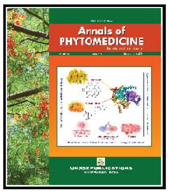
Annals of Phytomedicine 14(1): 888-897, 2025

DOI: http://dx.doi.org/10.54085/ap.2025.14.1.89

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885



Original Article : Open Access

Formulation and nutritional evaluation of millet-pulse-based functional food for protein deficiency

Deeksha Rana, Renuka Aggarwal◆, Harpreet Kaur, Aditi Sewak, Kiran Bains and Inderpreet Kaur Dhaliwal*

Department of Food and Nutrition, Punjab Agricultural University, Ludhiana-141004, Punjab, India

**Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana-141004, Punjab, India*

Article Info

Article history
Received 11 January 2025
Revised 25 February 2025
Accepted 26 February 2025
Published Online 30 June 2025

Keywords
Finger millet
Chickpea
In vitro protein digestibility
Protein digestibility
Amino acid

Abstract

Inadequacy of the food consumed in providing amino acids in required amounts can impact dietary protein quality and can lead to growth retardation in children. The diet consumed by Indian children lacks lysine which is the first limiting amino acid in cereal-based diets, making it poor in terms of protein quality. The present investigation was carried out to formulate and nutritionally evaluate the millet-pulse-based food product by replacing traditional cereal. Chocomills was formulated using finger millet-chickpea combination and tested for its acceptability and nutritional composition against conventional cereal. The overall acceptability of chocomills prepared from finger millet-chickpea was 7.98 and was comparable with the wheat-based products. The finger millet chickpea chocomills had a considerable amount of protein (18.50 g/100 g), lysine (5.38 g/100 g), *in vitro* protein digestibility (81.33%) and protein digestibility amino acid score (0.54). The chocomills when stored for 3 months was found to be organoleptically acceptable till 45 days. The developed product was cost-effective and nutritionally superior to its traditional and market counterparts. The study concluded that the developed millet pulse-based product met 30% Recommended Dietary Allowance (RDA) for protein and more than 100% of the lysine requirements of school-going children. Hence, the developed finger millet-chickpea combination can be effectively used as a replacement for wheat for preparing various food products with good quality protein.

1. Introduction

Protein energy malnutrition is a major public health problem in developing countries including India. According to the World Health Organization (2023), 148 million children under 5 years were estimated to be stunted and 45 million were wasted which accounts for 22.3 and 6.8 per cent of children, respectively. Malnutrition in the case of school-age children can lead to serious issues, including cognitive impairment that affects their academic performance, Stunted growth, reduced work capacity, and ultimately lower individual incomes, which further impacts the Nation's Gross Domestic Product (Katoch, 2022). To combat malnutrition, it is crucial to establish efficient food systems encompassing high-quality protein, energy, minerals, trace metals, and vitamins in sufficient amounts to meet requirements which is as crucial as the diet quantity alone (Neumann *et al.,* 2004).

Numerous reports and dietary surveys conducted worldwide highlight a significant risk of protein and amino acid deficiency, particularly lysine, due to inadequate dietary supplies in low-income nations, particularly in Southeast Asia where plant-based diets, highly reliant on cereals, supply nearly two-thirds of the protein primarily from wheat, depending on age and sex (Moughan, 2021). A diet lacking in lysine affects the protein anabolism of people of all ages but its deficiency leads to serious health complications in children. While the overall crude protein intake of children in India seems adequate when compared with their requirements, the quality of protein being consumed by them is not sufficiently good. There is considerable concern regarding adequate dietary intake of lysine since it is found in limited amounts in sources like staple food grains, thereby affecting the protein quality of cereal-based diets consumed by Indians significantly. The lysine requirement in infants and children typically varies from 35 to 45 mg/kg per day, but in poor socio-economic conditions, a notably substantial increase can be observed due to concomitant energy deficits or persistent subclinical illnesses and intestinal parasites (Kurpad and Thomas, 2020). Roughly 10% of the children with lower socioeconomic status are at risk of dietary lysine deficiency (Pillai *et al.,* 2015).

Lysine plays a fundamental part in proper growth and development, and disease prevention in children. Insufficiency arises primarily from factors including limited food intake, consumption of staple diet heavily reliant on cereals, and lysine losses during food processing (Aggarwal and Bains, 2022). The lack of lysine intake is reported to be a causative factor responsible for a greater risk of a range of deleterious medical ailments in children. Since children's linear growth is known to be influenced by the protein quality of their diet, insufficient lysine intake negatively affects the overall quality of protein, thereby, leading to impairment in the growth. On that account, children of developing countries who consume grain-based staple diets are potentially at a higher risk of receiving inadequate amounts of available lysine in comparison to the recommended daily intake

Corresponding author: Dr. Renuka Aggarwal
Scientist, Department of Food and Nutrition, PAU, Ludhiana-141004, Punjab, India
E-mail: renukaaggarwal@pau.edu
Tel.: +91-9855444401

levels (Pillai *et al.,* 2015). The protein quality of the diet can be improved by doing mutual supplementation of cereals and legumes to complete amino acids like lysine and tryptophan which is far less expensive than animal protein (Joshi *et al*., 2024). In addition, replacing cereal with millet can provide a nutrient-dense food.

Millets, such as finger millet (*Eleusine coracana* L,) commonly called Ragi, is a nutrient-rich cereal in the "Poaceae" family, extensively cultivated in India and Africa. With a protein content of 9.8% and notable levels of crude fiber (4.3%) and minerals (2.7%), finger millet stands comparably alongside staple cereals like wheat, rice, and maize but with a low calorific value. Consumption of low-calorie and reduced-fat products can mitigate the risk of ailments such as cancer and heart disease (Patel *et al*., 2022). Essential amino acids constitute approximately 44.7% of its protein content, surpassing 33.9% of FAO reference protein (Thagunna *et al*., 2022). Finger millet is rich in calcium content, at 344 mg per 100 Grams while its amino acid profile shows higher proportions of isoleucine, leucine, methionine, and phenylalanine, addressing deficiencies common in other cereals, contributing to overall health and development (Chandel *et al*., 2014; Gull *et al*., 2014). Being a gluten-free alternative to grains like wheat and rice, finger millet holds promise in various value-added products, cementing its role as a vital component of global food security and nutrition strategies (Jagati *et al*., 2021).

Considering the nutritional properties of finger millet and its role in improving protein quality in combination with pulses being a vital component in the prevention of metabolic disorders and growth retardation by providing vital vitamins and micronutrients (Anushree *et al*., 2024; Pathak and Singh, 2022). Thus, the present study had been planned to formulate innovative chickpea-fortified finger millet-based food products for enhancing the protein quality of school-age children.

2. Materials and Methods

2.1 Procurement of sample

Finger millet (IE 2402, ICRISAT) and wheat (PBW 826) were sourced from the Department of Plant Breeding and Genetics at Punjab Agricultural University (PAU), Ludhiana, immediately after harvest, and pulses (chickpea) were purchased from the local market.

2.2 Development of finger millet-chickpea-based food product

Food product namely chocomills considering the likings of children was developed. For the development of the value-added product, a white variety of finger millet (IE 2402, ICRISAT) with chickpea was used. The developed product was subsequently compared with recipes prepared using cereal counterparts such as wheat serving as control.

Table 1: Development of finger millet chickpea product

Ingredients	Chocomills	
	Control	Experimental
Wheat flour	61 %	12.5 %
Finger millet flour	-	45 %
Chickpea flour	-	30 %
Semolina	39 %	39 %
Coco powder	35.5 %	35.5 %
Sugar	85.05 %	85.05 %
Milk powder	35.5 %	35.5 %
Corn flour	19.84 %	19.84 %
Butter	8.5 %	8.5 %
Cream	-	-
Dark compound	-	-
Baking powder	2.84 %	2.84 %
Baking soda	0.71 %	0.71 %

2.3 Organoleptic evaluation of the developed food product

Ten semi-trained individuals affiliated with the Department of Food and Nutrition at Punjab Agricultural University Ludhiana conducted sensory evaluations of standardized product. The product, derived from finger millet-chickpea combination was assessed based on various sensory attributes including color, appearance, texture, taste, flavor, and overall acceptability. The evaluation was performed utilizing a nine-point Hedonic rating scale, as outlined by Nicolas *et al*. (2010), where a rating of 9 represented "like extremely" and a rating of 1 represented "dislike extremely".

2.4 Nutritional evaluation of millet pulse-based food product

The developed product alongside its respective control counterpart (wheat-based) underwent comprehensive analysis for various nutritional parameters as discussed below:

2.4.1 Proximate composition

Proximate parameters namely moisture, crude protein, crude fat, crude fiber, and ash were analyzed using three replications of each formulation using the standard method given by AOAC (2000). For moisture determination, 5 g of sample was weighed and placed in pre-weighed china crucibles in a hot air oven at 105°C for 8 h to dry to a constant weight. For the determination of nitrogen, the macro-kjeldahl method was used. Nitrogen was converted to crude protein using a conversion factor of 6.25. The crude fat content was determined using the Automatic Soxhlet apparatus (SOCSPLUS - SCS 06 AS DLS TS), where the moisture-free sample was put in a thimble. Petroleum ether was used as a solvent. The extracted fat from the sample was weighed after evaporating the remaining solvent. For crude fiber, 5 g (moisture and fat-free) sample was refluxed first with 1.25% sulphuric acid followed by 1.25% sodium hydroxide (NaOH). It was further oven-dried, ignited in a muffle furnace, and cooled in a desiccator, the weight loss was estimated. The ash content was analyzed by igniting the weighed samples at 550°C in a muffle furnace for 4 h. After cooling in a desiccator, the crucible with residue was weighed again. The carbohydrate content was calculated by subtracting the sum of all proximate parameters (moisture content, crude protein, crude fat, crude fiber, and total ash) from 100.

2.4.2 Mineral composition analysis (atomic absorption spectrophotometer)

The powdered flour was digested by adding a triple acid combination composed of nitric acid (HNO_3), perchloric acid ($HClO_4$), and sulfuric acid (H_2SO_4) to facilitate the measurement of iron, zinc, calcium, and magnesium using standards for these elements with an atomic absorption spectrophotometer (Analyst 200, Perkin Elmer).

2.4.3 Amino acids by GC-MS reagents

Amino acid extraction: The sample (0.2 g), in ground form, was homogenized with 1.5 ml of 0.1M HCl and centrifuged. The supernatant was collected and stored at minus – 80°C until analysis.

Deproteinization and derivatization: The extract (100 µl) was combined with 250 µl of acetonitrile in a safe-lock micro test tube and centrifuged (10,000 rpm/ 3 min). The supernatant was mixed with 100 µl of an internal standard (IS) solution (5 µg/ml) and transferred to heat-resistant tubes, subsequently dried under nitrogen. 1- chloromethane (50 µl) was added to the dried samples and the mixture was evaporated. Next, MTBSTFA (50 µl) and acetonitrile (50 µl) were added and incubated at 100°C for 60 min. Subsequently, the tubes were refrigerated for storage and later analyzed by GC-MS for amino acids.

2.4.4 *In vitro* protein digestibility

It was analyzed by the methodology described by Akeson and Stachman (1964). The digestibility coefficient was determined by subtracting the residual protein from the initial protein content based on 100 g of the sample.

2.4.5 Protein digestibility corrected amino acid score PDCASS (Rutherfurd *et al.*, 2015)

PDCAAS was calculated using the formula given by FAO/WHO (1991):

PDCAAS = (mg of limiting amino acid in 1 g of test protein/mg of same amino acid in 1 g reference protein) × *In vitro* protein digestibility

where,

- Amino acid lysine was considered as the most limiting amino acid in the composite meals.
- Reference amino acid pattern was taken as the amino acid requirement of preschool children of 2-5 year of age.
- Values greater than 1.00 were truncated to 1.00.

2.5 Shelf-life evaluation of the developed food product

The developed food product was placed in low-density polyethylene pouches (thickness- 51 microns) at room temperature. The organoleptic characteristics of the stored product was evaluated every 15 days using a 9 Point Hedonic scale for 3 months.

2.6 Consumer acceptability of the developed food product

Consumer acceptability of the developed product was assessed by at least 50 school-going children using the Likert Rating Scale (Likert, 1932).

2.7 Statistical analysis

The data was subjected to statistical analysis using SPSS software (version 23). Mean values, standard deviations and t-test was employed.

3. Results

The raw grains were selected and nutritionally evaluated before the development of the food product. The chickpea and finger millet were found to have higher protein (21.43 and 10.78 g/100 g), lysine (5.21 and 3.96 g /100 g), *in vitro* protein digestibility (77.58 and 75.67 %) and protein digestibility amino acid score (0.60 and 0.37), respectively.

3.1 Organoleptic evaluation of finger millet-chickpea product

The value-added food supplementing traditional cereal (wheat) combined with chickpea was developed, keeping in view the preferences of school-going children. The developed food was subjected to organoleptic evaluation from a panel of semi-trained judges. The finger millet-chickpea chocomills was developed using the substitution of traditional cereal with millet (45%) and pulse (30%). The chocomills prepared using finger millet-chickpea obtained a higher overall acceptability score (7.98) than its control counterpart and was found to be acceptable by the panel of judges as it obtained a score more than 7.5 (Figure 1).

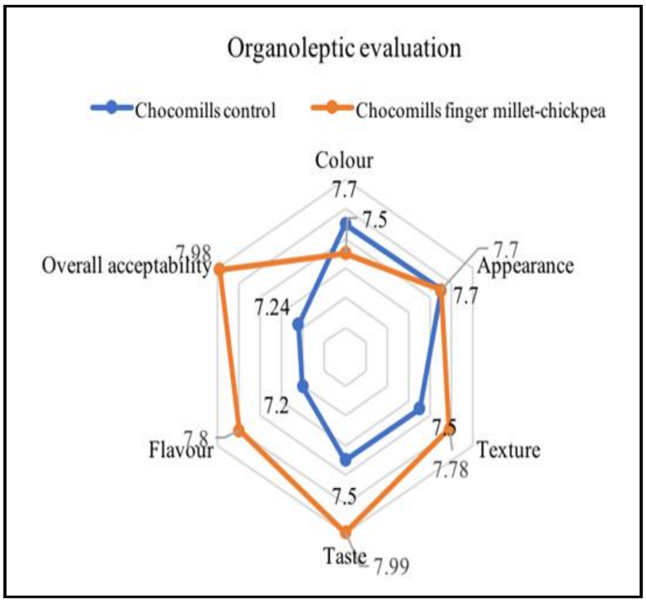


Figure 1: Organoleptic evaluation of finger millet-chickpea product.

Table 2: Nutritional composition of finger-millet-chickpea product (g/100 g, dry weight basis)

Product	Moisture(%)	Crudeprotein	Crude fat	Crudefiber	Ash	CHO
Chocomills	C 4.90 ± 0.10	13.16 ± 1.25	10.06 ± 0.15	0.88 ± 0.33	1.35 ± 0.46	69.65 ± 1.67
	E 5.03 ± 0.15^{NS}	18.50 ± 0.50**	8.30 ± 0.60^{NS}	4.33 ± 0.57^{NS}	2.00 ± 0.52^{NS}	61.84 ± 0.67**

C-Control, E-Finger Millet-Chickpea; Values are expressed as Mean ± SD of triplicates.

Values in columns having control and experimental group only show **significance at ($p \leq 0.01$) level.

Table 3: Amino acid composition of finger-millet-chickpea product (g/100 g, dry weight basis)

Product	Indispensable amino acids								
Chocomills	Leu	Lys	Met	Phen	Ile	Val	Thr	Trp	His
	C 8.11 ± 0.11	3.83 ± 0.12	1.56 ± 0.19	2.83 ± 0.11^{b}	3.47 ± 0.35	2.13 ± 0.05	1.74 ± 0.13	1.17 ± 0.14^{b}	1.48 ± 0.43^{a}
	E 14.17 ± 0.07**	5.38 ± 0.40*	1.86 ± 0.10^{NS}	6.35 ± 0.50^{NS}	5.06 ± 0.02^{NS}	6.37 ± 0.06*	3.52 ± 0.02^{NS}	1.66 ± 0.02^{NS}	0.75 ± 0.05^{NS}
	Dispensable amino acids								
	Ala	Arg	Asp	Cys	Glu	Gly	Pro	Ser	Tyr
	C 7.15 ± 0.07	2.72 ± 0.04	4.64 ± 0.12	1.71 ± 0.11	34.07 ± 1.71	6.48 ± 0.16	9.55 ± 0.12	4.66 ± 0.51	3.84 ± 0.06^{a}
	E 7.85 ± 0.09**	0.92 ± 0.05*	7.82 ± 0.15**	1.18 ± 0.18^{NS}	25.47 ± 1.36**	1.43 ± 1.19**	1.30 ± 0.06^{NS}	1.28 ± 0.96^{NS}	1.95 ± 0.23^{NS}

Leu-leucine, Lys-lysine, Met-Methionine, Phe-phenylalanine, Iso-Isoleucine, Val-Valine, Thr-Threonine, His-Histdine, Ala-Alanine, Arg-Arginine, Asp-Aspartic acid, Cys-Cysteine, Glu-Glutamic acid Gly-Glycine. Pro-Proline, Ser-Serine and Tyrosine Tyr, C-Control, E-Finger Millet-Chickpea. Values are expressed as Mean ± SD of triplicates. Values in columns having control and experimental group only show **significance at ($p \leq 0.01$) level.

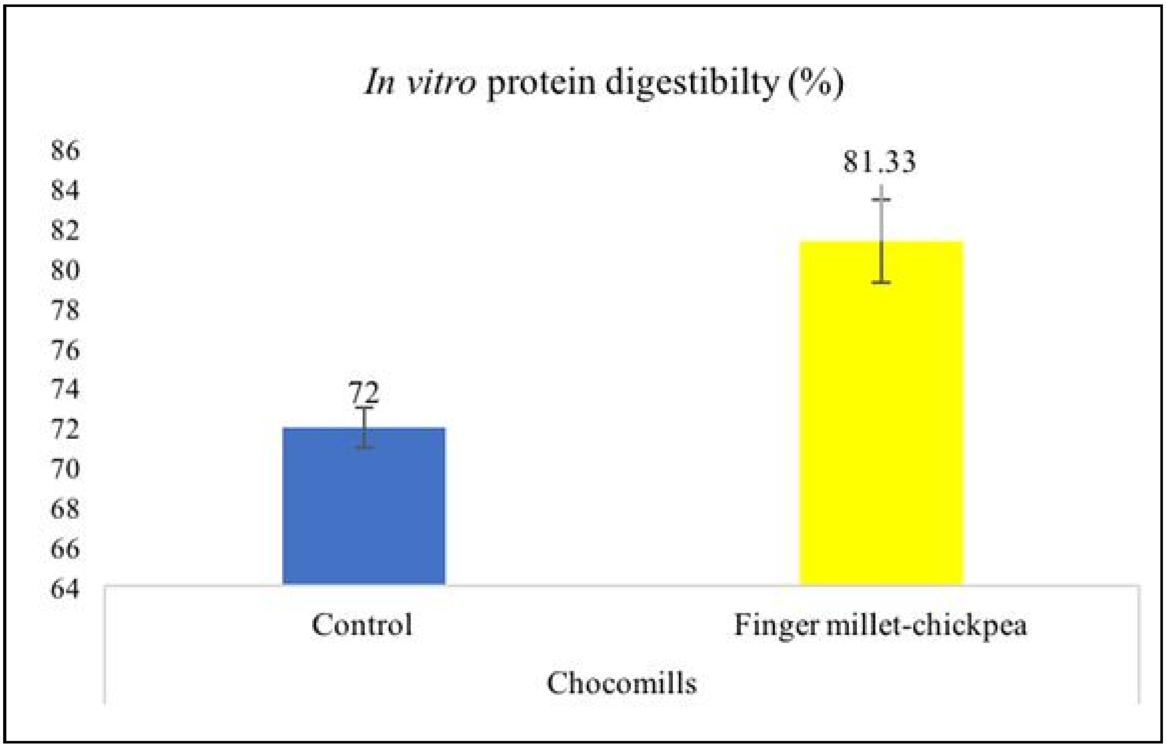


Figure 2: *In vitro* protein digestibility of finger millet-chickpea product (100 g, dry weight basis).

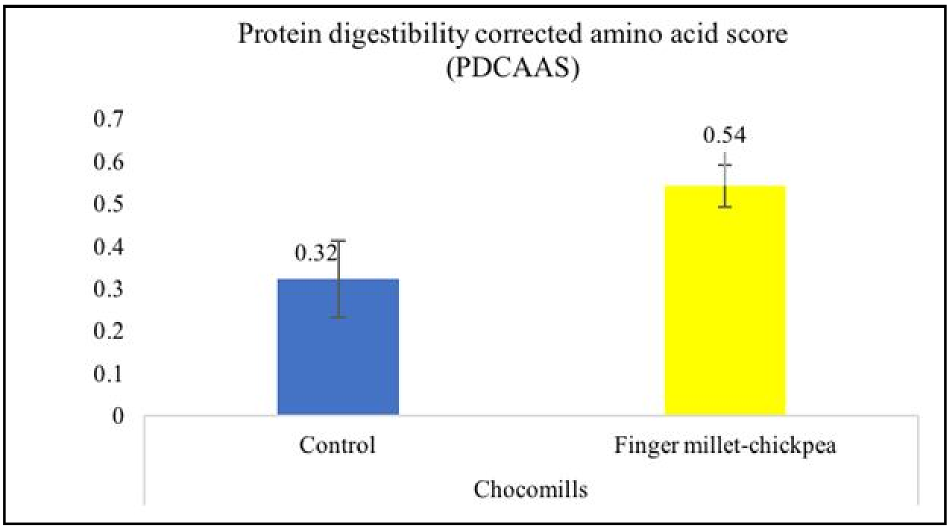


Figure 3: Protein digestibility corrected amino acid score of finger millet-chickpea product (100 g, dry weight basis).

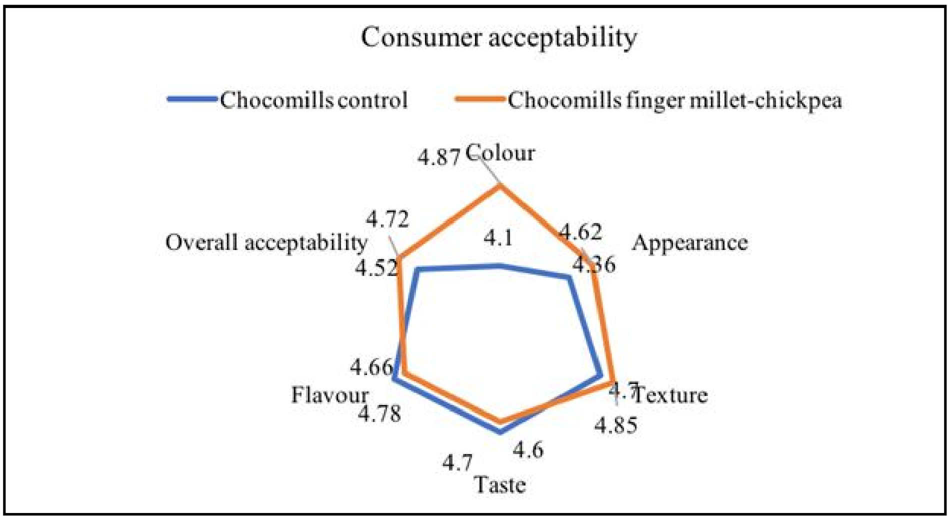


Figure 4: Consumer acceptability of finger millet-chickpea product (100 g, dry weight basis).

3.2 Amino acid composition

The quality of protein in any food is determined by its amino acid profile and its digestibility. The amount of the most limiting amino acid lysine in cereal diets was found to be significantly ($p \leq 0.05$) higher in the developed finger millet-chickpea chocomills at 5.4 g/ 100 g, surpassing the control (Table 3). Other indispensable amino acid namely methionine, valine, leucine, isoleucine, phenylalanine, threonine, tryptophan, and histidine varied in a narrow range. However, an increase of 40.47 per cent in the lysine content of chocomills was observed. The developed product yielded higher lysine concentrations when compared to their control counterparts.

Likewise, it was found that all the dispensable amino acids varied significantly ($p \leq 0.05$), among the developed product (Table 3). Aspartic acid was observed to be present in higher amounts in chocomills (7.8 g/100 g). However, the values of tyrosine were found to be less in the developed product in comparison to other amino acids.

3.3 *In vitro* protein digestibility and protein digestibility corrected amino acid score (PDCAAS) of finger millet-chickpea product

The *in vitro* protein digestibility (IVPD) and protein digestibility corrected amino acid score (PDCAAS) of the control and developed product has been displayed in Figures 2 and 3, respectively. Significant ($p \leq 0.05$) higher digestibility was found in chocomills (81.3 %). The developed chocomills with higher *in vitro* protein digestibility also depicted a higher PDCAAS of 0.54. The per cent increase of *in vitro* protein digestibility was found to be 12.96 per cent which can be attributed to the different percentages of millet pulse combinations used for the development of the product.

3.4 Consumer acceptability of finger millet-chickpea product

The developed product was tested for its acceptability by the consumers. Fifty children in the age group of 7-12 years were asked to evaluate the developed product based on the Likert scale. This scale provides a quantitative way to capture respondents' attitudes and perceptions on a scale ranging from extremely liked to extremely disliked with scores of 5 and 1, respectively (Figure 4). Statistically significant ($p \leq 0.01, 0.05$) higher overall acceptability score was obtained by chocomills (4.72).

3.5 Shelf-life evaluation of finger millet-chickpea product

The chocomills made from combinations of finger millet with chickpea were sealed in low-density polyethylene pouches (thickness-51 microns) and stored at a constant room temperature of 37°C in cool and dry conditions. The shelf-life of the developed product was evaluated every 15 days over three months through sensory assessments conducted by a semi-trained panel using a 9-point Hedonic scale (Table 5). The scores for control and millet pulse-based chocomills was found to be 7.50 and 7.80 on the 0th day and reduced to a scale of 5.50 and 5.80 on the 90th day.

3.6 Nutritional composition of finger millet-chickpea product (on a per-serving basis)

The nutritional composition of the developed product prepared from finger millet-chickpea based on its serving size is presented in Figure 5. The amount per serving was calculated using the standardized measuring containers and comparing with its control counterparts available in the market. It was observed that the serving size of chocomills was standardized to 25 g. In the current study, the target group was school-going children, and chocomills being the most preferred food at this age, the millet pulse-based chocomills provided 4.62 g of protein and 1.35 g of lysine. However, for consuming chocomills, it needs to be mixed with 100 ml of milk. Chocomills has to be soaked in milk for 4 minutes before consumption and provide a protein content of more than 7 g per serving.

Therefore, consuming one serving of chocomills with milk can meet more than 30% of RDA for protein. The lysine content of one serving of developed chocomills was found to have approximately 100 per cent adequacy of RDA [The Recommended Dietary Allowance (RDA) mentioned in the RDA table by ICMR for 13-15 years aged children has been considered for calculating the per cent contribution of the product in meeting RDA].

3.7 Cost estimation of finger millet-chickpea product

The cost of the developed product was estimated to know the difference in price with the control group and also with the products available in the market. The cost estimation of the product concerning its control was done considering the cost of raw ingredients used along with overhead charges (30%) on a per-serving basis. It was observed that the developed chocomills was prepared with the amount of Rs 25.34/- (on a per-serving basis including the cost of 100 ml milk).

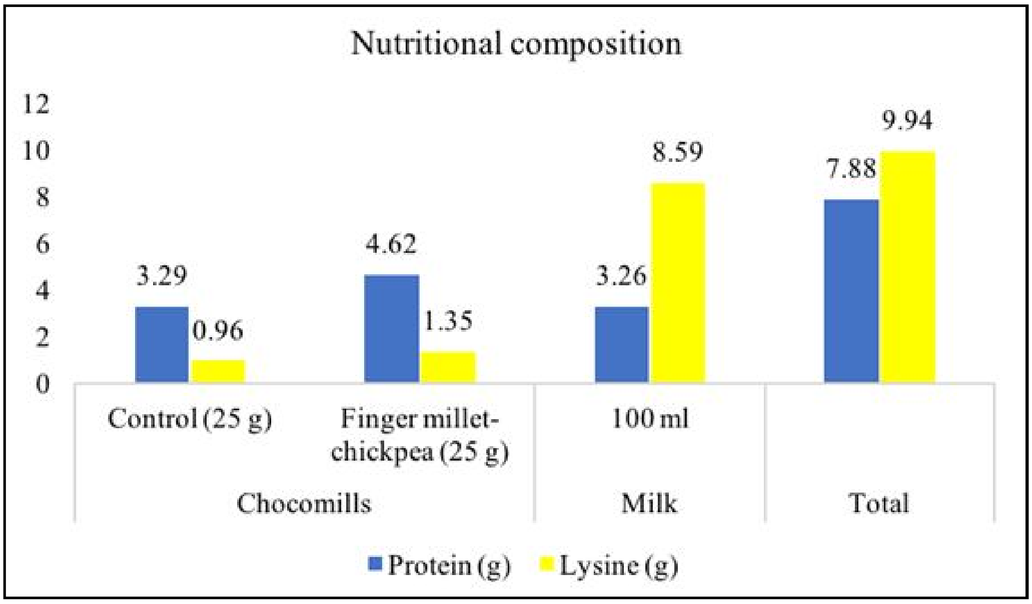


Figure 5: Nutritional composition of finger millet-chickpea product (per serving basis).

Table 4: Cost-benefit ratio of finger millet-chickpea product

A	Input cost per serving	Rs. 15/-
B	Total servings prepared annually	36000
C	Total annual input costRaw material (15/- x 36000) + Equipment (100000/-)	Rs. 6,40,000/-
D	Selling price per serving	Rs. 50/-
E	Total annual sale (50/- x 36000)	Rs. 18,00,000/-
F	Cost Benefit Ratio (E/C)	2.81

3.8 Cost-benefit ratio of finger millet-chickpea product

As observed from Table 4, the cost benefit ratio is found to be 2.81 which shows that the developed product is profitable and sustainable.

Table 5: Sensory scores of chocomills prepared from finger millet-chickpea (100 g, dry weight basis) at an interval of 15 days for 3 months

Products	Colour	Appearance	Texture	Taste	Flavour	Overall acceptability
			0th Day			
C	7.70 ± 0.82	7.70 ± 0.82	7.40 ± 0.52	7.60 ± 0.70	7.50 ± 0.71	7.50 ± 0.71
E	8.20 ± 0.48NS	7.70 ± 0.48NS	7.50 ± 0.53NS	7.70 ± 0.48NS	7.60 ± 0.70NS	7.80 ± 0.52NS
			15th day			
C	7.70 ± 0.82	7.70 ± 0.82	7.40 ± 0.52	7.60 ± 0.70	7.50 ± 0.71	7.50 ± 0.71
E	8.20 ± 0.48NS	7.70 ± 0.48NS	7.50 ± 0.53NS	7.70 ± 0.48NS	7.60 ± 0.70NS	7.80 ± 0.52NS
			30th day			
C	7.70 ± 0.48	7.70 ± 0.48	7.40 ± 0.52	7.60 ± 0.70	7.50 ± 0.71	7.40 ± 0.71
E	7.70 ± 0.82NS	7.70 ± 0.82NS	7.50 ± 0.53NS	7.70 ± 0.48NS	7.60 ± 0.70NS	7.60 ± 0.52NS
			45th Day			
C	7.40 ± 0.52	7.30 ± 0.48	7.30 ± 0.48	7.40 ± 0.48	7.30 ± 0.67	7.20 ± 0.42
E	7.50 ± 0.70NS	7.40 ± 0.70NS	7.42 ± 0.63NS	7.50 ± 0.42NS	7.40 ± 0.52NS	7.50 ± 0.71NS
			60th day			
C	7.30 ± 0.67	7.10 ± 0.57	7.20 ± 0.42	7.30 ± 0.44	7.00 ± 0.60	6.00 ± 0.44
E	7.40 ± 0.52NS	7.30 ± 0.48NS	7.39 ± 0.50*	7.42 ± 0.55*	7.32 ± 0.49**	6.89 ± 0.66*
			75th Day			
C	6.00 ± 0.57	6.99 ± 0.47	5.00 ± 0.39	5.56 ± 0.48	5.90 ± 0.60	5.50 ± 0.38
E	6.20 ± 0.50NS	6.00 ± 0.38NS	6.19 ± 0.40*	5.17 ± 0.56**	5.99 ± 0.49NS	5.90 ± 0.65*
			90th Day			
C	6.20 ± 0.47	6.30 ± 0.45	6.00 ± 0.35	4.56 ± 0.38	5.90 ± 0.63	5.50 ± 0.48
E	6.40 ± 0.55NS	6.52 ± 0.39NS	5.23 ± 0.38**	5.86 ± 0.46*	5.99 ± 0.48NS	5.80 ± 0.55*

C-Control, E-Finger millet-chickpea

Values are expressed as Mean ± SD of triplicates.

Values in columns having control and experimental group only show *significance at ($p \leq 0.05$) level; Values in columns having control and experimental group only show *significance at ($p \leq 0.05$) level.

4. Discussion

4.1 Organoleptic evaluation of the value-added product

In the current study, cereals were replaced with a combination of millets and chickpea to develop a high-quality protein product optimized to meet the preferences of school-going children. Finger millet was replaced with wheat from 30 to 50% depending upon the acceptability of the product. Chocomills developed from finger millet-chickpea obtained higher overall acceptability scores than control, mainly due to its appearance, taste, and flavor, which were specifically noted by evaluators as standout features. The results of the study are in line with the findings of Geetha *et al*. (2020) who used different minor millets (Ragi and Sorgnum) to develop choco fills and reported a higher organoleptic score of the developed products in terms of its color, flavour texture appearance and overall acceptability. Likewise, Chuwa and Dhiman (2022) reported high overall acceptability scores (7.43-8.55) for instant muffin mix prepared using pearl millet and finger millet.

4.2 Nutritional composition of the value-added product

In the current study, the crude protein content was found to be more than 10 g/100 g in a developed product which could be attributed to the millet and pulse combination. The protein content of developed chocomills was observed to be 40.57 per cent higher than the control.

The protein present in millet is higher than in traditional cereals like wheat and rice (Gyawali, 2021). Out of all amino acids, 44.7 per cent of the amino acids present in millets are essential. It was observed that the developed value-added food product had higher protein content than traditional counterparts indicating the fact that these can be used as a nutrient-dense food by the targeted group and may help in alleviating undernutrition among them. The results of the current investigation are in line with a study conducted by Venugopal *et al*. (2018) who developed nutri-rich RTE using finger millet and corn in the ratio of 25:75 and reported protein content of 12.25 g/ 100 g. The crude fiber content of any product depends upon the processing techniques used for its preparation. In the current study, the results showed that the fiber content was higher in the developed product than its control counterpart which can be due to the presence of higher amounts of fibre in millet and pulse grains. Similar results have been reported by Chobuey (2022) who found 6.24 g/100 g of crude fiber in sprouted finger millet chakli (Namitha *et al*., 2019).

4.3 Amino acid composition of the value-added product (g/100 g, dry weight basis)

The presence of indispensable amino acids in a food improves its quality and the absence of any one of them makes the protein inferior and it is not utilized by the body to make muscle protein. Therefore, in the current study, an attempt was made to replace cereals with millets and pulses to improve the quantity and quality of protein. The food product developed with a millet-pulse combination resulted in a better amino acid profile.

Lysine, the limiting amino acid of cereals was found to be increased in the developed novel product. The per cent increase in lysine content of developed chocomills was observed to be 40.46 per cent. Fakiha *et al*. (2020) reported that combining millets and pulses increased the lysine content and can effectively address the lysine deficiency.

4.4 *In vitro* protein digestibility and protein digestibility corrected amino acid score (PDCAAS) of finger millet-chickpea product

In vitro protein digestibility of any product depends upon its amino acid profile, protein content, pH ionic strength, temperature, and anti-nutritional factors. The processing technology applied also affects the digestibility. The *in vitro* protein digestibility of the developed chocomills was found to be 81.33 per cent, which was 12.95 per cent higher than the control. The *in vitro* protein digestibility led to a high PDCAAS value of more than 0.5 in chocomills (0.54). The combination of millet and pulse has led to the improvement in protein digestibility and protein digestibility corrected amino acid score because this combination makes a more balanced amino acid profile, improving overall protein quality (Fakiha *et al*., 2020).

4.5 Consumer acceptability of finger millet-chickpea product

The consumer acceptability evaluation scale is a measure of using the Likert liking of consumers for food items in terms of their taste, texture, appearance, flavor, *etc*. In the current study, the developed product obtained a score higher than its control counterpart. The consumers showed great satisfaction and liking for the developed millet pulse-based product which is clear from the overall acceptability score. Another study by Sewak *et al*. (2020) reported that pearl millet-based dalia had higher acceptability scores compared to their control counterpart. The addition of chickpeas in the product in the current study might have improved the taste and overall consumer acceptability. The combination not only balances the flavor profile but also improves texture and nutritional quality, making the product more appealing and beneficial. Rawat *et al*. (2023) reported that the addition of pulses improved and gave a unique aroma and texture to millet-based foods and also made them more appealing to consumers.

4.6 Shelf-life evaluation of finger millet-chickpea product

Millets with high-fat content can oxidize when exposed to air at varying rates, which degrades both their nutritional value and sensory quality. The shelf life of millet flour is shortened as a result of oxidative and hydrolytic deterioration due to the presence of enzymes such as lipase and lipoxygenase, which trigger the oxidation of a large amount of fat present in flour, resulting in the production of an off-odour and flavour (Bekele *et al*., 2020). The oxidation of phenolic components by polyphenol oxidase and peroxidases, in addition to fatty acid oxidation, causes off-flavor and browning of millet flour during storage (Goyal and Chugh, 2017). To study the changes in organoleptic parameters of the developed product, it was stored for 3-month periods and evaluated at an interval of 15 days. It was observed that the acceptability declined with an increase in storage period. This could be due to the cooking methods used. The developed product was acceptable till the period of 45 days after which less acceptability scores were obtained. A similar study by Sobana (2017) observed that a significant drop in the overall acceptability of a millet-based composite sports bar was noted from 38.3 to 13.1 over three months.

4.7 Nutritional composition (per serving basis) of finger millet-chickpea product

The millet pulse-based product has been developed for school-going children so it is important to know the number of nutrients on a per serving basis. The developed food product was found to be rich in protein and lysine based on their one portion in comparison to its control counterpart. Hence, consumption of one portion of the millet pulse-based developed chocomills in the current study can help in combating malnutrition in the country. Similar results have been reported by Rao and Devi (2019) who emphasized that adding pulses to millet-based food increases both protein and lysine content.

4.8 Cost estimation of the materials used to prepare value-added finger millet-chickpea product

The cost comparison of the developed product with the available options in the market showed that the same serving size of the developed product with good quality ingredients of various brands (25 g) had 34.1 per cent lesser cost. The data highlighted the fact that the developed product involved less money in its preparation than its control and market counterparts while having higher nutritional value. Therefore, the product developed in the current study is an economical option for recommendation to the target group for combating undernutrition.

5. Conclusion

The finger millet-chickpea combination can be used for developing value-added cost-effective products with high organoleptic scores, nutritional profile, shelf-life, and consumer acceptability. The developed product offered good quality protein with improved *in* *vitro* protein digestibility and protein digestibility corrected amino acid score (PDCAAS) higher consumer acceptability and a shelf-life of up to 45 days and provided more than 30% RDA for protein and exceeded 100% of the lysine requirement for school going children. From the foregoing results, it can be interpreted that millet-pulse-based foods can help in improving nutritional health and food security, especially in developing countries where cereals are consumed as staple foods. Hence, millet and chickpea-based products offered enhanced nutritional profiles per serving compared to traditional cereal-based items, making it an effective strategy to combat malnutrition and bolster food security. Therefore, millet-pulse combinations are particularly recommended for vulnerable groups, including school-going children, pregnant women, and adolescent girls, to ensure sufficient high-quality protein intake. These nutrient-dense products can also be incorporated into National Feeding Programs to address malnutrition within communities. The prospects of millet-based food products for children are highly promising, driven by increasing demand for nutritious, allergy-friendly, and sustainable foods. The rise of functional foods, gluten-free diets, and personalized nutrition creates opportunities for product innovation, such as millet-based formulations prepared in the current study.

Acknowledgments

The authors acknowledge the financial support provided by the Central Institute of Women in Agriculture (CIWA), Bhubaneswar for purchasing the requisite chemicals and other facilities required to carry out this research work.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

Akeson, W.E. and Stachman, M.A. (1964). A pepsin-pancreatin digest index of protein quality evaluation. J. Nutr., **83**:257-261.

Anushree, R.K.; Kushwaha, A.; Panwar, R.K.; Lohani, U.C. and Devi, O.R. (2024). Examining the sensory and cooking qualities of noodles enriched with lentils and investigating the physical and functional attributes of composite flours. Ann Phytomed., **13**(1):916-923.

AOAC (2000). "Official Methods of Analysis. Association of Official Analytical Chemists". 16th ed. Washington, DC

Aggarwal, R. and Bains, K. (2022). Protein, lysine, and vitamin D: critical role in muscle and bone health. Crit. Rev. Food Sci. Nutr., **62**(9):2548-2559.

Bekele, E.K.; Nosworthy, M.G.; Henry, C.J.; Shand, P.J. and Tyler, R.T. (2020). Oxidative stability of direct-expanded chickpea sorghum snacks. Food. Sci. Nutr., **8**:4340-4351.

Chandel, G.; Meena, R.K.; Dubey, M. and Kumar, M. (2014). Nutritional properties of minor millets: Neglected cereals with potentials to combat malnutrition. Curr. Sci., **107**(7):1109-1111.

Choubey, D. (2022). Process standardization for the development of finger millet mix jaggery chocolate. (Doctoral dissertation). GB Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand.

Devi, P.B.; Vijayabharathi, R.; Sathyabama, S.; Malleshi, N.G. and Priyadarisini, V.B. (2014). Health benefits of finger millet (*Eleusine coracana L.*) polyphenols and dietary fiber: A review. J. Food Sci. Technol., **51**:1021-1040.

Chuwa, C. and Dhiman, A.K. (2022). Development and nutritional evaluation of iron-rich instant muffin mix as a complementary food for children. Ann. Phytomed., **11**:638-647.

Fakiha, A.; Tul-Noor, Z.; Paoletti, A.; Pencharz, P.B.; O Ball, R.; Levesque, C.L.; Elango, R. and Courtney-Martin, G. (2020). Bioavailable lysine, assessed in healthy young men using indicator amino acid oxidation, is greater when cooked millet and stewed Canadian lentils are combined. J. Nutr., **150**(10):2729-2737.

FAO/WHO (1991). Protein Quality Evaluation: Report of the Joint FAO/ WHO Expert Consultation, FAO Food and Nutrition Paper 51. Rome: FAO.

Geetha, K.; Ilamaran, M.; Ramasamy, D.P. and Abdullah, E. (2020). Studies on optimizing the process for the development of millet-based chocofills. IJCS., **8**(1):2637-2639.(

Goyal, P. and Chugh, L. (2017). Shelf-life determinants and enzyme activities of pearl millet: A comparison of changes in stored flours of hybrids CMS lines, inbreds, and composites. J. Food. Sci. Technol., **54**:3161-3169.

Gull, A., Jan, R., Nayik, G.A., Prasad, K. and Kumar, P. (2014). Significance of finger millet in nutrition, health, and value-added products: A review. Magnesium (mg)., **130**(32):120.

Gyawali, P. (2021). Production trend, constraints and strategies for millet cultivation in Nepal: A study from a review perspective. Int. J. Agri. Appl. Sci., **2**:30-40.

Jagati, P.; Mahapatra, I. and Dash, D. (2021). Finger millet (Ragi) as an essential dietary supplement with key health benefits: A review. Int. J. Home Sci., **7**:94-100.

Joshi, A.; Kushwaha, A.; Dutta, A.; Kumar, A. and Shahi, N.C. (2024). Processing mediated changes on protein digestibility and iron bioavailability of selected underutilized millet and legume. Ann. Phytomed., **13**:958-965.

Katoch, O.R. (2022). Determinants of malnutrition among children: A systematic review. Nutr., **96**:111565.

Kurpad, A.V. and Thomas, T. (2020). Protein quality and its food source in the diets of young Indian children. The J. Nutr., **150**(6):1350-1351.

Likert, R. (1932). A technique for the measurement of attitudes. Arch. Psychol., **22**:1-55.

Minocha, S.; Thomas, T. and Kurpad, A.V. (2017). Dietary protein and the health-nutrition-agriculture connection in India. J. Nutr., **147**:1243-1250.

Moughan, P. J. (2021). Population protein intakes and food sustainability indices: the metrics matter. Glob. Food Sec., **29**:100548.

Namitha, M.Y.; Chavan, U.D.; Kotecha, P.M. and Lande, S.B. (2019). Studies on nutritional and sensory qualities of foxtail millet chakli. Int. J. Food Sci. Nutr., **4**(5):68-73.

Neumann, C.G.; Gewa, C. and Bwibo, N.O. (2004). Child nutrition in developing countries. Ped. Ann., **33**(10):658-674.

Nicolas, L.; Marquilly, C. and O'Mahony, M. (2010). The 9-point hedonic scale: are words and numbers compatible? Food Qual. Pref., **21**(8):1008-1015.

Pillai, R.R.; Elango, R.; Ball, R.O.; Kurpad, A.V. and Pencharz, P.B. (2015). Lysine requirements of moderately undernourished school-aged Indian children are reduced by treatment for intestinal parasites as measured by the indicator amino acid oxidation technique. The J. Nutr., **145**(5):954-959.

Rao, P.V. and Devi, P.U. (2019). Improving nutritional quality of millet-based products using pulses: A review. Int. J. Food Sci. Nutr. **10**:1080.

Rawat, M.; Varshney, A.; Rai, M.; Chikara, A.; Pohty, A.L.; Joshi, A. and Gupta, A.K. (2023). A comprehensive review on nutraceutical potential of underutilized cereals and cereal-based products. J. Agri. Food Res., **12**:100619.

Rutherfurd, S.M.; Fanning, A.C.; Miller, B.J. and Moughan, P. J. (2015). Protein digestibility- corrected amino acid scores and digestible indispensable amino acid scores differentially describe protein quality in growing male rats. J. Nutr. **145**(2):372-379.

Sewak, A.; Singla, N.; Javed, M. and Gill, G.S. (2023). Suitability of pearl millet (*Pennisetum glaucum* (L.) R. Br.) and sorghum (*Sorghum bicolor* (L.) Moench) based food products for diabetics. Acta Aliment., **52**(3):366-377.

Sobana, R.M. (2017). Quality evaluation of millet-based composite sports bar. Int. J. Food Sci. Nutr., **2**(4):65-68.

Thagunna, B.; Rimal, A.; Kaur, J.; Dhakal, Y. and Paudel, B. (2022). Finger Millet: A powerhouse of nutrients its amino acid, micronutrient profile, bioactive compounds, health benefits, and value-added products. J. Res. Agric. Animal Sci., **9** (8):36-44.

Venugopal, H.; Jayaprakasha, H.M. and Arunkumar, H. (2018). Nutririch millet (Finger millet) and Legume (*Macrotyloma uniflorum*) in developing Ready-To-Eat (RTE) food. Int. J. Adv. Res. Ideas Innov. Technol., **4**(4):136-139.

World Health Organization (2023). Levels and trends in child malnutrition child malnutrition: UNICEF/WHO/World Bank Group Joint Child Malnutrition Estimates: Key findings of the 2023 edition.

Citation **Deeksha Rana, Renuka Aggarwal, Harpreet Kaur, Aditi Sewak, Kiran Bains and Inderpreet Kaur Dhaliwal (2025). Formulation and nutritional evaluation of millet-pulse-based functional food for protein deficiency. Ann. Phytomed., 14(1):888-897. http://dx.doi.org/10.54085/ap.2025.14.1.89.**