7	36.9	15.1
6	Inform teachers about parental learning issues	0.9	4	0.9	66.2	28

of parental participation in children's school preparedness, particularly the function of activities such as home reading in supporting cognitive and emotional development. Their findings are consistent with the positive attitudes teachers in this study have towards family engagement.

Perception on ECCE and Parents

Teachers predominantly agreed that parents prioritize their child's early education, with 44.0% agreeing and 14.2% strongly agreeing. However, a notable percentage disagreed (30.2%) or strongly disagreed (6.7%), while 4.9% remained neutral. This reveals a mixed perception, suggesting that while many parents are seen as prioritizing ECCE, some teachers perceive otherwise. Concerning the role of preschools in enhancing children's readiness, many teachers strongly agreed (43.1%) and agreed (56.0%), with no disagreements or neutral responses. This indicates unanimous support for the importance of preschools in preparing children for school.

When asked about parents' awareness of ECCE, 73.3% of teachers disagreed and 17.3% strongly disagreed, reflecting a widespread perception of insufficient parental awareness. Only 4.9% agreed, 2.2% strongly agreed, and 2.2% were neutral, emphasizing the need for greater parental education and awareness about ECCE. The statement regarding shared parental responsibility in ECCE received strong support. Many teachers strongly agreed (53.8%) and agreed (42.7%), with only a small percentage disagreeing (2.7%), strongly disagreeing (0.4%), or remaining neutral (0.4%). This highlights a strong consensus on the importance of both parents' involvement in ECCE.

Regarding the impact of parental education on children's readiness, 40.0% disagreed, and 5.3% strongly disagreed. Conversely, 36.9% agreed, 15.1% strongly

agreed, and 2.7% were neutral, reflecting varied opinions. While many teachers acknowledge the influence of parental education, others perceive its impact as less significant. Finally, when considering the influence of socio-economic status on parental involvement in early education, 66.2% agreed and 28.0% strongly agreed. Only a small proportion disagreed (4.0%) or strongly disagreed and remained neutral (both 0.9%). This suggests that teachers generally associate higher socio-economic status with increased parental involvement in ECCE.

Influence of Teachers' age on perception on parental Involvement on ECCE

Considering the age of the participants, and to investigate the hypothesis H_2 , a one-sample analysis of variance was employed where three or more independent variables are involved. In this scenario, the independent variable was the age group (yrs.), consisting of four groups: 18-28, 29-39, 40-50, and 51-62. ANOVA was employed to differentiate the mean scores of the different age groups, and the results are presented in the table 3.

The findings of the test presented in Table 3 indicate that the p-value is lower than 0.05 for perception on ECCE and parents. Consequently, the analysis concluded that there the mean score of perception on ECCE and parents varies across age groups. Thus, hypothesis H_2 was rejected.

Aleman-Falcon *et al.*, (2023) found that teachers aged 53 years or older perceive greater participation from families in school decision-making compared to teachers aged between 24 and 44. The median score for teachers aged 24-44 years old was 4.29, while for teachers aged 53 years or older, it was 4.63, with a significance level $p = 0.012$. The correlations were found to be statistically significant at $p < 0.01$, indicating that teachers' positive attitude towards parental involvement increased with age ($r = 0.829^{**}$, $p < 0.01$)

Table 3. Mean, Standard deviation and F value for Age

Sl.No	Variable	Age	N	Mean	S.D	F	p
1	Perception on ECCE and parents	18-28	3	21.33	0.58	5.192	0.002
		29-39	24	21.04	2.61		
		40-50	93	20.81	2.61		
		51-62	105	22.25	2.70		

(Alzaidiyeen, 2016). Winder and Corter (2016) discovered that early childhood educators' projected that work with families is shaped by earlier experiences, which are commonly accumulated with age.

Influence of years of experience on Teachers' Perception on Parental Involvement on ECCE

Considering the years of experience of the participants, and hypothesis H_3 , evaluated using one-sample ANOVA test. In this instance, years of experience were regarded as independent variable, encompassing five groups: (a) Below 5 years, (b) 5-15 years, (c) 15-25 years, (d) 25-35 years, and (e) 35 years and above. ANOVA has employed to collate the mean scores of years of experience, and the outcome is depicted in Table 4.

The outcomes of the test displayed in Table 4 indicate that the p-value is lesser than 0.05 for perception on ECCE and parents. Therefore, it is ferred that mean score on perception on ECCE and parents varies with years of experience. Hence, the hypothesis H_3 , was rejected. Teachers with more experience demonstrated stronger perceptions of parental involvement's importance, likely reflecting their deeper understanding of its impact on

children's learning and development. With experience teachers also perceived parents to have a significant role in the overall wellbeing of the children.

The findings indicate that teachers with more years of experience have a greater appreciation for parental involvement in ECCE. Winder and Corter (2016) found that prior experiences influence early childhood educators' projected work with families, meaning that experienced instructors may place a higher priority on parental involvement. Research done by Alzaidiyeen (2016), found that a positive correlation ($r = 0.863^{**}$, $p < 0.01$) between the attitudes of teachers towards parental participation and their experience.

CONCLUSION

The study revealed that most (71.7%, $z = 36.005$, $p < 0.001$) of the Anganwadi teachers have a positive view of parental engagement in early childhood education. Older teachers (mean = 22.25, SD = 2.70) and those with more years of experience (mean = 22.81, SD = 2.63 for 25-35 years) expressed stronger positive perceptions of parental involvement ($p < 0.05$). Teachers emphasized the critical role of collaboration, with 96.5% agreeing or strongly agreeing that both parents and teachers are

Table 4. ANOVA for years of experience as an Anganwadi Teacher

Sl.No	Variable	Experience	N	Mean	S.D	F	p
1	Perception on ECCE and parents	Below 5 years	21	21.57	2.40	3.206	0.014
		5-15 years	76	21.39	2.62		
		15-25 years	86	20.99	2.79		
		25-35 years	36	22.81	2.63		
		35 years and above	6	22.50	2.07		

responsible for improving children's readiness skills. However, significant gaps were noted, with 73.3% of teachers perceiving a lack of parental awareness about ECCE, and socio-economic disparities were identified as influencing parental involvement. The study suggests two vital areas for improvement: Teachers should receive periodical training to enhance their skills in leveraging parental involvement for students' benefit. Improving communication, organizing seminars on home-based learning support for parents, and actively seeking their opinions can strengthen the collaboration between educators and parents.

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DEVELOPMENT OF READY-TO-EAT COOKIES FROM GEO SPECIFIC ANCHOVY (*STELOPHORUS HETEROLOBUS*) FORTIFIED WITH PUMPKIN SEED FLOUR

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ABSTRACT

The purpose of this study carried out in 2022-2023 was to develop and assess the sensory and nutrient characteristics of pumpkin seed flour fortified anchovy-based (*Stelophorus heterolobus*) cookies. The results showed that addition of pumpkin seed flour at a ratio of 30 percent and anchovy powder 10 percent did not change the consistency or flavour of cookies and enhanced the nutritive value. Fortified anchovy cookies were found to provide calorie (1256.8kcal), carbohydrate (74.63g), protein (19.13g) and fat (42.2g) per 100 grams. The fibre content of cookies was found to be 10.49g as pumpkin seed flour and wheat flour are rich in fibre. The calcium, iron, and vitamin C content of the sample were 116.63mg, 4.72mg, and 15.64mg respectively. Microbial analysis of cookies revealed that it was safe for human consumption in terms of E. coli with Total Plate Count of <10cfu/g and 6400cfu/g respectively. Fortification of cookies with vegetable seeds into products serves as a good alternative in promoting dietary diversification and sustainability.

Keywords: Anchovy, Fortified Cookies, Microbial analysis, Nutrient Analysis, Organoleptic, Pumpkin Seed Flour.

INTRODUCTION

In the present modern lifestyle, exists a rise in the need for a variety of instant food products to fulfil consumer preferences, dietary diversity and prevention of malnutrition which made the development of geospecific products critical. Food consumption trends have changed dramatically in recent years and because of changing lifestyle the number of meals eaten away from home have steadily increased. Lack of time for cooking and the affordability of such foods are two factors contributing to the growth of the ready-to-eat meal industry (Mohammadi-Nasrabadi *et al.*,

2021). Cookies are convenient for consumers since they offer a diverse selection of snack options with a lengthy shelf life and lower price. Fisheries and aquaculture serve a critical role in providing nutritious, low-carbon foods to a growing global population (FAO, 2021). The average annual increase in global consumption of fish (3.2%) outpaced the average growth in population (1.6%) between 1961 and 2016 (Bhandary *et al.*, 2021). The nutritional value of cookies is determined by their ingredients, which is improved by altering their composition (Abdel Moemin, 2015). Malnutrition occurs when people consume baked foods without any

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Fig. 1. Processing of anchovy cookies

vitamin supplements. As a result, cookies and ready to eat foods must be enhanced or fortified by addition of one or more necessary ingredients like pumpkin seeds that are not usually found in food in order to boost their nutritional content.

MATERIAL AND METHODS

The present study was carried out during 2022-2023 and funded by Directorate of Collegiate Education, Government of Kerala under ASPIRE Research Award. Anchovy (*Stelophorus heterolobus*) were collected from Fathima Matha fish market at Thiruvananthapuram, Kerala. The preliminary preparation of the anchovy viz washing, cutting, sundrying, grinding was adopted to enhance the palatability and acceptability of the products. The other major ingredients like pumpkin seed (*Cucurbita maxima*), were purchased from a

local market, in Alappuzha, Kerala. The seeds were taken from the fluffy portion of a ripe pumpkin after it was split into half (fibrous strains). The seeds were washed, dried in the oven (93°C, 3-4hours) and grounded into fine flour. The flour can be used for fortification as it is inexpensive, abundant in nutrients, and has excellent sensory qualities (Goranova *et al.*, 2019).

Production of cookies and assessment of quality

For the preparation of cookies initially all ingredients were weighed according to the percentage used as listed in Table 1. The cookies were made using the procedure outline (Goswami *et al.*, 2015). Cookies with anchovies were made using incorporation of anchovy powder, pumpkin seed flour and wheat flour at various levels and other ingredients were kept constant.

Table 1. Composition of variation of anchovy cookies

Sl. No	Ingredients(g)	Control group(C1)	Sample1 (S1)	Sample2 (S2)	Sample3 (S3)
1	Wheat flour	100	60	65	70
2	Anchovy powder	0	30	20	10
3	Pumpkin seed flour	0	10	15	20
4	Butter(unsalted)	30	30	30	30
5	Sugar	30	30	30	30
6	Ginger	5	5	5	5
7	Green chilly	12	12	12	12
8	Chilli powder	5	5	5	5
9	Garam masala	5	5	5	5
10	Salt	2	2	2	2
11	Gingelly seeds	4	4	4	4
12	Baking powder	2	2	2	2



S1 S2 S3

Fig. 2. Standardization of anchovy cookies

S1* S2* S3*

Fig. 3. Variations of anchovy cookies**Table 2. Mean value of organoleptic properties of anchovy cookies**

Sl.No	Product Characteristics	C1	S1	S2	S3
1	Appearance	7.2 ± 0.2	6.0 ± 0.836	6.2±0.447	8.0±0.707
2	Color	7.1 ± 0.21	6.0±0.707	6.2±0.447	8.2±0.836
3	Texture	8.05 ± 0.2	7.0±0.894	6.6±0.547	8.0±0.894
4	Taste and Odour	8.05 ±0.2	7.0±0.547	6.6±0.707	8.0±0.707
5	Flavor	7.5 ±0.15	7.0±0.894	7.2±0.547	8.6±0.836
6	Acceptability	7.25 ± 0.24	6.4±0.547	6.4±0.894	8.2±0.836

C1-Control (Wheat 100)

S1-(Wheat: Anchovy: Pumpkin 60:30:10)

S2-(Wheat: Anchovy: Pumpkin 65:20:15)

S3-(Wheat: Anchovy: Pumpkin 70:10:20)

Nutrient, microbial and organoleptic analysis of cookies was done. Control cookies were prepared using all ingredients except anchovy powder and pumpkin seed powder following above procedure.

Sensory evaluation

Sensory evaluation has been used to accept or reject food products from the beginning of humanity (Ruiz-Capillas *et al.*, 2021). The sensory evaluation for the developed anchovy cookies was done in three palatability trials with a trained panel of twenty-five members and the products were evaluated using Hedonic 9 point rating scale to assess the acceptability of the product (Hajela, 2017).

Statistical analysis and interpretation of data

After gathering score given by the panelists, mean and standard deviation were derived for comparing the different sensory characteristics of the developed products and data was interpreted.

RESULTS AND DISCUSSION

Standardization of cookies

After undergoing verification, product evaluation, market study the quantity of the ingredients were standardized to get one serving portion of anchovy. The standard quantity of the ingredients for the development of the anchovy products are given below in Table 1. The cookie yield was 13g while taking

100g of raw material, and each cookie weighed 15.2 ± 0.057 for S1, S2 and S3 samples respectively.

Sensory evaluation of the products

The variations of anchovy products were served separately for organoleptic evaluation of appearance, color, texture, flavour, taste, odour and overall acceptability. The evaluation of scores for anchovy cookies along with control are presented in Table 2.

For sample S1, the mean value of scores obtained each for texture and flavor was 7.0 ± 0.894 , for appearance, colour, taste and odour the mean score was 6.0 ± 0.836 , 6.0 ± 0.707 and 7.0 ± 0.547 respectively compared to control group. Mean score for sample S3 was 8.0 ± 0.707 for appearance, 8.2 ± 0.836 for colour, 8.0 ± 0.894 for texture and 8.0 ± 0.707 for taste and 8.6 ± 0.836 for flavor. Sample S3 has the highest overall acceptability (8.2 ± 0.836) which makes it better among the three samples. Sample S1 and S2 were the second acceptable cookies with mean score of (6.4 ± 0.547 and 6.4 ± 0.894).

The scores of cookies formulated with anchovy powder are slightly higher for attributes of appearance and texture, but lower for attributes of taste and odor. Panelist assessed that the cookies formulated with 10% anchovy powder showed a better appearance compared to control, because of homogenous shape and smooth surface. The color in

Table 3. Nutritive value calculation of anchovy cookies

Sample	Energy (kcal)	CHO (g)	Protein (g)	Fat (g)	Fibre (g)	Calcium (mg)	Iron (mg)	Vitamin C(mg)
Control C1/100g	349.89	70.98	11.52	2.21	2.98	42.34	4.13	0.01
Anchovy cookies per 100 g	1256.8	74.63	19.13	42.2	10.49	116.63	4.72	15.64

*CHO Carbohydrate

Table 4. Nutritive analysis of anchovy cookies

Sl.No	Nutritional composition per 100g	Procedure	Mean score
1	Energy(kcal)	Bomb calorimeter method	469.66±10.0
2	Carbohydrate(g)	Phenol sulphuric acid method	41.64±5.0
3	Protein(g)	Biuret method	26.41±0.5
4	Fat(g)	Chloroform/methanol extraction method	21.94±0.1
5	Fibre(g)	Colorimetric method	4.60±0.1
6	Vitamin C(mg)	2,6-Dichloroindophenol (DCIP)	79.06±2.0

cookies is strongly influenced by the basic ingredients used, namely anchovy powder which has a slightly brownish color. In terms of texture, addition of small quantity of anchovy powder into formulation produced cookies with more crispy but soft texture inside the mouth. Addition of 10% of anchovy powder into cookies formulation lowered the hardness of the cookies. However, study reported that addition of higher concentration of anchovy powder (up to 20%) into cookies formulation produced higher hardness. For attributes of taste and odour, cookies formulated with anchovy powder were still lower compared to control. Addition of anchovy powder into cookies was identified to produce fish odour and a slightly bitter aftertaste according to panelists. Similar results were also reported by other study, which stated that addition of fish-derived ingredient into food products affects negatively the sensory characteristics of the product, especially for attribute of flavor and odour, if it used at inappropriate concentration (Ikasari *et al.*, 2020). From the mean score it was observed that, sample S3 has good flavor and taste than other two samples and higher overall acceptability.

Nutritive Value Calculation and Nutrient Analysis of Developed Anchovy Cookies

A fundamental strategy for raising the nutritional quality of supplemental feeds is to ensure dietary diversity. A diet's quality can be improved and micronutrient requirements can be met by diversifying it more (Yankah *et al.*, 2020). Nutritional quality is one of the criteria that determines the consumer acceptance of the developed product. In this study nutritional composition of the developed anchovy products were calculated with help of Indian Food Composition Tables (Longvah *et al.*, 2017). In order to assure nutritional quality of the developed products, nutrients like energy content, carbohydrate, protein, fat, fibre, iron, calcium and vitamin C of the cookies was determined.

The nutritive value calculation of anchovy cookies were done using Nutrical software 3.0 version compared to control cookies as shown in Table 3. From the 3 variations, the variation with highest acceptability S3 (10:20:70) was selected and nutritive value was calculated.

Table 5. Microbial analysis of anchovy cookies

Microbial analysis	Anchovy cookies per gram	Mean Score
E.coli	<10cfu/g	3.6±0.22
Total Plate Count(TPC)	6400cfu/g	4.4±0.21

Anchovy cookies incorporated with pumpkin seed were highly nutritious and high in vitamin C and calcium (Thalib *et al.*, 2021). Fortified anchovy cookies were found to provide calorie (1256.8kcal), carbohydrate (74.63g), protein (19.13g) and fat (42.2g) per 100 grams. The fibre content of cookies was found to be 10.49g as pumpkin seed flour and wheat flour are rich in fibre. The calcium, iron, and vitamin C content of the sample were 116.63mg, 4.72mg, and 15.64mg respectively. The developed cookies is nutritious and balanced and provide protein, fat and carbohydrate intake of 1/3rd portion of RDA.

Nutrient analysis of cookies

The laboratory analysis has estimated the exact value of composition present in the anchovy cookies using various techniques for the respective chemical composition.

Table 4 shows the result of nutritional composition of anchovy cookies. 100g of cookies provide 41.64 g of carbohydrates and 469.66 Kcal of energy. The results of protein analysis of cookies showed an average of 26.41 g per 100 g. Fish has a high-quality protein content since they contain complete amino acids and possess excellent digestive qualities. According to a recent study (Jeyanth *et al.*, 2018), the cookies produced from 50% dried anchovy powder substitution had the highest protein content of 18%. The result shows that cookies on an average contains 21.94 g of fat. Pumpkin seed flour is also rich in phytosterol, a variety of polyunsaturated fatty acids of 37 to 45% (Kaur and Sharma, 2018). Fat from cookies provide 469.66 kcal of energy per 100 g of the final product. In order to prevent obesity and protein deficiency in youngsters as they get older, food should have a low fat level and a high protein content. Analysis of fibre content of cookies displayed an average of 4.60g fibre per 100 g of cookies. Nutrient analysis Table-4 shows that anchovy cookies contained high amount of vitamin C

(79.06mg) which occurs possibly as a result of fortification with pumpkin seed flour.

Table 5 shows the E. coli content in anchovy cookies. An indication of the safety of food is the absence of E. coli bacteria utilized as a sign of the absence of pollution from human and animal waste as well as of adequate food and water sanitation. The E. coli levels in developed cookies was <10cfu/g compared to normal range of the E.coli <20cfu/g. From the findings, the Total Plate Count (TPC) microbes of anchovy cookies were 6400 cfu/g compared to normal range of TPC 10^3 to $< 10^4$ that revealed the microbial safety of cookies.

CONCLUSION

Current research study has tried to improve the nutritional value of cookies with the addition of anchovy powder fortified with pumpkin seeds. The developed product was acceptable in terms of organoleptic qualities and balanced in terms of nutrition and found to be a good option in combating micronutrient deficiencies promoting sustainability. It was substantiate from the result that the fortified cookies can be recommended as a substitute for snacks to meet the recommended dietary allowances enhancing the nutritional well-being of malnourished population and for the management of specific disease conditions.

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ANTHROPOMETRIC MEASUREMENTS AND NUTRITIONAL DEFICIENCIES AMONG ADOLESCENT GIRLS IN EAST KHASI HILLS, MEGHALAYA.

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ABSTRACT

The present study was conducted among 467 unmarried adolescent girls (13-18 yrs) with an aim to assess the anthropometric measurements and to screen for nutritional deficiencies among adolescent girls in East Khasi Hills District of Meghalaya, India. Data on Sociodemographic and clinical examination were collected using a pre-tested semi-structured questionnaire. Parameters viz., height and weight were recorded and BMI was calculated. From the 476 adolescent girls, 55.88 % were aged between 13-15 years, 63.03 % belonged to nuclear families, 69.96 % followed Christianity and 33.82 % belonged to low-income groups. The average standing height and body weight were significantly lower than the ICMR standards ($p < 0.01$) demonstrating growth deficit. The BMI analysis showed that 20 % of the adolescent girls were underweight, 6.09 % were overweight and 1.26 % were obese. Iron Deficiency Anaemia (IDA) was noticed in 35.5 % of adolescent girls, indicating a moderate public health concern. Vitamin C deficiency was observed in 19.6 % of the adolescent girls showing signs of spongy and bleeding gums, also classified as a mild public health problem. Vitamin A deficiency (VAD) was observed in 5 % of adolescent girls and it was classified as a mild public health problem. Additionally, 33.3 % of adolescent girls had Vitamin D deficiency, presenting with muscle and bone pain. In view of these findings, implementing targeted micronutrient interventions is imperative to mitigate deficiencies and strengthen the overall nutritional profile.

Keywords: Adolescent girls, Anthropometry, Iron Deficiency, Meghalaya, Nutritional deficiencies.

INTRODUCTION

Adolescence is an important stage in life, as it is the period when physical, emotional, intellectual changes and developments occur. During this stage, hormones cause physical changes such as puberty and the growth of organs, while the brain continues to develop, allowing for higher- level thinking and abstract

ideas. This stage is the stepping stone for the journey to adulthood, as adolescence gain more independence and take on responsibilities. Adolescent girls are the future mothers; therefore, they wield an important influence in the development of a country.

According to the Centres for Disease Control and Prevention (CDC), anthropometry

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provides a valuable assessment of the nutritional status of children and adults (Fryar *et al.*, 2016). Nutritional anthropometry is an important tool to determine the nutritional status. Quantitative measures of the body taken non-invasively are called anthropometric measurements. The principal core elements of anthropometry involve standing height, body weight, and body mass index (BMI), which are essential for evaluating nutritional status (Casadei and Kiel, 2022). Among anthropometric indices, the body mass index is being more closely linked to nutritional factors rather than genetic ones (Weir *et al.*, 2023)

Clinical observation is the process of careful clinical examination of a person to ascertain their nutritional status. Clinical observation or inspection is one of the most important aspects of physical examination because it leads to diagnosis and treatment. During clinical observation, the clinician uses all their senses to patient effectively. Additionally, they can also identify any underlying clinical symptoms that are not visible to the naked eye (Dover *et al.*, 2023)

Adolescent girls constitute 11.82 percent of the total population of Meghalaya with an

estimated female adolescent population of 3,50,605 (Statisticstimes, 2024). Malnutrition remains a significant concern in the East Khasi Hills district, particularly among adolescent girls aged 13 – 18 years, however, its extent has not been specifically quantified in this age group (Radhakrishnan *et al.*, 2021).

Due to the lack of reliable prevalence data and targeted intervention strategies, this issue raises serious public health concerns. Therefore, the present study was undertaken to assess the socio-economic status, body weight, height and clinical signs of adolescent girls aged 13 to 18 years in the East Khasi Hills district of Meghalaya, using nutritional anthropometry and clinical examination.

MATERIAL AND METHODS

The present study was conducted in the East Khasi Hills districts, Meghalaya, where the state capital Shillong, is located. The towns in East Khasi Hills are the most populous and have the most schools and colleges. Therefore, the lack of prevalence data and intervention strategies remains a pressing issue.

The study was conducted from January 2023 to January 2024 and followed a



Fig. 1: Map of the East Khasi Hills included in the study

descriptive cross-sectional design. The sample size was estimated using an online tool available at <http://riskcalc.org:3838/samplesize/>. A total of 476 adolescent girls aged 13-18 years from the East Khasi Hills were included in the study. A Stratified random sampling method was used to select eight different schools from five blocks - Mawlai, Mawpat, Mylliem, Mawphlang and Mawrynkneng - dividing the data into various sub-groups (strata) (Wang and Cheng 2020). Permissions were obtained from schools and informed consent was collected from parents and participants, who were asked to sign a consent form.

Ethical Approval

After obtaining ethical clearance from the Avinashilingam Institute of Home Science and Higher Education for Women, Coimbatore (IHEC clearance No. IHEC/21-22/FSN-26) and the Directorate of Health Services (Medical Institute) Shillong, Meghalaya. Additionally, permission was obtained from the Headmasters of the selected schools and individual consent was secured from the parents of the adolescent girls.

Sociodemographic

A semi-structured questionnaire was used to collect the sociodemographic data.

Anthropometric Assessment

The study followed the standard anthropometric assessment guidelines outlined by Casadei and Kiel (2022), for obtaining general information and anthropometric measurements of adolescent girls.

Standing Height

The height of each adolescent was measured in centimeter using stadiometer. The adolescent girls were instructed to stand upright, facing forward, with their bottoms, shoulders and head touching the walls, heels jointly, toes spaced out and hands hanging by their sides.

Body Weight

The digital human weighing scale, with a maximum capacity of 120 kg and minimum divisions of 0.5 kg was used to record body weight of adolescent girls. Adolescent girls were instructed to stand upright on the scale, barefoot and in minimal clothing without leaning on or holding onto anything and their weights were recorded in kilograms (kg) to the nearest 0.1 kilograms. The instrument was calibrated with known weights at regular intervals. Three consecutive reading was collected for each adolescent girl and the average value was recorded.

Body Mass Index (BMI)

BMI has been advocated as the foremost anthropometric measure for assessing nutritional status. The body mass index is calculated using the formula described below (Thomas *et al.*, 1997).

$$\text{BMI} = \frac{\text{Weight (Kg.)}}{\text{Height (meter }^2\text{)}}$$

Socio-demographic assessment

A semi-structured questionnaire was administered to collect information on the participants socio-demographic status. The questionnaire covered variable such as type of family, religion, occupation of the head of the family, annual household income, parental education and occupation, which were used to categorise the participants based on the Kuppuswamy scale.

Anthropometric assessment

The study followed the standard assessment guideline outline by Casadei and Kiel (2022).

Clinical Examination

Clinical examination was conducted to identify visible signs and symptoms of nutritional deficiencies using the World Health

Table 1. Sociodemographic Profile of Adolescent Girls**n=476**

Parameters	Criteria	Freq.	Percent
Age (years)	13-15	266	55.88
	16-18	210	44.12
Type of family	Nuclear	300	63.03
	Joint	176	36.97
Religion	Christian	333	69.96
	Hindu	15	3.15
	Seng Khasi	128	26.89
Occupation of the Heads of the Families	Unemployed	23	4.83
	Craft-related trade workers	119	25.00
	Agriculture	133	27.94
	Skilled Workers and Shops & Markets	85	17.86
	Sales workers	71	14.92
	Working professionals	38	7.98
Family Income (Rs)	Rs. 6,293-47,034 (LI) ^a	161	33.82
	Rs. 47,035-62,874 (ULI) ^a	142	29.83
	Rs. 25,0000 (EWS) [^]	103	21.64
	Rs. 25,001- Rs. 50,000 (LIG) [^]	70	14.71
Educational Qualification of the Head of the family	Illiterate	85	17.86
	Dropout	48	10.08
	Primary school	133	27.94
	Higher Secondary	123	25.84
	Graduate	71	14.92
	Post graduate	16	3.36

[^]HUDCO, 2017; LI-Lower Income; ULI-Upper Lower Income;
EWS- Economically Weaker Section, LIG- LIG-Low Income Group

Organization (WHO) proforma for nutritional deficiencies. The examination focused on common deficiency indicators such as pallor of the conjunctive and nails (Iron deficiency anaemia), Bitot's spots and night blindness (Vitamin A deficiency), Spongy or bleeding gum (Vitamin C deficiency) and bone muscle tenderness (Vitamin D deficiency).

Data Analysis

Data were recorded in Microsoft Excel and analyzed using SPSS version 25 (trial version). The tests used in this study were

percentage analysis, mean and standard deviation with a chi-square test and unpaired t-test.

RESULTS AND DISCUSSION

Table 1 provides information on the sociodemographic features of adolescent girls.

The majority of the selected subjects (55.88 %) were between 13 and 15 years old and belonged to nuclear families (63.03 %). Most of the adolescent girls followed Christianity (69.96%), with a notable proportion identifying as Khasi (26.89 %). The

Table 2. Mean Body Weight of Adolescent Girls Compared with ICMR Standards

n= 476

Age (yrs)	Sample size	ICMR Standard (kg)	Mean Body Weight(kg)	SD	Mean Difference	t _{value}
13	97	43.6	37.92	5.04	-5.68	-7.17*
14	38	46.4	41.89	4.16	-4.51	-4.51*
15	121	48.4	43.35	5.45	-5.05	-10.20*
16	143	49.7	44.63	4.65	-5.07	-9.00*
17	45	50.9	46.71	5.35	-4.19	-5.25*
18	39	52.0	48.59	4.60	-3.42	-2.89 ^{NS}

Source: ICMR , 2024. NS– Not Significant; *P <0.01 – Statistically Significant

heads of their families were primarily engaged in craft-related trades (27.94 %) and farming (25.00 %), while others worked as skilled laborers and shop or market workers (17.86 %), sales workers (14.92 %), or professionals (7.98 %); a small percentage were unemployed (4.83 %). Family income varied, with 33.82% falling under the low-income group (Rs. 6,293–47,034) and 29.83% under the upper low-income group (Rs. 47,035–62,874), while 21.64% were from the economically weaker section (up to Rs. 25,000) and 14.71 % from the lower income group (Rs. 25,001–50,000). In terms of education, the majority of heads of

families had completed primary school (27.94 %) or higher secondary education (25.84 %), while 17.86 % were illiterate, 14.92 % were graduates, 10.08 % were school dropouts and only 3.36 % were postgraduates.

Anthropometric Measurement

A. Mean body weight

Table 2 presents the mean body weight of adolescent girls compared with the ICMR (2024) standard.

The results of the study, where in adolescent girls aged 13 to 18 years were

Table 3. Mean Standing Height of Adolescent Girls

n= 476

Age (yrs)	Sample size(N= 476)	ICMR *Standard Height(kg)	Mean Standing Height in(kg)	SD	Mean Difference	t _{value}
13	97	152.2	143.09	5.43	-9.11	-16.59**
14	38	154.7	144.03	4.16	-10.67	-15.81**
15	121	155.5	145.77	10.84	-9.73	-9.87**
16	143	156.9	147.49	5.65	-9.41	-19.92**
17	45	157.4	148.04	4.99	-9.36	-12.58**
18	29	157.8	148.84	5.15	-8.96	-9.69**

****P= <0.001 *ICMR 2024**

assessed for their body weight, showed that the mean body weight for all age groups was consistently lower than the ICMR standard values. Among the 476 selected subjects, the mean weight at age 13 was 37.92 ± 5.04 kg compared to the ICMR standard of 43.6 kg. Similarly, mean weights for ages 14 to 18 were 41.89 ± 4.16 kg, 43.35 ± 5.45 kg, 44.63 ± 3.65 kg, 46.71 ± 5.35 kg and 48.59 ± 4.60 kg respectively, all lower than their corresponding ICMR standards of 46.4 kg, 48.4 kg, 49.7kg, 50.9 kg and 52 kg. An independent t- test showed that these differences were statistically significant ($p < 0.01$) for all age groups except age 18, where the differences was not significant. This indicates a noticeable growth deficit among the adolescent girls in the study when compared to national standards recommended by ICMR (2024).

B. Mean standing height

Table 3 provides the mean standing height of adolescent girls compared with the ICMR reference value (2024).

The average height of adolescent girls aged 13-18 years was 143.09 cm, 144.03 cm, 145.77, 147.49 cm and 148.04 and 148.84 cm, respectively, indicating a gradual improvement in height with age. However, all age groups did not surpass the respective ICMR 2022 standards. Statistical analysis revealed significant deviations from the ICMR standards, with the mean differences ranging from -8.96 cm to -10.67 cm and t-values between -9.69 and -19.92, are highly significant ($p < 0.01$). Despite the general trend of increasing height with age, the average heights of the adolescent girls remained notably below the ICMR standard throughout.

Dipika (2014) reported that the weight and height of girls between the ages of 7 and 9, 10 and 12 were considerably ($p < 0.05$) less than the reference value. (126.4 cm and 142.7 cm) and weight (19, 26.9 and 31.5 kg) respectively.

Majumder *et al.*, (2024) reported that the newly proposed Indian growth references

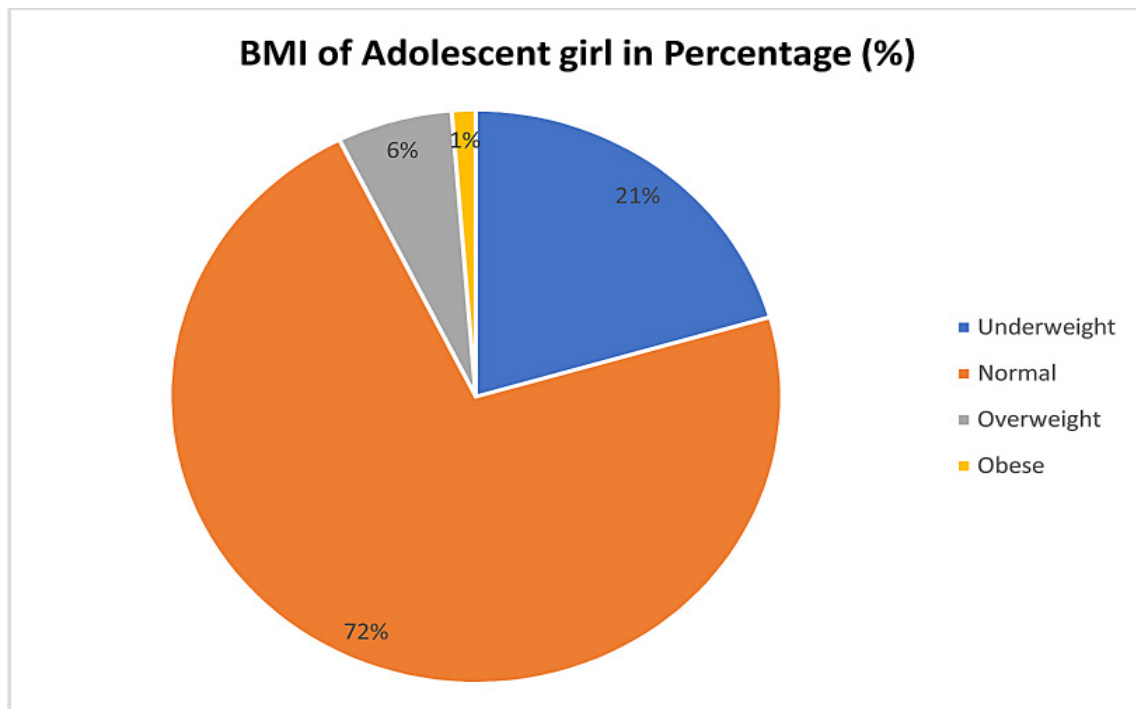


Fig. 2. BMI of Adolescent girls in different age group (N= 476)

Table 4: Clinical signs on nutritional deficiencies of Adolescent Girls

n=476

SIGNS	East Khasi Hills						
	Rural Area (n=276)		Urban Area (n=200)		Total (N= 476) (÷²)		
	No	(%)	No	(%)	No	(%)	
Loss of appetite	96	34.7	20	10	106	22.2	38.64
Oedema	0		1		1		1.38
Muscle wasting	110	23.1	50	10.5	160	33.6	11.47
Irritability	56	11.7	37	7.7	93	19.5	0.24
Hair- Loss of luster/discolored	45	9.4	29	6.1	74	15.5	0.29
Dry or rough skin/Hyperkeratosis	84	17.6	43	9	127	26.6	4.73
Eyes-pale/ dull	135	28.3	34	7.1	169	35.5	51.58
Angular Stomatitis	30	6.3	12	2.5	42	8.8	3.42
Dermatitis	10	2.1	1	0.2	11	2.3	5.01
Bleeding Gums	50	10.5	67	14	117	24.5	14.8
Bitot's Spot/Conjunctival Xerosis	14	2.9	18	3.7	32	6.7	2.85
Dental caries/ Teeth discoloration	67	14	80	16.8	147	30.8	13.43
Red/ Pigmented/Tongue/Ulceration	60	12.6	36	7.5	96	20.1	1.01

reveal a consistent downward shift in growth distributions when compared to the WHO global standards, with the exception of the first six months of life. Notably, when applying these India-specific references, the observed rates of growth faltering among Indian children and adolescents dropped by more than 50% compared with the estimations derived from the WHO growth standards.

C. Body Mass Index (BMI)

Fig. 2 provides the BMI of adolescent girls compared with the Asian-Indian Specific BMI guidelines.

The normal BMI range between (18.5-22.9 kg/m²) encompasses the majority 72 % (343) of respondents. However, 20.5% (98) were underweight and had a BMI (<18.5 kg/m²), 6.09 % (29) were overweight with a BMI between (23-24.9 kg/m²) and only 1.26 % (6) were classified as obese with a BMI (>25 kg/m²).

A similar finding by Siraj *et al.*, (2018) showed that about 21 % were early

adolescents (10–13 years) the proportion of underweight. Conversely, girls in the mid and late-adolescent age groups exhibited a significantly lower risk of being underweight, indicating a marked decrease in the prevalence of underweight as age increases

Ravula *et al.*, (2024) reported on the age-specific nutritional status of adolescent girls, revealing key differences between early and late adolescence. The study found an overall prevalence of underweight, stunting, and thinness at 23%, with early adolescents showing a higher rate (26%) than late adolescents (20%). The combined prevalence of underweight and stunting was 17.70%, again higher in early adolescents (22.69%) than in late adolescents (13.06%).

Clinical Examination

Table 4 shows the clinical signs of nutritional deficiencies in adolescent girls from urban and rural areas.

The prevalence of pale/dull eyes was 35.5 %, indicating that iron deficiency anemia (IDA) was more common in urban girls (28.3 %), while muscle wasting (33.6 %) dental caries (30.8 %) suggested vitamin D deficiency, with muscle wasting higher in urban areas (23.2 %) and dental issues more in rural areas (16.8 %). Dry/rough skin (26.6 %) was more frequent in urban girls (17.6 %), while bleeding gums (24.5 %) indicated Vitamin C deficiency, higher in rural areas (14 %). Red tongue pigmentation (20.1 %) indicating folate deficiency, which is more common in urban girls (12.6 %). Other notable signs included irritability (19.5 %), angular stomatitis (8.8 %), Bitot's spot (6.7 %) linked to Vitamin A deficiency (higher in rural areas) and dermatitis (2.3 %) suggesting Vitamin B3 deficiency. The chi-square analysis revealed significant differences for pale/dull eyes ($\chi^2=51.58$) and loss of appetite ($\chi^2 = 38.64$), with notable variation in muscle wasting ($\chi^2= 11.47$), bleeding gums (14.8) and dental caries/teeth discoloration ($\chi^2 = 13.43$), while irritability ($\chi^2= 0.24$), hair loss/luster (0.29) and red/pigmentation tongue ($\chi^2 = 1.01$) showed no significant association with the area, implying that some clinical signs may be influenced by geographical or socio-economic factors others remain consistent across urban and rural populations.

According to WHO (2024), a prevalence of anaemia between 20.0 % and 39.9 % is considered to have moderate Public Health Significance (PHS). As shown in Table 3, 35.5 % of adolescent girls in East Khasi Hills had Iron Deficiency Anaemia (IDA), placing the district within the WHO moderate PHS category. In addition, 33.3 % of the girls demonstrated Vitamin D deficiency and 19.6 % had Vitamin C deficiency. Both fall under the WHO classification of mild to moderate public health concerns defined as 10-29 % for vitamin C and 20-39 % for vitamin D. Furthermore, 6.7 % of the participants were found to have Vitamin A Deficiency (VAD), which, according to WHO (2-9 %) indicates mild PHS.

The study revealed that majority of the respondent fell in the Lower income group category and the education levels of family heads were found to be at primary level, thus lack of income support and awareness on balanced nutrition. These findings are supported by Sarna *et al.*, (2020) noted that iron deficiency anaemia remains the most common form of anaemia among adolescents, with a national prevalence of 28.4 % (4064 of 14,300). Similarly, Bhalsod *et al.*, (2019) reported high rates of nutritional deficiencies in adolescents with Vitamin B complex deficiency most common (21.9 %), followed by protein-energy malnutrition (10.1 %), fatty acid deficiency (10.9 %), vitamin C deficiency at (8.4 %) and vitamin A deficiency at (7.4 %). Namita *et al.*, (2018) also found that 37.5% of the rural girls, particularly those under 12 years showing signs both tribes revealed that vitamin C deficiency was the most widespread, often indicated by spongy and bleeding gums, followed by iron deficiency anaemia. Taken together, these findings and supporting studies highlight a consistent and concerning burden of micronutrient deficiencies among adolescents, particularly among rural and tribal populations, underscoring the urgent need for targeted nutritional interventions and public health strategies.

CONCLUSION

The study revealed alarming rates of undernutrition (20.5 %) and multiple micronutrient deficiencies among adolescent girls in the East Khasi Hills district of Meghalaya. Anthropometric measurements, when compared with ICMR (2022) standards, showed significant deficits in body weight and growth parameters. Clinical signs further confirmed a high prevalence of iron deficiency (35.5 %), vitamin D deficiency (30.8 %), fluoride deficiency and vitamin C deficiency (19.6 %), all of which point to a critical public health concern in this population. These findings underscore the urgent need for multi-

faceted interventions focused on nutritional education, improved dietary intake and targeted public health strategies. Raising awareness with nutritionally vulnerable groups, particularly adolescent girls through school based programs, community engagement and policy level support could play a vital role in combating malnutrition and promoting long term health outcomes in the region.

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GROWTH RATE OF PRODUCTION, PRODUCTIVITY AND AREA OF PEPPER IN KERALA: A COMPARATIVE STUDY BETWEEN PRE AND POST GLOBALIZATION ERA

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ABSTRACT

The present study has analyzed the growth performance of pepper in Kerala in terms of area, production, productivity and price for the past 50 years (1970-71 to 2019-20) and quantified the impact of productivity growth and area growth on production growth. The analysis was carried out for three periods: pre-globalization period (1970-71 to 1990-91), post-globalization period (1991-92 to 2019-20) and the overall period (1970-71 to 2019-20). There was a decelerating trend in the area and production of pepper in the pre-globalization period. The rate of deceleration was high in production (7.5%) compared to that of area (6.8 %). However, productivity and real price have shown an increasing trend. The post-globalization period has shown a decelerating trend in the area, production, productivity and real price. The rate of deceleration was high in productivity (7.3 %) when compared with area (1 %), production (4.7 %) and price (0.1 %). The overall (50 years) trend has shown a deceleration in area, production and productivity of pepper. The rate of deceleration was high in production and productivity. However, the real price has accelerated by 0.2 % per year. The decomposition analysis has shown the contributing factors to the growth of pepper production in the state which has increased in the case of area, from pre globalisation to globalization era. However, productivity has shown a negative effect. The interaction effect has increased by 11.25 % in 50 years.

Keywords: Decomposition analysis, Growth analysis, Globalisation, Pepper

INTRODUCTION

In India, the highest area utilized for pepper production is from Kerala and contributes a major share in the production of pepper compared to other states. Kerala had a monopoly in the pepper production for a long period of time. The two major pepper growing districts in Kerala are Idukki and Wayanad.

Idukki district stands first position with an area of 42090.45 ha and the contribution to state total is 51.25 %. Wayanad district stands second position in area during the last 10 years. It is 11.25 % of the state total during 2020-21 (Agricultural Statistics, 2022). These two districts together accounted for 62.5 % of the total area under pepper cultivation in

Kerala in 2022. In 1971, Kerala accounted for 89 % of the total production in India. But the pepper production in the state has slipped to 33 % in 2019-20. Since 1970-71, for about 40 years, Kerala had a dominant position in the production of pepper. Thereafter, a decreasing trend started and the production and productivity of the pepper in Kerala were showing declining trend over the period of time.

In the new liberal era, the demand for pepper has been increasing in the international market as well as in the domestic market and India is striving to expand new markets and develop competitiveness in new areas. But it is being observed that in the post globalisation era there was a declining trend in the production and productivity of pepper. In 1991-92, the production of pepper in Kerala was 178126 tonnes and the productivity was 282 Kg/ha and in 2019-20 the production was 20000 tonnes and the productivity was 242 Kg. Price variation tempted the pepper cultivators of the major pepper growing districts of Kerala like Idukki and Wayanad to switch over to other crops (Thomas, 2019). One of the main risks that influenced the production, profitability and well-being of the pepper cultivators was volatile pepper prices (Jose, 2018).

It is an established empirical fact that pepper production in the state has been sinking and many studies in the Kerala context have reported that the production of pepper has been seriously declining. The purpose of the study was to find out how the area, production, productivity and price level of pepper in the state have changed over the years.

Thus, the study was undertaken with an objective to estimate the growth rate of production, productivity, area and price of pepper in Kerala.

MATERIAL AND METHODS

Data Sources

Secondary data were used to analyse trends in terms of area under cultivation, production and productivity of pepper in Kerala. Secondary data have been retrieved from various publications, official reports, research papers/articles, Ph.D. theses etc. The data sources mainly include reports of Spices Board of India, Kochi (various issues), Directorate of Arecanut and Spices Development Ministry of Agriculture, Government of India Calicut, Kerala and Pepper Statistical Yearbook -International Pepper Community Jakartha (various issues).

Tools for analysis

The long-term growth path was traced by estimating the annual growth rates statistically using annual time series data. The rate of change of growth was then measured by the acceleration/deceleration of growth. Fifty years of time series data were collected from 1970-71 to 2019-20. The analysis was carried out for three periods, the pre-globalization period (1970- 71 to 1990-91), post-globalization period (1991- 92 to 2019-20) and overall period (1970-71 to 2019-20). Decomposition Model was used to estimate the contribution of area and productivity in the production of pepper.

Analysis Framework

The analysis was carried out to (a) estimate the growth rate of area, production and productivity of pepper (b) quantify the impact of productivity growth and area growth on production growth.

In order to calculate the compound growth rate of area, production, price and productivity of pepper in India during pre and post-globalization periods, the following exponential function was used.

$$Y = a b^t e^e \dots\dots\dots (1)$$

Where, Y = Area / Production / Productivity

a = Intercept

b = Regression coefficient

t = Time variable

e = Disturbance term in the year 't'

By transforming equation (1) into log linear form: $\log Y = \log a + t \log b + e$

We can calculate the compound growth rate using the following equation:

$$CGR = [\text{antilog } b - 1] * 100 \dots\dots\dots (2)$$

The equation (2) has been estimated by applying the Ordinary Least Square (OLS) method. The t- test was applied to test the significance of 'b'. This equation presumes that a change in agricultural output in a given year would depend upon the output in the preceding year. The models are framed on the basis of the pattern of relationship derived by plotting the variables. Log linear models and log Quadratic models were framed as per the nature of the relationship revealed by the data. Using both models allows to choose the best fit for each parameter, increasing the accuracy of estimates and model predictions.

Growth Rate of Area under Cultivation of Pepper

Estimation of growth rates of Area in 1970-71 to 1990-91 period,

Log-Quadratic model $\log Y = a + b t + c t^2 + e$

Estimation of growth rates of area in period 1991-92 to 2019-20,

Log-linear model $\log Y = a + b t + c \text{Lag} (\log Y) + e$.

Estimation of growth rates of Area in 1970-71 to 2019-20 period using

Log-linear model $\log Y = a + b t + c \text{Lag} (\log Y) + e$.

Where,

Log Y - Growth rate of area after applying logarithmic transformation.

a - Intercept

b - Regression coefficient of t (time variable)

c - Regression coefficient of t^2

e - Disturbance term in the year 't'

c Lag – Coefficient of Auto correlation component

Growth Rate of Production of Pepper

Estimation of growth rate of production in 1970-71 to 1990-91 periods using Log-Quadratic model

$$\log Y = a + b t + c t^2 + e.$$

Estimation of growth rate of production from 1991-92 to 2019-20 period using Log-linear model

$$\log Y = a + b t + e.$$

Estimation of growth rate of production in 1970-71 to 2019-20 periods using Log-linear model

$$\log Y = a + b t + c \text{Lag} (\log Y) + e.$$

Where,

Log Y - Growth rate of production after applying logarithmic transformation.

a - Intercept

b - Regression coefficient of t (time variable)

c - Regression coefficient of t^2

e - Disturbance term in the year 't'

c Lag – Coefficient of Auto correlation component

Growth rate of Productivity under cultivation of pepper

Estimation of growth rate of Productivity in 1970-71 to 1990-91 periods using Log-linear model

$$\text{Log } Y = a + b t + e.$$

Estimation of growth rates of Productivity in 1991-92 to 2019-20 period using Log-Quadratic model

$$\text{Log } Y = a + b t + c t^2 + e.$$

Estimation of growth rate of Productivity in 1970-71 to 2019-20 period using Log-linear model

$$\text{Log } Y = a + b t + c \text{Lag} (\text{Log } Y) + e.$$

Where,

Log Y - Growth rate of productivity after applying logarithmic transformation.

a - Intercept

b - Regression coefficient of t (time variable)

c - Regression coefficient of t^2

e - Disturbance term in the year 't'

c Lag – Coefficient of Auto correlation component

Growth rate of Real Price of pepper

Estimation of growth rates of Real Price of pepper in 1970-71 to 1990-91 period Using Log-linear model

$$\text{Log } Y = a + b t + c \text{Lag} (\text{Log } Y) + e.$$

Estimation of growth rates of Real Price of pepper in 1991-92 to 2019-20 period using Log-linear model

$$\text{Log } Y = a + b t + c \text{Lag} (\text{Log } Y) + e.$$

Estimation of growth rates of Real Price of pepper in 1970-71 to 2019-20 period using Log-linear model

$$\text{Log } Y = a + b t + c \text{Lag} (\text{Log } Y) + e.$$

Where,

Log Y - Growth rate of real price after applying logarithmic transformation.

a - Intercept

b - Regression coefficient of t (time variable)

c - Regression coefficient of t^2

e - Disturbance term in the year 't'

c Lag – Coefficient of Auto correlation component

Decomposition Model

Decomposition analysis is attempted to examine the impact of area growth and productivity growth on the output growth.

If A_0 , P_0 and Y_0 , respectively area, production and productivity in base year and A_n , P_n and Y_n are values of the respective variable in n^{th} year item.

$$P_0 = A_0 \times Y_0 \text{ and } P_n = A_n \times Y_n \dots (1)$$

Where, A_0 and A_n represent the area and Y_0 and Y_n represents the yield in the base year and n^{th} year respectively.

$$P_n - P_0 = \Delta P, A_n - A_0 = \Delta A, Y_n - Y_0 = \Delta Y \dots (2)$$

From equation (1) and (2) we can write $P_0 + \Delta P = (A_0 + \Delta A) (Y_0 + \Delta Y)$

$$\text{Hence, } P = A_0 \Delta Y \times 100 / \Delta P + Y_0 \Delta A \times 100 / \Delta P + \Delta Y \Delta A \times 100 / \Delta P$$

Production = Productivity effect + Area effect + Interaction effect.

RESULTS AND DISCUSSION

Analysis of the growth rate of area, production and productivity of pepper

The table 1 provided the trend in the area under cultivation of pepper. It was

Table 1. Growth rate of area under cultivation of pepper

Growth rate of area under cultivation of pepper in pre - globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 1990-91	11.823* (210.86)	-0.068* (-5.82)	0.004* (7.40)	0.830	Decelerating	6.8	1.6
Growth rate of area under cultivation of pepper in post - globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1991-92 to 2019-20	2.689 (1.95)	-0.010* (-2.16)	0.786* (7.09)	0.853	Decelerating	1.0	2.1
Growth rate of area under cultivation of pepper - 1970-71 to 2019-20							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 2019-20 (Overall)	0.695 (0.968)	-0.001 (-1.04)	0.944* (15.47)	0.840	Decelerating	0.1	2.1

* indicates significant at 5 % level; Parenthesis indicates t-value; NGR-Nature of growth rate; DW – Durbin Watson

analysed for the pre and post globalisation era, along with the overall change between 1970-2020.

The trend, during the pre-globalization era has defined by quadratic linear model and the result showed that the model can explain the variation by 83 % as the R-square value is 0.83. It also gives that the data is positively autocorrelated as the Durbin Watson test value is 1.6. It indicates that the autocorrelation lies in a satisfactory range and the result of the regression is fit to explain the variation. The t-value for the corresponding co-efficient i.e. (-5.82) supported a significant decelerating trend in the growth rate of area under cultivation of pepper in the pre-globalization era (1970-71 to 1990-91). The growth rate decelerated by 6.8 % per year.

The change in the area of cultivation during the post globalisation era was explained by a log linear model. The R-square value, say 0.853, supports the capacity of the model to

explain 85.3 % of the variation, if all other factors are kept constant. The Durbin Watson test result that bears the value of 2.1 supports the fitness of the model and a negative autocorrelation in data. There was a statistically significant decelerating trend in the area under cultivation of pepper in the post-globalization era (1991-92 to 2019-20) as the t-value of the coefficient is (-2.16). There was an impact of pepper price fluctuations and post globalization trade policy on the production of pepper. The pepper price fluctuations led to a reduction in productivity, mixed farming, and a shift into other crops which have resulted in the decline in the area under pepper cultivation (Thomas, 2019). The growth rate has decelerated by 1 percent (including denomination).

The log linear model to address the change in the area under pepper cultivation in Kerala for 50 years i.e. (1970-71 to 2019-20), provided a decelerating trend in growth

Table 2. Growth rate of production of pepper

Growth rate of production of pepper in pre - globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 1990-91	10.329* (78.65)	-0.075* (-2.74)	0.005* (3.92)	0.665	Decelerating	7.5	1.5
Growth rate of production of pepper in post - globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1991-92 to 2019-20	11.186* (144.87)	-0.047* (-10.54)		0.804	Decelerating	4.7	1.3
Growth rate of production of pepper 1970-71 to 2019-20							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 2019-20	1.386 (1.76)	-0.002 (-0.84)	0.871* (11.53)	0.744	Decelerating	0.2	2.5

Source: Computed data

* indicates significant at 5 % level; Parenthesis indicates t-value; NGR-Nature of growth rate; DW – Durbin Watson

as the t-value is (-1.04). The growth rate has decelerated by 0.1%. Here also, the Durbin Watson test has a value of 2.1 that indicates negative autocorrelation, and it is within the admissible limit. The result supports the fitness of the model and the model is able to explain 84 % of the variation as the R-Square value is 0.84.

Growth rate of Production of pepper

Table 2 contains the change in the production of pepper from 1970-71 to 2019-20. The change in production during the pre and post globalization era was separately analyzed along with the overall change during 50 years. The results give that there was a significant decelerating trend in the growth rate of production of pepper in the pre-globalization era (1970-71 to 1990-91) as the t-value is -2.74. The growth rate decelerated by 7.5 % per year. The log quadratic model framed to address the change is fit for explaining the variation, as the Durbin Watson test result has

a value of 1.5. It also supported the presence of positive autocorrelation in the data. The model has the power to explain 66.5 % variation as the R-square value is 0.665.

The change in production of pepper during the post globalization period also shows a decelerating trend by 4.7 % per year and the t-value, say -10.54, supports the same. The log linear model explained 80.4% variation as the R-square value is 0.804. The Durbin Watson test supports the fitness of the model. The value of the Durbin Watson test is 1.3, which is admissible and it indicates positive autocorrelation in data. The deceleration in production is mainly due to the fact that pepper was not included under the purview of the Minimum Support Price of the government and there was a risk of a decrease in price and incurrence of losses in production and FTAs. An important feature of the present trade of pepper is related to the free import of pepper into India from Sri Lanka through an FTA between India and Sri Lanka. The FTAs such

Table 3. Growth rate of productivity of pepper

Growth rate of productivity of pepper in pre - globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 1990-91	5.337* (85.27)	0.013* (2.69)		0.276	Accelerating	1.3	1.7
Growth rate of productivity of pepper in post - globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1991-92 to 2019-20	5.955* (36.56)	-0.073* (-2.93)	0.002* (2.48)	0.295	Decelerating	7.3	1.2
Overall Growth rates of productivity from 1970-71 to 2019-20							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 2019-20	2.563* (3.73)	-0.002 (-0.69)	0.539* (4.35)	0.313	Decelerating	0.2	2.1

Source: Computed data

* indicates significant at 5 % level; Parenthesis indicates t-value; NGR-Nature of growth rate; DW – Durbin Watson

as the ASEAN and ISFTA, were a serious concern to pepper cultivators as it harms the domestic market and reduces the production of pepper. (Jose, 2018).

Log linear model was built to explain the overall growth in the production of pepper. The model can explain 74.4 % variation as per the R-square (0.744) value. The Durbin Watson test value is 2.5, which indicates both the fitness of the model and the negative autocorrelation in data. The results show that there was a significant decelerating growth rate of the production of pepper over 50 years (i.e. 1970-71 to 2019-20) and the same is supported by the corresponding t-value (-0.84). The growth rate has decelerated by 0.2 %.

Growth rate of Productivity of pepper

Table 3 depicts the change in the productivity of pepper from 1970-71 to 2019-20. The analysis of the trend in productivity was carried out for 50 years. The productivity

during the pre and post globalization was analyzed separately. The results give the trend in the growth rate of productivity of pepper in the pre-globalization era (1970-71 to 1990-91). The growth rate was accelerated by 1.3 % per year and the effect is supported by the value of t-statistic, say 2.69. The model followed a log linear function and the R-square value (0.276) gives that the model explains 27.6 % variation, keeping all other factors as constant. The Durbin Watson test results support the fitness of the model and its value 1.7 indicates positive autocorrelation in data.

The log quadratic model framed provided that there was a significant decelerating trend in the growth rate of productivity of pepper in the post-globalization era (1990-91 to 2019-20) as the t-value is -2.93. The growth rate has decelerated by 7.3 % per year. The R-square value (0.295) gives that the current model can explain 29.5 % variation in productivity during post-

Table 4. Growth rate of real price of pepper

Growth rate of Real price of pepper during pre-globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 1990-91	0.485 (1.478)	0.003 (0.015)	0.741* (4.181)	0.52	Accelerating	0.3	1.2
Growth rate of Real price of pepper during post-globalization era							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1991-92 to 2019-20	0.441 (1.508)	-0.001 (-0.012)	0.804* (6.772)	0.67	Decelerating	0.1	1.4
Overall Growth rates of Real price of pepper from 1970-71 to 2019-20							
Period	Regression Coefficients			R-Square	NGR	Growth Rate	DW
	a	b	c				
1970-71 to 2019-20	0.391* (2.199)	0.002 (0.852)	0.781* (8.508)	0.66	Accelerating	0.2	1.3

Source: Computed data

Foot note:* indicates significant at 5 % level; Parenthesis indicates t-value; NGR-Nature of growth rate; DW – Durbin Watson

globalization era. The Durbin Watson test value, say 1.2, supported the existence of positive autocorrelation in data and the fitness of the model.

There were statistically significant decelerating trends in the growth rate of productivity of pepper for 50 years (i.e. 1970-71 to 2019-20) and the t-statistics the log linear model value, say -0.69, provided for the same. The growth rate has decelerated by 0.2 %. The R-square value (0.313) gives that 31.3 % variation can be represented by the model. The fitness of the model is given by the Durbin Watson test and its value 2.1 revealed the existence of negative autocorrelation in data.

Growth rate of real price of pepper

Table 4 shows the trend in the real price of pepper. The log linear model framed to explain the change of the price of pepper during the pre-globalisation period (1970-1991) reveals that it has accelerated by 0.3 %

per year. The value of the t-statistic supports such trend as it is 0.015. The result of Durbin Watson test provided that the model is appropriate to explain the variation, as its value lies between the admissible limit, say 1.2. But it also supports the existence of positive autocorrelation in data. The R-square value (0.52) gives that the particular model can explain 52 % variation in the real price during pre-globalisation era.

The real price of pepper during the post-globalization period had shown a deceleration by 0.1 %. The value of t-statistics of log linear model formulated to define the changes, supported such trend, as its value is -0.012. The R-square value revealed that 67 % of the variation in the real price can be explained by the model. The Durbin Watson test that was used to verify the fitness of the model shows that there was positive autocorrelation among the data. However, the value of the test, say

1.4, is within the permissible limit and it gives the existence of the model.

The growth rate of the real price of pepper for 50 years (i.e. 1970-71 to 2019-20) has accelerated by 0.2 % per year and the value of the t-statistic (0.852) corresponding to the coefficient given by the log linear model supports the effect. As per the R-square value, 66 % of the change in real price from 1970-2020 is explained by the model. The Durbin Watson test result supported the existence of the model and its value i.e. 1.3 provided for positive autocorrelation in the data. Acceleration of price is very slow (only 0.3 %) compared to other cash crops in Kerala (Ratish and Scaria, 2023).

Quantification of the impact of productivity growth, area growth and price growth on production growth

Increase in production of pepper is the result of increase in area and increase in productivity of pepper in Kerala. Variation in both components (area and productivity) at different rate impacts the production. Decomposition analysis was used to estimate the contribution of area and productivity in the production of pepper in Kerala. The output change in pepper is split into three components: output change due to change in area alone, change in productivity alone and the interaction in area and productivity. The components could be respectively referred to as the area effect, the productivity effect and the interaction effect on output.

Table 5 shows that in the pre globalisation era i.e. 1970-71 to 1990-91 period the contribution of productivity (60.86 %) was higher than the area (37.27 %) i.e. Productivity effect > Area effect. The interaction effect was 1.88 per cent. In the post globalization era the contribution of area (70.61 %) is larger than the productivity (31.39 %), Area effect > Productivity effect. The interaction effect was -2. The overall production (50 years) of pepper i.e. 1970-71 to 2019-20 shows that about 464 % growth in pepper was due to area effect whereas there was negative productivity (-375.15 %) effect, Area effect > Productivity effect. The interaction effect was 11.25 %.

The result provided that the pre globalisation period was a higher yielding period for pepper as the productivity effect dominates than the area effect. It means that the yielding capacity from the available cultivating land is comparatively higher. The cultivators have got the advantage of the better production. But the effect cannot be viewed simply as effective utilisations of land as the study has not considered other determinants of pepper production.

The decomposition analysis has shown the contribution of factors in the growth of pepper production in state has increased in case of area in 50 years, however the productivity has shown a negative effect. The interaction effect has increased by 11.25 in 50 years. The rise in interaction effect supports

Table 5. Relative contribution of different factors in the growth of pepper production

Effect	Period		
	1970-71 to 1990-91	1991-92 to 2019-20	1970-71 to 2019-20
Area	37.27	70.61	463.9
Productivity	60.86	31.39	-375.15
Interaction	1.88	-2	11.25

Source: Computed data

Appendix**Area (Hectare), Production (Tonnes) and Productivity (Kg) of pepper in Kerala
from 1970-71 to 2019-20 (50 Years)**

Year	Area	Production	Productivity
1970-71	117540	25000	213
1971-72	116343	25100	216
1972-73	116343	25150	216
1973-74	118250	27750	235
1974-75	118410	27000	230
1975-76	108250	24580	227
1976-77	108700	24500	225
1977-78	101045	20146	199
1978-79	80500	20420	254
1979-80	107180	26793	250
1980-81	105770	28600	270
1981-82	108070	28500	264
1982-83	106710	25670	241
1983-84	103470	21470	210
1984-85	105835	17350	164
1985-86	121565	33121	272
1986-87	128865	30378	236
1987-88	146081	46819	321
1988-89	157006	43241	275
1989-90	167104	54135	324
1990-91	168507	46802	278
1991-92	178126	50620	284
1992-93	183478	49670	271
1993-94	184410	49850	270
1994-95	186720	59260	317
1995-96	190840	59940	314
1996-97	172600	53770	312
1997-98	173860	55520	319
1998-99	230890	68510	297
1999-00	184370	47540	258
2000-01	202130	60930	301
2001-02	203960	58240	286
2002-03	208610	45500	218

GROWTH RATE OF PRODUCTION, PRODUCTIVITY AND AREA OF PEPPER IN KERALA

Year	Area	Production	Productivity
2003-04	216440	43400	201
2004-05	237670	49000	206
2005-06	237990	34000	143
2006-07	216710	33400	154
2007-08	175679	33950	193
2008-09	153711	33950	221
2009-10	171489	27500	160
2010-11	172182	20640	120
2011-12	172182	16500	96
2012-13	84710	25000	295
2013-14	84065	20000	238
2014-15	85430	30000	351
2015-16	85940	21000	244
2016-17	85210	20000	235
2017-18	85140	22000	258
2018-19	82761	17000	205
2019-20	82540	20000	242

Source: Spices Board of India, Kochi & Directorate of Arecanut and Spices Development
Ministry of Agriculture Government of India, Calicut, Kerala

the existence of exogenous factors that determine the production of pepper.

CONCLUSION

The trend analysis of Kerala for 50 years from 1970-71 to 2019-20 shows that in the pre-globalization period i.e., from 1970-71 to 1990-91, there were decelerating trends in the area and production. The rate of deceleration was comparatively high in production compared to the area. However, the productivity and price have shown an increasing trend. The acceleration rate of productivity was comparatively higher than the price.

There was a decelerating trend in the area, production, productivity and real price of pepper in the post-globalization period. The rate of deceleration was comparatively high in

productivity when compared to area and production. The real price decelerated by 0.1 %. The overall (50 years) trend of pepper from 1970-71 to 2019-20 has shown a deceleration in the area, production and productivity of pepper in the state. The rate of deceleration was comparatively high in production and productivity. However, the real price has accelerated by 0.2 % per year.

The decomposition analysis has shown that the contribution of factors to the growth of pepper production in the state has increased in the case of area in 50 years, from the pre globalisation to the globalisation era however, productivity has shown a negative effect. The interaction effect was also increased from pre-globalization to the globalization era.

The study concludes that the pepper economy of Kerala is in a crisis situation. A holistic approach is needed to bring out the interrelationships among the various factors associated with the problems and prospects of the pepper economy of Kerala.

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ASSESSMENT OF TIME SERIES MODELS FOR FORECASTING RICE PRODUCTION IN KERALA AND INDIA: ARIMA VERSUS HOLT'S EXPONENTIAL SMOOTHING

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ABSTRACT

The study conducted in 2023-24 compared two univariate time series forecasting models, ARIMA and Holt's Exponential Smoothing (HES), to predict rice production in India and Kerala from 1980-81 to 2022-23. The models were evaluated based on various model accuracy measures like Mean Absolute Error (MAE), Mean Absolute Scaled Error (MASE), Root Mean Squared Error (RMSE), Mean Absolute Percent Error (MAPE), and Akaike Information Criterion (AIC), with results showing that the ARIMA model had higher accuracy than HES. The forecast for India predicted steady growth, from 135,687.7 in 2024 to 150,444.4 in 2028, with HES slightly higher than ARIMA. Similarly, in Kerala, HES forecasted a higher increase, from 569.68 in 2024 to 581.08 in 2028, compared to ARIMA, which showed slightly lower values across the period. Overall, ARIMA demonstrated better predictive performance over HES for rice production.

Keywords: ARIMA, Forecasting, Holt's Exponential Smoothing Model, Production, Rice, Time Series.

INTRODUCTION

Rice played a pivotal role in India, not only as the backbone of its agrarian economy but also from the perspective of global food security. As the staple food for over 65% of the Indian population, rice held strategic importance in ensuring nutritional stability. It remained the dominant crop, occupying nearly a quarter of the total cultivated land, and was grown extensively across diverse agro-ecological zones, especially in tropical and rain-fed regions (Prasanna, 2018).

India emerged as the second-largest producer of rice globally and became the leading rice exporter (Kumar *et al.*, 2022), accounting for nearly 23% of global production

(FAO, 2024). In the agricultural year 2023–24, the country produced approximately 135.7 million tonnes of rice, cultivated across 43.79 million hectares (Ministry of Agriculture & Farmers Welfare, 2024). Rice alone accounted for about 33.9% of the total area under foodgrains and contributed 41.5% to the total foodgrain production during the same year (MoAFW, 2024).

Despite this growth, India's rice sector faced several challenges. Regional disparities in productivity persisted, and the positive impacts of successive generations of modern technology on rice yields appeared to decline. Even in high-productivity regions, trends showed stagnation and deceleration in yield

growth (Kumar *et al.*, 2022). Moreover, multiple agronomic constraints including insufficient soil moisture, waterlogging, low soil fertility, erosion, floods, erratic monsoons, and inadequate fertiliser use continued to affect rice production (Bhattacharya, 2022).

In contrast to the national trend of rising rice production, Kerala presented a unique and challenging scenario. Historically, rice occupied a central place in the state's agrarian culture and food habits. However, over the decades, Kerala witnessed a consistent decline in both the area under rice cultivation and total production. The state's share in national rice output reduced substantially, despite the crop once dominating its agricultural landscape. Several factors such as high population density, increasing urbanisation, labour shortages, and the conversion of paddy fields for non-agricultural purposes contributed to this decline. Nonetheless, recent trends indicated a marginal improvement in productivity, with an 8% increase recorded in 2022-23 compared to the previous year (Economic Review, 2023), suggesting that efforts to enhance per-hectare yield had yielded some positive results. This divergent trajectory between national expansion and regional contraction called for a deeper examination through time series analysis to forecast and plan future interventions effectively.

Given these contrasting trends at the national and state levels, it became essential to analyze past production patterns and forecast future trends. Time series modelling offered a valuable tool in this regard, providing a basis for making informed agricultural and policy decisions. Ramadhan *et al.*, (2024) emphasized the importance of time series models for estimating and forecasting agricultural production. Forecasting played a critical role in managing price volatility, planning

resource allocation, and adapting to climatic and market uncertainties. In states like Kerala, where cultivation declined, forecasting supported efforts to improve productivity and address the dynamics of agricultural land use.

Several researchers had applied time series models to agricultural forecasting. Sodha and Saha (2016) demonstrated their effectiveness in crop management. Annadanapu and Ravi (2017) fitted an ARIMA model to food production data from 1961 to 2013. Mgaya and Yildiz (2019) applied the ARIMA model to forecast livestock product consumption. Purohit *et al.*, (2021) forecasted agricultural product prices using hybrid methods involving both additive and multiplicative models, focusing on crops like tomato, onion, and potato. Mahto *et al.*, (2021) used ARIMA and Artificial Neural Networks (ANN) for short-term forecasting of agricultural commodities. Annamalai and Johnson (2023) applied ARIMA, Holt's exponential smoothing, and NNAR models to forecast rice cultivation area in India. Zelingher and Makowski (2023) explored machine learning models to forecast agricultural commodities and identify high-producing regions.

The literature made it evident that models like ARIMA, Holt-Winters, and NNAR were widely applied in forecasting agricultural variables such as price, production, area, and consumption. However, most studies focused either at the national or regional level—comparative forecasting studies across multiple geographic scales were relatively limited.

India provided a broad national context for examining long-term rice production trends, having seen a significant increase in cultivated area and output since the 1950s. In contrast, Kerala presented a unique case of declining area and production despite continued importance of rice. Interestingly, Kerala still ranked third in India in terms of income per

hectare from rice cultivation. This divergence between national expansion and state-level contraction, along with Kerala's economic efficiency, made a comparative forecasting study both relevant and necessary.

Therefore, the present study assessed rice production in India and Kerala using two popular time series models ARIMA and Holt's Exponential Smoothing. These models, known for their effectiveness in level forecasting, were applied to historical data to generate predicted values. The forecasts were then compared with actual values to evaluate and compare the predictive accuracy and performance of each model.

MATERIAL AND METHODS

The dataset for the study was the total quantity of production of rice in Kerala and India from 1981 to 2023. The data was sourced from the Directorate of Economics and Statistics, Thiruvananthapuram and National Accounts Statistics Publication Reports, Government of India. The study attempted to forecast the production of rice in Kerala as well as in India for the next five years using different time series forecasting methods/models. These models used historical data to predict the future values by incorporating the variations in the time, like trend, seasonality, etc. It was imperative to note that multiple models using the same dataset might not yield the same result, so it was critical to check which model best suited the dataset.

The study analysed the effectiveness of two popular time series forecasting methods known as Holt's Exponential Smoothing Method and ARIMA.

Holt's Exponential Smoothing Method/ Holt Winters Forecasting

Using weighted averages of past observations was the key to the exponential

smoothing technique, a tool used to generate reliable forecasting models for time series. Holt (1957) developed an extension of the simple exponential model to forecast a time series with a linear trend. This method involved two equations, one a smoothing equation and another a trend equation. The model could be written as:

Forecast equation is $y_{t+h} = l_t + hb_t$

Level equation is $l_t = \alpha y_t + (1-\alpha)(l_{t-1} + b_{t-1})$

Trend equation is $b_t = \hat{\alpha}(l_t - l_{t-1}) + (1-\hat{\alpha})b_{t-1}$

Where:

h is the time steps you want to forecast

l_t denotes an estimate of the level of the series at time t

b_t denotes an estimate of the trend (slope) of the series at time t

α is the smoothing parameter for the level and $\hat{\alpha}$ is the smoothing parameter for the trend.

Auto Regressive Integrated Moving Average (ARIMA)

Autoregressive models stemmed from the concept that future values of a time series could be predicted from the past values and past values of its errors. ARIMA models were relatively easy to implement and interpret and were a popular choice for both beginner and experienced time series analysts. The model accounted for patterns of growth/decline (trend), the rate of change and the relationship of 'noise' (error) between consecutive time points. ARIMA models addressed the autocorrelations in the data and combined the autoregression, differencing and moving average in the model. An ARIMA model could be written as ARIMA (p,d,q), where p was the order of the Auto Regressive (AR) term, d was the order of the Integrated (I) term and q was the order of the Moving Average (MA) term.

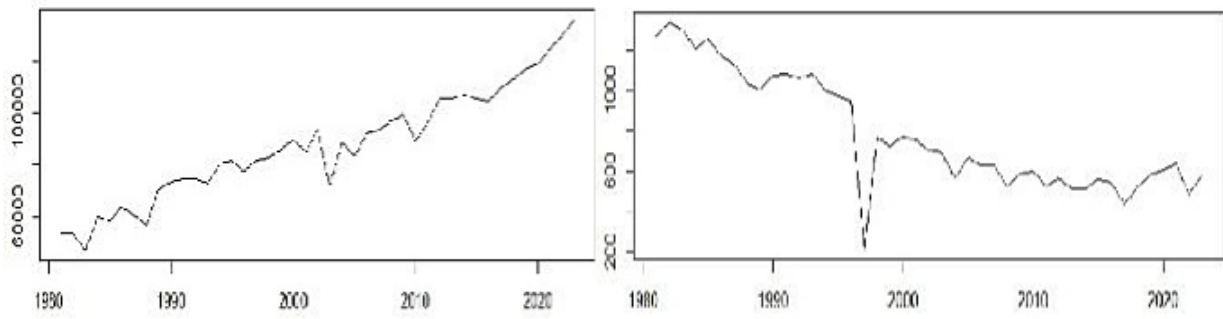


Fig 1. Rice production of Kerala and India.

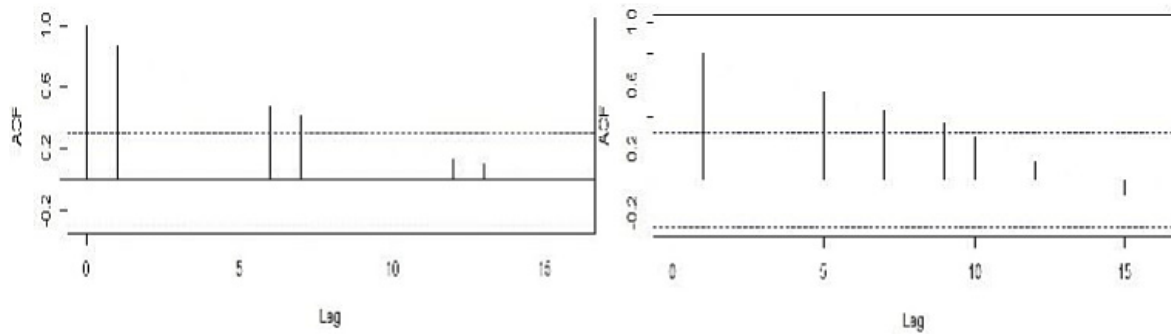


Fig 2. ACF – Rice Production of Kerala and India.

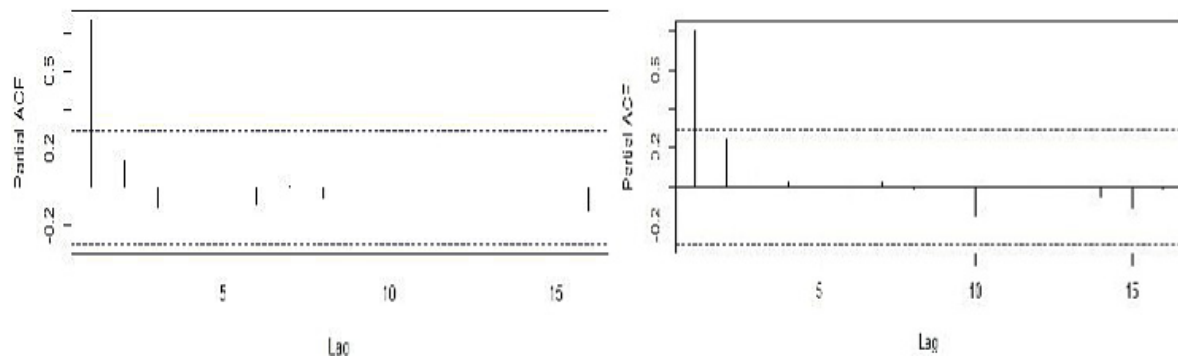


Fig 3. PACF – Rice Production of Kerala and India

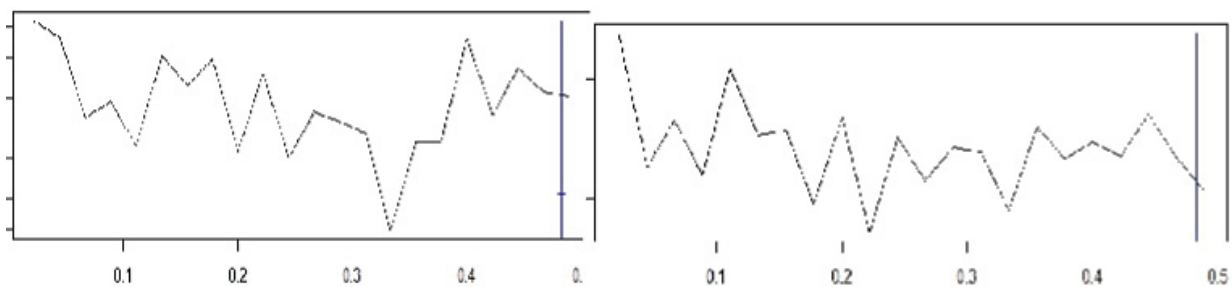


Fig 4. Periodogram – Rice Production of Kerala and India

The model could be written as:

$$y_t = c + \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} + \phi_1 \varepsilon_{t-1} + \dots + \phi_q \varepsilon_{t-q} + \varepsilon_t$$

where;

y is the differenced series

p is the order of the autoregressive part;

d is the degree of first differencing involved;

q is the order of the moving average part.

RESULTS AND DISCUSSION

Before fitting any model to the time series data, the first thing to do was to visualize the data, which could help to identify any trend, seasonality and other properties of time series data. Plotting the data was of utmost importance for any researcher of time series. As mentioned earlier, we were using the production of rice in Kerala and India as two different univariate time series and attempted to forecast the future production for the next five years for both the series. Plotting the data using a statistical package helped to identify trend, seasonality and stationarity.

While examining Figure 1 of both the series, one could easily identify the upward trend for rice production in India and the downward trend for rice production in Kerala.

The ACF, PACF and Periodogram of both the series (fig. 2, 3, and 4), however, referred to no seasonality as there were no strong lags at 1 and 12 for ACF and no dominant spikes in the periodogram. Hence, it was interpreted that the series was non-seasonal. The lags of ACF and upward/downward trend of the series also denoted the data was non-stationary. We could use the Augmented Dickey Fuller test to check if the series was non-stationary. If the series was non-stationary, we could differentiate it to make the series stationary. The results of the test were mentioned in table 3.

Rstudio software was used to analyse the data and interpret Holt's Exponential method and ARIMA. As the data exhibited no seasonality, Holt's Exponential method was run with the seasonality option as 'FALSE' (gamma = FALSE). It was also noted that as Holt Exponential method would take care of trend and seasonality, there was no need to differentiate the series before fitting the Holt Exponential model. However, the time series had to be stationary for fitting the ARIMA model. The statistical package would fit the best model based on AIC model (for ARIMA) and based on Alpha and Beta values (for Holt's Exponential Smoothing model).

Table 4. was the forecast of rice production for India and Kerala using ARIMA

Table 3. ADF Test Results Before and After Differencing

ADF Test Results	India	Kerala
Test Static	-1.5351	-1.787
P-value	0.7574	0.6579
Result	Non-stationary	Non-stationary
ADF Test Results (after differencing)	India	Kerala
Test Static	-5.1486	-4.7686
P-value	0.01	0.01
Result	Stationary	Stationary

Source:Computed

Table 4. Forecast for Next Five Years: India and Kerala

Year	INDIA		KERALA	
	Holt's Exponential Smoothing	ARIMA	Exponential Holt's Smoothing	ARIMA
2024	135687.7	132115.4	569.68	507.15
2025	139376.9	133994.5	572.53	488.73
2026	143066	135873.7	575.38	470.3
2027	146755.2	137752.9	578.23	451.88
2028	150444.4	139632	581.08	433.46

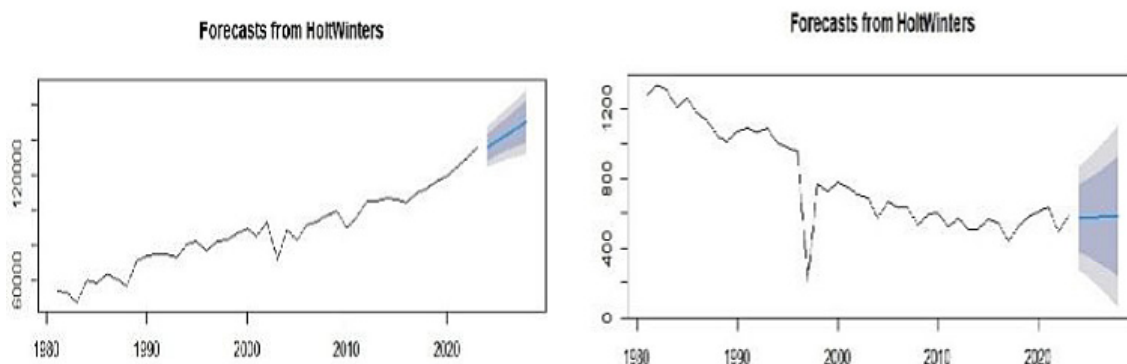
Source: Computed

and Holt's Exponential Model for a period of 5 years from 2024 to 2028. The forecasted data revealed a clear divergence between Holt's Exponential Smoothing and ARIMA methods. At the national level (India), Holt's model predicted consistently higher values, rising from 135687.7 thousand tonnes in 2024 to 150444.4 thousand tonnes in 2028, compared to ARIMA's forecasts, which ranged from 132115.4 thousand tonnes in 2024 to 139632.0 thousand tonnes in 2028, indicating a more optimistic growth trajectory. Conversely, at the state level (Kerala), ARIMA forecasted a decline from 507.15 0 thousand tonnes in 2024 to 433.46 0 thousand tonnes in 2028, while Holt's model showed a steady increase from 569.68 0 thousand tonnes in 2024 to 581.08 0 thousand tonnes in 2028. This contrast highlighted ARIMA's sensitivity to

potential downturns versus Holt's focus on long-term trends.

The figure 5 showed the forecasted coconut production in India and Kerala using Holt-Winters' method, demonstrating a steady upward trend from 1980 to 2023 at the national level and showing a declining trend from 1980 until stabilizing in recent years in the case of Kerala.

Figure 6 explained national-level data, showing a consistent upward trend with growing values over time, suggesting steady growth or improvement in the forecasted metric. The state-level data showed a declining trend initially, followed by stabilization and modest recovery in the forecast, indicating localized challenges or slower growth compared to the nation. The contrasting trends

**Fig. 5. Holt's Exponential Smoothing Forecast – Kerala and India**

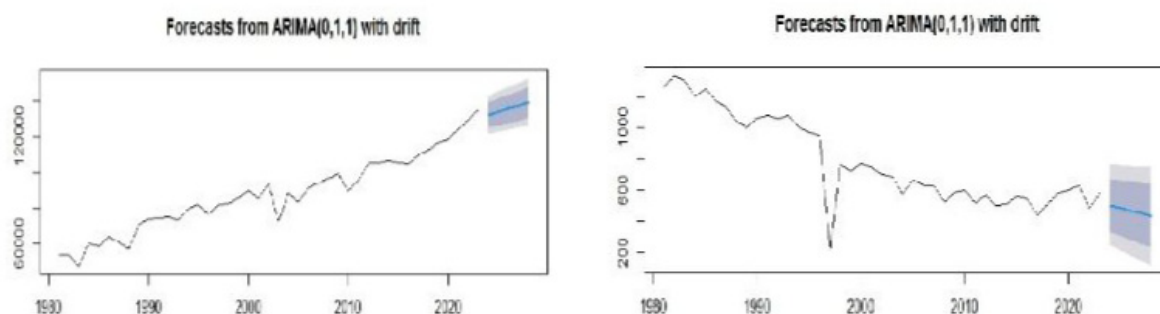


Fig. 6. ARIMA Forecast – Kerala and India.

highlighted differences in performance or development patterns between the national and state levels.

Table 5 presented the comparison between fitted values and true values of the outcome variable for India and Kerala using ARIMA and Holt's Exponential Smoothing Model. At the national level, actual values increased from 116500 thousand tonnes in 2019 to 135500 thousand tonnes in 2023, with Holt's predictions ranging from 113386.31 to 129627.46, and ARIMA closely following, from 11369.43 to 127249.95. In Kerala, actual production increased from 578.3 thousand tonnes in 2019 to 581.4 thousand tonnes in 2023. Holt's model showed consistent growth, from 486.29 to 552.55, while ARIMA captured

variability, starting at 459.08 and ending at 497.01. Both models aligned reasonably well with actual trends, but Holt's smooth predictions contrasted ARIMA's sensitivity to fluctuations.

Residual Analysis and Measures of Accuracy

Residual analysis and verifying the measures of accuracy helped to analyse the performance of the model and also to select the best model.

In terms of residual analysis plotting (Fig. 7, 8, 9, and 10), the residuals against time were a visual method to check for constant mean and variance. The histogram plot helped to identify whether the residuals were

Table 5. Fitted Values: India and Kerala

Year	Actual Value	INDIA Fitted Values		Actual Value	KERALA Fitted Values	
		Holt's Exponential Smoothing	ARIMA		Holt's Exponential Smoothing	ARIMA
2019	116500	113386.31	11369.43	578.3	486.29	459.08
2020	118900	116739.7	116589.12	605.6	531.68	481
2021	124400	119903.55	119304.74	633.8	575.17	504.73
2022	129500	124417.3	123028.22	487	616.69	529.98
2023	135500	129627.46	127249.95	581.4	552.55	497.01

Source: Computed

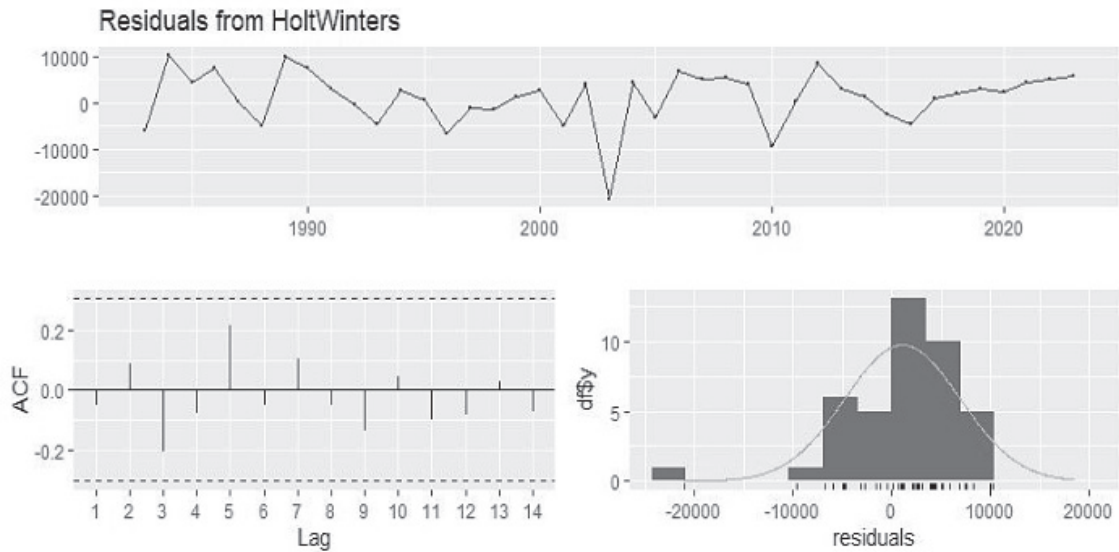


Fig. 7. Residuals from Holt Exponential Smoothing Model – Rice production in India

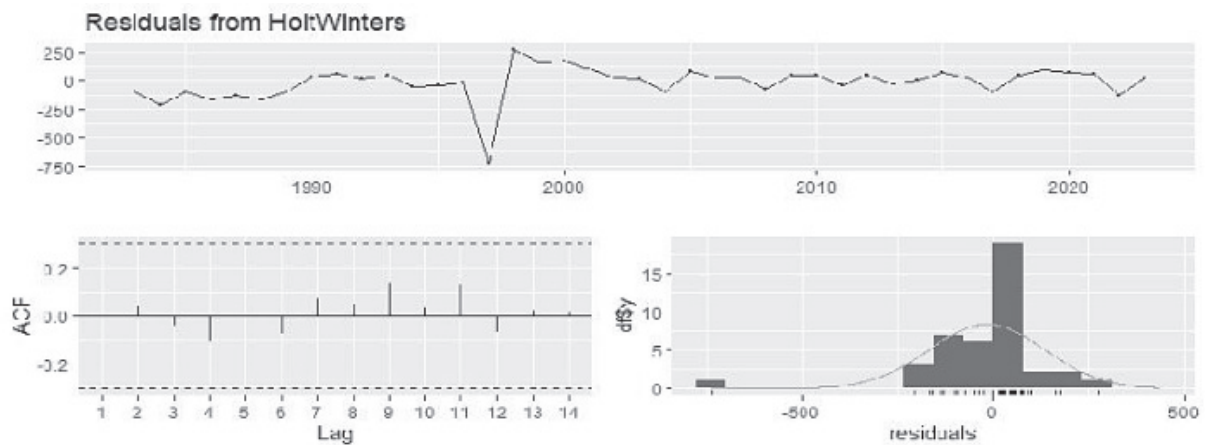


Fig 8. Residuals from Holt Exponential Smoothing Model – Rice production in Kerala

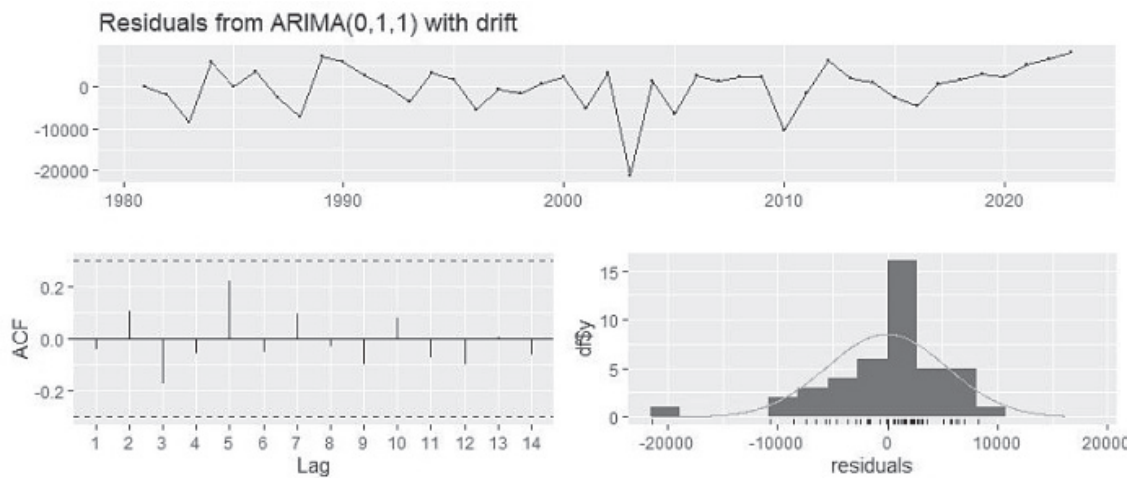


Fig. 9. Residuals from ARIMA Model – Rice production in India

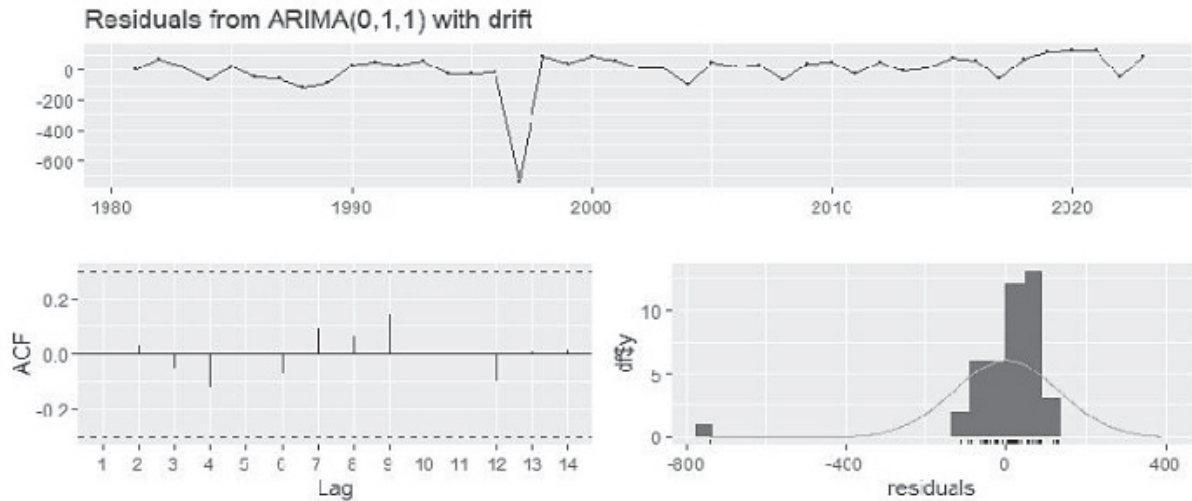


Fig. 10. Residuals from ARIMA Model – Rice production in Kerala

Table 6. Residual Analysis Ljung Box Test

Ljung-Box Test	Holt Winters		ARIMA	
	India	Kerala	India	Kerala
P-Value	0.6367	0.983	0.6602	0.9357

distributed normally. Residual analysis was a method to identify if the model had captured the information in the data adequately. ACF plot of the residuals helped to check whether the residuals were independent. No spikes from zero points indicated a lack of correlation and thus it could be assumed that the residuals were not correlated. The below visual implementation methods were rechecked using Ljung-Box Pierce statistic (Table: 6) to ascertain the independence of the residuals.

Various model accuracy measures (Table 7) like Mean Absolute Error (MAE), Mean Absolute Scaled Error (MASE), Root Mean Squared Error (RMSE), Mean Absolute Percent Error (MAPE) and Akaike Information Criterion (AIC) were accuracy measures based on the historical data. Care was taken that though these measures could be used as an indicator of the forecast accuracy, they did not carry over to future values. A lower MAE indicated

superior model accuracy and was the simplest measure of forecast accuracy. For India, the MAE for Holt's Exponential Smoothing was 4553.62, while for ARIMA, it was 3866.89, showing that ARIMA had better accuracy. If MASE was greater than 1, then the model was worse than the naive model. For India, the MASE for Holt Exponential Smoothing was 0.8949, and for ARIMA, it was 0.7599, showing ARIMA performed better. The lower the MASE, the better the model. RMSE helped to gauge the degree of inaccuracy in a model, and 0 indicated that the expected and actual values matched precisely. For India, RMSE for Holt Exponential Smoothing was 5873.25, while for ARIMA, it was 5362.52, indicating that ARIMA made more accurate predictions. Low RMSE values showed that the model made more accurate predictions and fit the data well. MAPE

Table 7. Measures of Accuracy

Parameters	Holt Winters		ARIMA	
	India	Kerala	India	Kerala
MAE	4553.62	93.9066	3866.89	68.4133
MAPE	5.6603	18.7406	4.8241	15.5673
MASE	0.8949	1.149	0.7599	0.8327
RMSE	5874.25	150.11	5352.52	128.39

of different models could be compared to evaluate the superiority of model performance in terms of forecasting accuracy. The MAPE for Holt Exponential Smoothing in India was 5.6603, while for ARIMA, it was 4.8241, showing ARIMA indicated higher accuracy with a lower MAPE value. Lower values of MAPE indicated higher accuracy.

CONCLUSION

For both models, the time plot of the residuals showed that the variation of the residuals stayed within a range and much the same across the historical data and hence the variance could be treated as constant. The histogram suggested that the residuals might not be normal the left tail seemed a little too long. Consequently, forecasts from this method would probably be quite good, but prediction intervals that were computed assuming a normal distribution might have been inaccurate. The comparative analysis of forecasting performance clearly establishes that the ARIMA model is more effective than the Holt's Exponential Smoothing model in predicting rice production in both India and Kerala. This is evident across all accuracy metrics. For India, ARIMA recorded lower errors with a MAE of 3866.89, MAPE of 4.8241%, MASE of 0.7599, and RMSE of 5362.52, compared to Holt's MAE of 4553.62, MAPE of 5.6603%, MASE of 0.8949, and RMSE of 5873.25. In Kerala, the pattern was similar. ARIMA had a MAE of 68.4133, MAPE of 15.5673%, MASE of 0.8327, and RMSE of 128.39, while Holt-Winters showed higher values across the board (MAE: 93.9066, MAPE: 18.7406%, MASE: 1.143, RMSE: 150.11). These results confirm that ARIMA not only provides better forecast accuracy but also fits the historical data more effectively, making it the more robust and reliable model for rice production forecasting in both regions.

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PRODUCTION AND MARKETING CONSTRAINTS FACED BY THE CUCUMBER FARMERS IN BISHNUPUR DISTRICT OF MANIPUR AND SEPAHIJALA DISTRICT OF TRIPURA

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Cucumber (*Cucumis sativa* L.), a member of the family Cucurbitaceae, is regarded as an essential vegetable for fresh consumption worldwide and is a rich source of vitamins, minerals, and antioxidants. Cucumber is a low-calorie food, consisting of 90 percent water, which is why it provides superior hydration (Sallam *et al.*, 2021). Cucumber is a very popular vegetable worldwide (Liu *et al.*, 2021). The total cucumber production (including gherkins) in 2022 was 94,718,397 metric tonnes from 1.984 million hectares. However, cucumbers need to be marketed quickly because they are perishable and their prices fluctuate in the market. Consumer prices are high and unstable, while farmers only receive a small share of these prices and with farmers, there is no trustworthy source of market information (Kalita, 2017). In Manipur and Tripura, suitable agro-climatic conditions, which range from temperate to tropical and sub-tropical zones provide ample opportunity for its cultivation. Despite these inherent benefits, horticulture industry has only recently begun to show signs of growth. This is because, there is a significant gap between the technologies developed and its adoption. Another key reason for lagging in horticulture development is a lack of investment. Only 16 per cent of the region is under cultivation, and the total cropped area including area under multiple

cropping doesn't exceed 22 per cent by 2013 (Dikshit *et al.*, 2014). Cucumber production is aided by certain inputs or resources that increase productivity. The productivity of cucumbers is enhanced by using the resources efficiently. Resource use efficiency differs from farmer to farmer due to various reasons may be access to inputs, socio-economic condition of the farmers, non-availability of suitable high-yielding varieties of seed, low, unbalanced, and untimely use of chemical fertilizers, irrigation, plant protection measures, technical knowhow, etc. These variations, combined with an inefficient use of various resources and constraints faced by the farmers, resulted in low productivity and lower returns, hence a study has been conducted to examine the constraints in attaining higher productivity and income level of cucumber farmers of Tripura and Manipur states.

The study was conducted in Bishnupur district in Manipur and Sepahijala district in Tripura in the year 2022-23. These districts were selected purposively, as they had more prospects in cucumber cultivation with the highest area. Two blocks i.e., Charilam Block in the Sepahijala district of Tripura and Bishnupur Block in the Bishnupur district of Manipur were selected based on the concentration of cucumber farmers. A total of four villages were selected purposively from

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two blocks, of which two villages were taken from each block *i.e.* Bishnupur block-Kwasiphai village and Nachou, and the other two villages *viz.* the Chesrimai, the Uttar Charilam were taken from Charilam block based on the number of cucumber growers. From each village 20 respondents were selected randomly. A total of 80 respondents were selected using the Simple random sampling technique. The constraints in practicing cucumber cultivation were enlisted from practicing farmers and literature. Further, all of the constraints that were found were divided into two categories: Marketing and Production constraints. The respondents were asked to rate the constraints on a five-point Likert Scale from very severe, quite severe, severe, not so severe, and least severe. The collected details were analyzed using Garrett's Ranking technique. The following is Garrett's formula for translating ranks to percentages,

$$\text{Percent position} = 100 \times (R_{ij} - 0.5) / N_j$$

Where,

R_{ij} = rank given for i^{th} factor by j^{th} individual

N_j = number of factors ranked by j^{th} individual

It is important to understand the constraints faced by the cucumber farmers in order to increase their production and productivity. Constraints can give us a way to plan our policy for the betterment of the farmers. Garrette's ranking technique was used to identify and rank the constraints. The main advantage of this method over simple frequency distribution is that the limitations are ranked in order of respondents' perceived relevance.

Table 1 reveals that about 77.5 percent of cucumber farmers in Tripura and 35 percent in Manipur belonged to the marginal farm category (less than 1 ha land holding). Whereas, remaining 32.5 percent in Tripura

and 65 percent in Manipur belonged to the small farm category. The overall literacy rate of cucumber farmers in Tripura was 82.43 per cent and in Manipur 76.08 percent. A literacy rate of 77.77 percent and small farmers of 80.75 percent. Table 1 reveals that out of 40 respondents in Manipur, 9 belonged to the small farming category and 31 belonged to the marginal farming category. The overall literacy rate of cucumber farmers in Tripura was 82.43 per cent and marginal farmers have a literacy rate of 87.09 percent and small farmers 77.77 percent.

In order to improve the productivity and output of cucumber growers, it is critical to comprehend the limitations they confront. We may design our policy to benefit farmers by using constraints as a guide.

The constraints faced by the farmers are categorized into the following different components.

1. Production constraints
2. Marketing constraints

Constraints related to the Production of cucumber in the study area

Different production problems faced by sample farmers are shown Table 2 and Table 3, which affected the yield and ultimately income of the cucumber farmers. In Manipur and Tripura, a major problem faced by farmers was due to lack of institutional and infrastructural facilities (Garrett mean score 70). It was reported by the farmers that they were not getting loans from the institutional agencies and the money was borrowed by them from the money lenders to purchase inputs for cucumber cultivation.

In Manipur, as indicated by the Garrett mean score of 68, the majority of the cucumber growers were not getting skilled labour in the production of cucumber cultivation due to

Table 1. Sample size of cucumber growing farmers in Tripura and Manipur **n=80**

S.No.	Particular	Farm category in Tripura			Farm category in Manipur		
		Marginal	Small	Overall	Marginal	Small	Overall
1	No. of Farm	31 (77.50)	9 (32.50)	40 (100)	14 (35)	26 (65)	40 (100)
2	Total Operational holding (Ha)	11.48	18.46	29.94	10.43	42.60	53.03
3	The average size of farm (Ha)	0.37	2.05	0.75	0.75	1.65	1.33
	Literacy rate	87.09	77.77	82.43	71.41	80.75	76.08
4	Farm workers						
	Female	52 (46.43)	54 (46.55)	106 (46.49)	51 (45.13)	56 (47.46)	107 (46.72)
	Male	60 (53.57)	62 (53.45)	122 (53.51)	62 (54.87)	62 (50.54)	122 (53.28)
5	Total worker	112 (100)	116 (100)	228 (100)	113 (100)	118 (100)	229 (100)

Figures in parenthesis indicate percentages

migration of skilled rural youth to cities for better wages and no local training or skill development programs, followed by high seed cost (Garrett mean score of 57) as quality hybrid seeds are costlier but not available locally at reasonable prices, which is one of the key inputs in the production of cucumber.

In Tripura, the majority of the cucumber growers (Garrett mean score 68) had high seed costs followed by a lack of skilled labour (Garrett mean score 55). Good quality crop is possible with good quality seeds at less cost of seed. The farmers were tempted to grow any seed that was available in the market as the good quality seeds were very costly and farmers were unable to afford that cost. It was opined by the cucumber growers that the cost of seed was high due to high demand and non-availability of seed in the market at the time of showing of cucumber. In Tripura and Manipur,

it is indicated by the Garrett mean score of 50 that the cucumber farmers face challenges of high insects and pest attacks in the cucumber crop. The use of resistant varieties of cucumber may help in minimizing the risks that arise due to this problem to a greater extent. Awareness and training provided by the extension agencies in educating farmers about the usage of good quality seeds might help them in tackling this problem.

In Manipur and Tripura, the Garrett mean score of 47 and 45 respectively, shows that due to the unavailability of perennial sources for irrigation water, they could not provide enough irrigation to cucumber crops for better production. Garrett mean score of 45.7 and 47.61, respectively shows that the farmers were facing problems like the non-availability of PPC and fertilizers. Cucumber farmers also faced the problem of lack of awareness and

guidance in Manipur (Garrett mean score 32.75) and in Tripura (Garrett mean score 33.27). In Manipur and Tripura, farmers faced the problem of Poor productivity as reflected by Garrett mean score of less than 30.

Marketing problems in sample farms of cucumber production

The survey was conducted for sample farmers who sold their produce to understand the problems encountered while marketing cucumber (Table 2 and Table 3).

In Manipur, the majority of sample farmers faced the problem of unavailability of

market yards (Garrett mean score 68) followed by high transportation costs (Garrett mean score 60.30) incurred by intermediaries which seems to be inevitable as the produce must be brought down from the place of production to the final consumers at the market level. In Tripura, respondents expressed a high transportation cost (Garrett mean score 72.6) followed by the problem of unavailability of market yards (Garrett mean score 61.56).

In Manipur and Tripura, Garrett mean scores of 54.35 and 48.16, respectively expressed a lack of storage facilities during the marketing of cucumber. The cucumber is

Table 2. Problems faced by farmers during the production of cucumber – Manipur

n=80

S.No.	Constraints	Categories of farmers (Garrett mean score)			
		Marginal	Small	Overall	Rank
A.	Production Constraints				
1.	Lack of Institutional and infrastructural facilities	69.65	70	69.82	I
2.	Unavailability of skilled labour	68.38	67.71	68.04	II
3.	High seed cost	57.46	57.71	57.58	III
4.	Incidence of pest attack	50.34	49.36	49.99	IV
5.	Non-availability of perennial sources for irrigation	47.15	46.64	46.89	V
6.	Non-availability of PPC and fertilizers	45.04	46.36	45.7	VI
7.	Lack of awareness and guidance	32.73	32.78	32.75	VII
8.	Poor productivity	29.23	29.428	29.32	VIII
B.	Marketing constraints				
1.	Unavailability of market yard	68	68.14	68.07	I
2.	High Transportation cost	60.54	60.07	60.30	II
3.	Lack of storage facilities	54.85	53.86	54.35	III
4.	No proper weighing system at the market	52.27	52.43	52.35	IV
5.	No support price	33.77	33	33.38	V
6.	Lack of market information	29.58	31.5	30.54	VI

Table 3. Problems faced by farmers during the production of cucumber – Tripura

n=80

S.No.	Constraints	Categories of farmers (Garrett mean score)			
		Marginal	Small	Overall	Rank
A.	Production Constraints				
1.	Lack of Institutional and infrastructural facilities	73.33	70.61	71.97	I
2.	High seed cost	68.56	68.19	68.38	II
3.	Unavailability of skilled labour	54.33	57.65	55.99	III
4.	Incidence of pest attack	51.56	49.90	50.72	IV
5.	Non-availability of PPC and fertilizers	48.78	46.45	47.61	V
6.	Non-availability of perennial sources for irrigation	43.89	45.97	44.93	VI
7.	Lack of awareness and guidance	34.22	32.32	33.27	VII
8.	Poor productivity	25.33	28.90	27.12	VIII
B.	Marketing constraints				
1.	High Transportation cost	73.89	71.39	72.64	I
2.	Unavailability of market yard	61.67	61.45	61.56	II
3.	Lack of storage facilities	47.56	48.77	48.16	III
4.	No proper weighing system at the market	47.33	47.29	47.31	IV
5.	No support price	36.78	38.58	37.68	V
6.	Lack of market information	31.78	31.52	31.65	VI

bulky and perishable produce. Traditional methods were being followed by the farmers for a short period to keep cucumber fresh.

The lack of proper weighing facilities for cucumber producers in Manipur (Garrett mean score 52.35) and Tripura (Garrett mean score 47.31) was found to be a constraint as there were no electronic weighbridges or standard weighing machines at local markets, dependence on middlemen who may cheat on quantity and small farmers can't afford private scales and it finally affected the total sale value.

In Manipur and Tripura, Garrett mean scores of 37.68 and 33.38, respectively

expressed that there was no minimum support price or floor price for the produce because vegetables like cucumber do not fall under MSP crops, Absence of government procurement, High price volatility in local markets and Perishability forces distress sales, this leads to uncertainty in the selling price. Due to low prices in the local market, farmers were marketing to the distant markets which finally impacted the income of the farmers.

In Manipur and Tripura, farmers mentioned that they have no proper market information (Garrett mean score 30) for the disposal of the produce and the price prevailing at the consumer level. Due to no

organized system to update farmers about market rates in different towns, Limited mobile/ internet penetration and digital literacy and Absence of cooperative marketing or contract farming arrangements.

The Garrett ranking technique has allowed the researchers to create, analyze, and draw conclusions by identifying the constraints from both the sponsors and farmers' perspectives. According to the survey, farmers' greatest challenges were their susceptibility to pests and diseases, followed by the lack of financial support and the least farmer's dependency on firms for resources. The decision-makers need to take into account the technical support on pest and disease management and make provision for financial support by providing a minimum amount for establishment cost or by maximizing the resource input by providing raw materials in the production process.

The study also observed that contract price or fixing the price of the final product is the most prominent constraint faced by the sponsors due to regular fluctuation of price in the market. The use of the Garrett ranking technique for identifying constraints of contract farming from farmers as well as sponsors' points of view has enabled the researchers to formulate the study, analyse, and conclude. It ranks the component based on the preference of the respondents. The study shows that the most prominent constraints faced by the farmers were susceptible to pests and diseases followed by the lack of financial support and the least farmer's dependency on firms for resources. The decision-makers need to take into account the technical support on pest and disease management and make

provision for financial support by providing a minimum amount for establishment cost or by maximizing the resource input by providing raw materials in the production process. The study also observed that contract price or fixing price of the final product is the most prominent constraint faced by the sponsors due to regular fluctuation of price in the market

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NAVIGATING AGRICULTURAL CHALLENGES AND CONSTRAINTS FOR FARMER PRODUCER COMPANIES IN BARPETA DISTRICT, ASSAM

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Agriculture is the backbone of India, providing livelihoods for nearly 45 percent of the population. Small and marginal farmers play a critical role in reducing poverty and sustaining rural communities (Chopade *et al.*, 2019). FPCs aim to transform traditional farmers into producer-sellers by improving their access to technology, market information, and business services (Katiki *et al.*, 2021; Chauhan *et al.*, 2021).

These organizations, supported by institutions like NABARD, SFAC, NAFED, and NCDC, help farmers secure inputs at better prices, connect to markets, and boost their incomes (Chowdary *et al.*, 2022; Phapale *et al.*, 2021). The idea of producer companies was introduced in 2002 by economist Y.K. Alagh's leadership and further developed through policy initiatives such as the 2013 "Policy and Process Guidelines for Farmer Producer Organisations" by the Department of Agriculture and Cooperation (Alagh, 2007; Department of Agriculture and Cooperation, 2013). However, while FPOs hold great promise, they face significant challenges, including financial, technical, infrastructural, and market-related issues. These barriers often prevent them from reaching their full potential as one-stop solutions for small and marginal farmers (Paty *et al.*, 2018). This study

aims to uncover these challenges and identify strategies to help farmers unlock the full benefits of working collectively.

The current study conducted during the year 2023, employed an ex-post facto research design. In total, nine FPCs operate in the Barpeta District. Out of nine FPCs, one, "HowlyAgro-Fish Farmers Producer Company Limited," was purposively selected. The basis for choosing "HowlyAgro-Fish Farmers Producer Company Limited" was its relative member strength and competence to other FPCs operating in the region (Government of Assam). Primary data were acquired from sample respondents utilising a well-structured interview schedule. The list of members of the chosen FPC was received from the office of "HowlyAgro-Fish Farmers Producer Company Limited". To accomplish the study's objective, 100 farmers were selected randomly. The gathered data was evaluated using Mean Scores and Rank.

An effort has been made to examine the constraints encountered by respondents in carrying out FPC activities and reaping the advantages. The constraints were classified as personal, economic, infrastructure, operational, and marketing. The structural questions were rated on a three-point scale ranging from strongly agree/most adequate,

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agree/adequate and disagree / least appropriate, with values of 2, 1, and 0. Participants were asked to offer choices for several aspects of the FPC, which were tabulated.

According to the data in Table 1, the respondents rated Lack of time as the most important constraint, with a mean score of 4.12. Increased workload was identified as another limitation on II rank, with a mean score of 3.34. This might be because the respondents were active in the production and processing of agricultural products while also having to devote time to other activities such as meetings, training, money collecting, company planning, and so on. The dual burden of a few female farmers to undertake both domestic tasks and farm operations contributes to these limits. The respondents rated constraints such as a Lack of initiative (mean score 2.98) and a Lack of family support (mean score 2.45) III and IV, respectively. Non-cooperation was the least common constraint ranked V, with a mean score of 2.21, since they were extremely cooperative within their groups and made collaborative efforts throughout the survey.

To address personal constraints, such as Lack of time and Increased workload, several opportunities can be explored. Implementing workforce training programs can significantly enhance time management and productivity skills among FPC members. Such programs can be tailored to address specific challenges faced by farmers, helping them balance their farming and FPC responsibilities more effectively. Additionally, involving family members in FPC activities can foster a supportive environment, alleviating some of the pressures on individual farmers. By encouraging family participation, FPCs can create a more collaborative atmosphere that supports members in their roles. Incentive programs can also be introduced to motivate

farmers to take more initiative and cooperate actively within the FPC. These incentives could include recognition for outstanding contributions or small financial rewards, thus, encouraging a more engaged and proactive membership.

Regarding the category of economic constraints, Table 1 shows that the majority of farmers encountered a shortage of sufficient financing at Ist rank, with a mean score of 4.34, posing challenges in implementing an enhanced package of practices. Other constraints classified II and III by FPO members were a lack of credit facilities and a lack of assistance from bank authorities, with mean scores of 4.12 and 3.89, respectively. As a result, they favoured non-institutional sources of financing over institutional ones. Respondents stated that receiving a loan is a time-consuming procedure that includes filling out forms, photocopying, document verifications, and organising relevant papers such as pictures, ID proofs, and meeting minutes, among other things. The member farmers also mentioned the constraint of high cost of labour, with a mean score of 3.15 and a rank of V. During peak seasons, respondents need to hire workers to carry out the cultivation and processing tasks. Furthermore, they must visit the bank several times, which takes a significant amount of time and results in a loss of wage-earning days for them.

Economic constraints, such as lack of sufficient finance and credit facilities, can be mitigated through various strategies. Forming microfinance groups within FPCs can provide farmers with more accessible credit options tailored to their needs. These groups can offer small loans with flexible terms, making it easier for farmers to invest in necessary inputs and practices. Additionally, leveraging public-private partnerships (PPP) can secure better financing terms and subsidies for FPC

members. By collaborating with both government and private sectors, FPCs can access funds and resources that may otherwise be unavailable. Implementing cost-sharing models is another effective approach, where the financial burden of inputs and labour is distributed among members. This model can help reduce individual costs and make investments in agriculture more feasible.

According to Table 1, the key constraints were the Lack of processing plants, rated first by member farmers with a mean score of 3.98, lack of storage facilities, ranked second with a mean score of 3.54, and Lack of irrigation facilities, ranked third with a mean score of 3.45. They noted that a Lack of suitable storage facilities at the organisational level leads to insect and other organism attacks, which reduces the crop's market value. On the other hand, the farmers encountered another constraint: a lack of a good training hall, which had a mean score of 2.98 and ranked IV. In this instance, the Krishi Vigyan Kendra in Barpeta supplied space for training, meetings, and so on.

To overcome infrastructural constraints such as Lack of processing and storage facilities, FPCs can explore several opportunities. Applying for infrastructure development grants from government bodies or non-governmental organizations can provide the necessary funding to improve rural infrastructure. These grants can be used to build or upgrade processing plants and storage facilities, enhancing the overall efficiency of FPC operations. Developing community-based irrigation systems is another valuable opportunity. These systems can be managed collectively by FPC members, optimizing water usage and reducing individual costs. Additionally, mobile training centres can be introduced to provide skills and knowledge to farmers in remote areas. These centres can

travel to different locations, offering training on best practices and new technologies, thus bridging the gap in infrastructure and education.

Table 1. shows the operational constraints experienced by the respondents. The data in the table show that respondents regarded Lack of technical expertise as the biggest barrier, with a mean score of 4.42. Interactions with members found that members were having difficulty adopting improved agricultural practices, licencing, and certifying organic goods due to a lack of technical expertise. ICT tools may assist farmers increase their productivity and gain greater access to market information, funding, and other facilities and services. According to the data, farmers placed lack of understanding of ICT tools as the second constraint, with a mean score of 4.29, preventing them from reaping the benefits of ICT tools. Lack of education and digital illiteracy were identified as the causes of a lack of knowledge of ICT technologies.

Lack of information regarding grading and packing was another operational limitation ranked III by farmers with a mean score of 3.83 due to a lack of training on improved packaging procedures, product processing, and storage practices. Other challenges stated by farmers with ranks IV, V, and VI were limited access to recommended methods, a high frequency of diseases, pests, and crop failure, and a lack of technical assistance. The farmers asserted that crop production using conventional methods is inexpensive, however, using HYVs, insecticides, herbicides, and fertilisers in the recommended package of practice costs more money, which they were unable to pay owing to their low financial situation. Unavailability of labour was a less severe limitation experienced by farmers, with a mean score of 3.01 and a ranking of VII.

Table 1. Constraints faced by members of HowlyAgro-Fish Farmers Producer Company Limited**n=100**

Sl.No	Constraints	Mean Percent Score (MPS)	Rank
Personal Constraints			
i	Lack of time	4.12	I
ii	Increase workload	3.34	II
iii	Lack of initiative	2.98	III
iv	Lack of family support	2.45	IV
v	Non-cooperation	2.21	V
<i>Overall Score</i>			3.02
Economic Constraints			
i	Lack of sufficient finance	4.34	I
ii	Lack of credit facilities	4.12	II
iii	Lack of assistance from bank officials	3.89	III
iv	High cost of recommended inputs	3.56	IV
v	High cost of labour	3.15	V
<i>Overall Score</i>			3.81
Infrastructural Constraints			
i	Lack of processing facility	3.98	I
ii	Lack of storage facility	3.56	II
iii	Lack of irrigation facility	3.45	III
iv	Lack of training hall	2.98	IV
<i>Overall Score</i>			3.49
Operational Constraints			
i	Lack of technical knowledge	4.42	I
ii	Lack of knowledge of ICT tools	4.29	II
iii	Lack of awareness of grading and packaging	3.83	III
iv	Less access to recommended practices	3.54	IV
v	High incidence of pest, disease and crop failure	3.28	V
vi	Lack of technical guidance	3.16	VI
vii	Unavailability of labour	3.01	VII
<i>Overall Score</i>			3.65
Market Constraints			
i	Lower price for produce	4.51	I
ii	Lack of latest market information	4.37	II
iii	High cost of transportation	4.28	III
iv	Distant market	3.96	IV
v	Perishable nature of products	3.79	V
vi	Exploitation by middle men	3.56	VI
vii	Delayed payment	3.34	VII
<i>Overall Score</i>			3.97

*Source: Researcher's primary data

Addressing operational constraints requires targeted interventions to improve technical knowledge and access to resources. Organizing technical workshops and seminars can provide farmers with the latest agricultural techniques and information on ICT tools. These workshops can be designed to address specific needs and challenges faced by FPC members, enhancing their operational efficiency. Establishing digital literacy programs is also crucial for improving members' proficiency with ICT tools. By providing training on digital technologies, FPCs can help members utilize these tools to their advantage, enhancing productivity and access to information. Collaborative problem-solving sessions can further support members by creating opportunities for them to share knowledge and solutions to common operational challenges. These sessions can foster a culture of cooperation and innovation within the FPC.

Marketing constraints are variables that limit the organization's capacity to fulfil its marketing objectives. Distant markets, a lack of up-to-date market knowledge, lower produce prices, high transportation costs and delayed payment were some of the marketing challenges faced by FPO members. Regarding these marketing constraints, data reported in Table 1 reveal that low produce prices were ranked I by farmers, with a mean score of 4.51. The farmers stated that they had no access to the most recent market information and ranked II with a mean score of 4.37. To get remunerative pricing, they must sell their goods at the main market, which is located far from their villages and incurs large transportation costs, for which they were ranked III and IV, with mean scores of 4.28 and 3.96, respectively. Other marketing challenges stated by respondents were the perishable nature of the items, exploitation by middlemen, and delayed payments.

Marketing constraints, such as limited access to profitable markets and high transportation costs, can be addressed through several strategic opportunities. Developing market linkage programs can connect FPCs with larger agricultural businesses or cooperatives, improving market access and stabilizing prices. These partnerships can provide farmers with better selling opportunities and reduce the impact of price fluctuations. Forming transportation cooperatives is another effective solution to reduce the cost and increase the efficiency of moving goods to market. By sharing transportation resources, FPC members can lower their expenses and improve logistics. Implementing real-time market intelligence technology can also empower farmers to make informed decisions about when and where to sell their products. Access to up-to-date market information can help farmers achieve better prices and avoid the pitfalls of market uncertainty.

The FPC members confronted five categories of constraints: personal, economic, infrastructure, operational, and marketing. The total mean score and rank were determined to be 3.02 (V), 3.81 (II), 3.49 (IV), 3.65 (III), and 3.97 (I) according to the constraints. Marketing and economic constraints were identified as the most significant challenges for FPC members. In order to address marketing inefficiencies, it is necessary to establish easily accessible digital platforms, possibly community-led or mobile-based, for real-time market intelligence. Also, it is necessary to establish direct connections with local and regional buyers and explore community e-commerce initiatives. At the same time, reducing economic vulnerabilities necessitates creating strong internal revolving funds within FPCs that are adapted to the financial realities of rural farmers and facilitating institutional

credit access through regional “credit camps.” Members will be empowered by promoting shared processing and storage facilities, improving operational capabilities through realistic, hands-on technical workshops, and offering basic digital literacy programs. Personal burdens will be lessened by creating a supportive atmosphere through efficient meeting scheduling and family involvement, which will help FPCs like HowlyAgro-Fish Farmers Producer Company Limited succeed in the long run.

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