Development of Brown Top Millet and Soy Fortified Noodles

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Abstract
The study was conducted to prepare soy enriched multigrain pasta with better nutritional value than conventional wheat pasta. Mixtures were prepared from wholemeal millet (10-40%) and a constant proportion of soy flour (20%) and gluten (2.5%). The nutritional composition, sensory properties and overall nutritional quality of the pasta samples were assessed. The results showed that the addition of millet improved the nutritional value especially for fiber, fat and ash content. The moisture content of the enriched pasta rose from 5.0% in the control sample to 7.3%, which is still within the acceptable range for shelf life (less than 14%). The ash content increased from 0.82 % in control sample to 2.53 % at highest enrichment levels, which is due to the higher mineral content of millet and soy flours. The crude fiber content in the fortified pasta increased from 0.45% in the control group to 1.01%, with higher dietary fiber content in the whole-grain soy and millet flours. In the control group, the natural fat content of fortified millet and soy flour samples also increased from 2.02% to 5.17%. Sensory analysis showed that the sample containing 20% millet flour had the best flavor, texture and overall quality. Color analysis revealed a significant change in the appearance of the noodles by the increase of enrichment. In noodles made with 40% millet flour, the illuminance value (L*) decreased from 44.93 to 25.08, which showed a darker color because of the presence of phenolic compounds and bran pigments. New research finds soy-enhanced multigrain noodles could be a healthy alternative to regular noodles without compromising on taste.

Keywords: Brown top millet, Cooking loss, Soy flour**,** Sensory acceptability.

1. Introduction

Noodles are a staple in the diet of people around the world, not only in Asia. In Asia, nearly 40% of total flour produced is used for noodle production [1]. The viscoelastic dough is then extruded or rolled into the desired shapes before cooking. They are prepared using different recipes depending on their composition and processing parameters. Global noodle consumption is increasing due to their easy preparation, taste, long shelf life, convenience, and availability [2]. Noodles are presently regarded as a universal food, enjoyed by people of all genders, ages, and cultural backgrounds. In 2016, the global noodle market produced approximately 97.5 billion servings, with forecasts suggesting an upward trend in this number [3]. Historical and archaeological evidence indicates that noodles originated in China. Traditional noodle technology was transmitted from China to neighboring Asian countries, such as Korea, Thailand, Malaysia, Indonesia, Singapore, and Vietnam, by traders and migrant communities [1].

The basic ingredients for making noodles are wheat flour, water, and alkalizing agents. Noodles can be classified into two types based on their moisture removal method. The moisture content of dry instant noodles ranges from 8 to 12%, whereas fried instant noodles range from 2 to 5%. Air-dried noodles are typically lower in fat (around 3%) than fried noodles (15-20%) and thus have a longer shelf life [3]. Popular noodle varieties include fresh noodles ("Cantonese-style"), wet or boiled noodles ("Hokkien-style"), dry noodles, raw egg noodles ("wonton" or "wonton"), and instant noodles [4]. The demand for multigrain-based foods has risen in recent years, as individuals become more conscious of the role of nutrition in disease prevention and treatment. Several studies have found that eating multigrain foods lowers the risk of cardiovascular disease and metabolic disorders. Multigrain foods, when properly prepared, can provide balanced nutrition as well as nutritionally adequate dietary components [5].

Refined wheat noodles are high in carbohydrates but low in important minerals and dietary fibre because nutrients are lost during the flour refining process. In addition, grain-based noodles are deficient in important amino acids such as threonine, tryptophan, and lysine [6, 7]. Flours obtained from alternative sources and containing high levels of nutrients are being increasingly used as composite flours to improve the nutritional value without compromising the technical, culinary, textural and organoleptic properties.

Soy (*Glycine max)* is an ideal ingredient for food fortification due to its high protein content (40%) and variety of essential amino acids. It also contains a significant amount of carbohydrates (23%), lipids (20%), omega-3 fatty acids, dietary fiber, vitamins, minerals, antioxidants, and phytochemicals such as phenolic acids, phytosterols, and lecithin. So, soy is an excellent supplement to cereal diets that are naturally low in lysine.

Brown millet is also known for its excellent nutritional profile. It is rich in protein (14.48 g), fiber (4.45 g), fat (1.48 g), and micronutrients such as iron (4.51 mg), copper (0.58 mg) and zinc (4.44 mg) [3]. Thus, the production of soy-enriched multigrain noodles is a promising method for improving the nutritional profile of classic wheat noodles while meeting growing consumer demand for healthier functional foods. By adding soy and nutrient-rich millet crops, such as brown millet, the product can provide improved protein, dietary fiber, and essential minerals without compromising its organoleptic and culinary characteristics. Therefore, the goal of this project is to develop and evaluate soy-enriched multigrain noodles as a nutritious, affordable, and consumer-friendly alternative to traditional noodles.

2. Raw materials

Raw ingredients including brown top millet flour, soy flour, refined wheat flour, salt, water, gluten powder were purchased from the resident market of Greater Noida, India.

2.1 Chemical and reagent

The analytical grade chemicals and reagents were acquired from Sigma Aldrich, Mumbai, India.

2.2 Noodle preparation

Noodles were made by substituting wheat flour with brown top millet flour in varying proportions of 10%, 20%, 30%, and 40%. The quantities of soybean and gluten were maintained at 20% and 2.5%, respectively. The prepared dough was placed in a polyethylene bag and allowed to condition at 25-27°C for one hour. Subsequently, the dough was sheeted by repeatedly passing it through the rollers of a pasta maker (Marcato Ampia 150, Italy) until a uniform width of 1.2 mm was attained. The sheets were then extruded through a die to form noodle strands. Noodles were dried in a hot air oven at 85 °C for a period of 90 min. The dehydrated noodles were equilibrated at ambient temperature, wrapped in LDPE film and stored for further physicochemical evaluation [3].

Table 1: Percentage of millet flour, soy flour, and gluten used in noodles preparation

Samples	Millet flour (%)	Soy flour (%)	Gluten (%)
A	-	-	-
B	10	20	2.5
C	20	20	2.5
D	30	20	2.5
E	40	20	2.5

Here; A: Control sample made with 100% wheat flour; B: Containing 10% brown top millet flour; C: Containing 20% brown top millet flour; D: Containing 30% brown top millet flour; and E: Containing 40% brown top millet flour.

2.3 Analysis of cooking quality of noodles

2.3.1 Duration of cooking

In a glass beaker on a hot plate, 200 ml of distilled water was mixed with about 5 g of noodles and heated to boiling. The ideal cooking time was determined when the white core of the noodle strand became transparent after gentle prodding with a spoon or pressing between fingers [8].

2.3.2 Mass of cooked product

The noodles were boiled for the ideal cooking duration, and the increase in mass was measured to determine the cooked weight. The recorded post-cooking mass (g) was considered the final cooked weight [9].

2.3.3 Cooking loss

A sample of noodles (5 g) was cooked in 200 ml of boiling water to determine the cooking loss or mass of solids remaining in the cooking water. The cooking water was collected in a pre-dried glass beaker and weighed in a hot air oven set to 105 °C until it was completely evaporated. Cooking loss [3] was then calculated as the percentage of dry matter lost during cooking divided by the dry sample weight.

$$\text{Cooking loss (\%)} = \frac{\text{Weight of dried residue}}{\text{Noodles weight before cooking}}$$

2.4 Estimation of sensory acceptability of multigrain noodles

The dehydrated noodles were soaked in boiling water and then immediately used for sensory evaluation. The sensory characters of the noodles were evaluated by 15 semi trained evaluators from Sharda University. Panelists were asked to rate the overall acceptability of the noodles on a nine-point hedonic rating scale of 1 = "dislike extremely" and 9 = "like extremely" [3].

2.5 Proximate analysis of multigrain noodles

2.5.1 Moisture content

Moisture percentage was estimated using a standard procedure [10]. Disposable aluminum dishes (diameter < 50 mm and depth < 40 mm) were used. The items were sequentially numbered, subjected to drying in an oven for 30 minutes, subsequently cooled in a desiccator, and then weighed. A two-gram specimen was measured thrice using the same method. Samples in aluminium dishes were taken out with tongs and placed in a drying oven at 130 °C for 1 hour. The samples were removed, cooled in a desiccator for 30 minutes and weighed. The moisture percentage was calculated by averaging the three measurements using the equation:

$$Moisture\ content\ (\%) = \frac{(W_2 - W)}{(W_1 - W)} \times 100$$

W = mass of empty aluminum dish, W1 = mass of dish and sample before drying, W2 = mass of dish and sample after drying

2.5.2 Ash percentage

The ash amount was estimated using the reference method [10]. Three measurements of 4 g of sample were taken and put into porcelain crucibles. After calcining, the crucibles were cooled in a desiccator, weighed and then placed in an electric muffle furnace. To ensure complete ashing, the temperature was maintained at 540°C overnight. The ash-filled crucibles were directly placed into the desiccator, permitted to cool for thirty minutes, and subsequently weighed immediately. Determination of ash content was done and was expressed as percentage using the following equation;

$$Ash\,\% = \frac{W_2 - W_1}{W} \times 100$$

Where, W = Sample mass; W_1 = Empty crucible mass; W_2= Mass of crucible + ash.

2.5.3 Fat content

A standard method [10] was used to determine the fat content. Oil was extracted using a goldfish extractor and petroleum ether. Three samples, two grams each, were wrapped in filter paper and placed in a cellulose condenser. Weighed goldfish cups were filled with 40 ml of petroleum ether solvent. The extraction process took 4 hours to completely extract all soluble components of the sample. The burners were allowed to cool for 30 minutes and the beakers were placed on a tray and covered with an evaporating watch glass. The beakers were left in a fume hood overnight to allow complete evaporation of the ether. The solvent was evaporated in the oven at 130°C for 15 min and cooled in a desiccator for 30 min and reweighed. The formula to calculate fat content was as follows:

$$Crude\ fat\ (\%) = \frac{Weight\ of\ ether\ soluble\ material\ (g)}{Weight\ of\ sample\ taken\ (g)} \times 100$$

2.5.4 Crude fiber content

The AACC protocol [11] was used to determine crude fiber. Briefly, 200 ml of 1.25% H_2SO_4 was introduced to 5 g of the defatted sample in a conical flask, and the mixture was refluxed for 30 minutes. The flask was then removed, and the contents were filtered using ashless filter paper and digested with hot water. After washing, the remaining residue was returned to the flask and digested for approximately half an hour using 200 ml of 1.25% NaOH. The residue was then filtered and washed several times with hot water. The residue was rinsed, transferred to a silica crucible and dried to constant weight in a hot air oven at 105 ± 1 °C. The dried crucible containing residue was weighed after a 30-minute cooling period in a desiccator. The crucible was heated to 550 ± 5 °C in a muffle furnace to incinerate the carbonaceous material. Subsequent to weighing, the crucible was transferred to the desiccator for cooling. The fraction of crude fiber was determined using the following equation:

$$Crude\ fibre\ (\%) = \frac{W_1 - W_2}{W} \times 100$$

W = weight of the sample; W1 = crucible + treated sample after oven drying; W2 = crucible + sample after ashing.

2.6 Colour measurement

Color of the noodles was taken utilizing a colorimeter (Konica Minolta Instrument, Osaka, Japan, Model: CM 5). The samples from each treatment and replication were evaluated for L* (lightness coordinate ranging from negative to positive), a* (color coordinate from green to red), and b* (color coordinate from blue to yellow) [12].

2.7 Statistical analysis

All the analyses were performed in triplicate and results are expressed as mean ± standard deviation

3 Results and discussion

3.1 Noodles cooking attributes

The results of cooking properties are shown in Table 2. Important cooking variables that influence the quality and consumer acceptability of noodles include cooking time, weight after cooking, and weight loss during cooking. Depending on the number of independent variables used, noodle cooking time ranges from 5 to 6 minutes. Sample B (10% millet, 20% soy, and 2.5% gluten) had the shortest cooking time, while sample E (40% millet, 20% soy, and 2.5% gluten) had the longest cooking time. As millet concentration increases in noodles, the cooking time increases because millet absorbs more water, has a denser structure, and delays starch gelatinization. Benhur et al. [13] found similar cooking behavior in sorghum-based pastas produced using extrusion technology. The study revealed that soy flour addition had no effect on cooking time and the optimum cooking time was obtained at 13.5 to 15% substitution level of soy flour. These results are inconsistent with those of Choi et al. [14], who found the opposite trend for buckwheat-fortified noodles. The difference could be described by the fact that replacing wheat flour with gluten-free ingredients disrupts the integrity of the gluten matrix, increasing liquid dispersion in the noodle strands and, consequently, reducing the cooking time.

Cooking loss, an vital quality characteristic linked to the appearance and consumer appeal of noodles, is influenced by the noodle surface structure. The dataset shows cooking loss values ranging from 7.02 to 14.05 g/100 g, with control sample (A) having the lowest and formulation E having the highest (containing 40% millet, 20% soy, and 2.5% gluten). The continued increase in cooking loss with higher millet levels may be due to dilution and weakening of the gluten network, reducing the integrity of the matrix and allowing soluble starch and solid leaching while cooking. These findings are consistent with Aydin and Gocmen [15], who described elevated cooking loss in noodles containing oat flour. They attributed the result to a smaller protein-starch structure, which contrasts with the strong gluten network characteristic of typical wheat noodles. Similarly, Benhur et al. [13] showed higher cooking losses (7.41–10.12 g/100 g) in sorghum-based pasta, which was most likely due to partial disruption of amylose interactions caused by the addition of sorghum powder.

The cooked weight of the noodle's samples ranged from 28 (sample A) to 21 g/5g (sample E). The decline in cooked weight with increasing levels of millet flour may be attributed to its elevated dietary fiber content, which can disrupt and dilute the gluten matrix, a trend also noted by De Pilli et al. [16] in oat-enriched spaghetti. In addition, the reduced gluten availability in the formulated noodles likely limited water absorption during cooking, contributing to the lower final cooked weight. Wheat flour contains gluten, which forms a strong viscoelastic network that traps water during cooking. When wheat is replaced by millet, this network becomes weaker, reducing the noodle's ability to retain absorbed water, resulting in lower cooked weight.

Table 2: Cooking behaviour of fortified noodles

Sample	Cooking time (min)	Cooking loss (%)	Cooking weight (g/5g)
A	6.00 ± 0.02	7.02 ± 0.05	28.00 ± 0.10
B	5.00 ± 0.03	11.08 ± 0.06	25.00 ± 0.12
C	5.30 ± 0.04	11.10 ± 0.07	23.00 ± 0.15
D	5.40 ± 0.05	12.02 ± 0.08	22.00 ± 0.11
E	6.05 ± 0.03	14.05 ± 0.09	21.00 ± 0.14

Here; A: Control sample made with 100% wheat flour; B: Containing 10% brown top millet flour; C: Containing 20% brown top millet flour; D: Containing 30% brown top millet flour; and E: Containing 40% brown top millet flour.

3.2 Sensory attributes of millet and soy fortified noodles

Table 3 presents the mean hedonic scores for the sensory attributes of different noodle formulations. The sensory characteristics, including colour, taste, texture, appearance, aftertaste, and overall acceptability, were significantly influenced by the type of flour used in the noodle preparation. The highest colour score was recorded for sample A (7.2), whereas the lowest score was observed for sample E (4.7). In terms of taste, sample A had the highest score (7.3), while sample E obtained the lowest score (6.3). For texture, sample C achieved the highest score (7.1), whereas sample B showed the lowest texture score. Regarding appearance and aftertaste, sample C obtained the highest scores, while sample D recorded the lowest scores for these attributes. Overall acceptability was highest for sample C, followed by samples A, B, and E, whereas sample D showed the lowest overall acceptance among all formulations.

Table 3 Sensory properties of soy and millet fortified noodles

Attributes	Sample A	Sample B	Sample C	Sample D	Sample E
Colour	7.2±0.94	5.7±1.22	6.8±1.08	5.1±0.99	4.7±1.09
Taste	7.3±1.04	6.5±1.06	6.2±1.20	5.9±1.09	6.3±1.54
Texture	6.4±0.74	6.3±0.72	7.1±0.83	5.2±0.77	6.4±1.59
Appearance	6.8±0.74	6.6±1.29	7.1±1.12	5.1±0.99	6.1±1.06
After taste	7.0±0.9	6.4±0.98	7.6±0.97	5.3±0.97	6.2±1.16
Overall acceptability	33.6±1.84	33.0±2.39	36.1±3.15	30.0±2.65	32±3.42

Here; A: Control sample made with 100% wheat flour; B: Containing 10% brown top millet flour; C: Containing 20% brown top millet flour; D: Containing 30% brown top millet flour; and E: Containing 40% brown top millet flour

3.3 Nutritional analysis

Table 4 shows the results of the nutritional analysis for the control (100% refined wheat flour) and multigrain noodles. The moisture content for control noodles was observed to be 5.0±0.01% which increased to 7.3±2.08% for millet fortified noodles and was in the permissible limit (<14%) for safe storage [13]. The moisture content of noodles with 10%, 20%, 30% and 40% millet was 5.1%, 6.1%, 7.1% and 7.3%, respectively. These results showed that, as the concentration of brown-top millet and soy flour increased in the prepared noodles, the moisture content consequently increased [9]. The ash content in millet-noodles was 1.72%, 1.96%, 2.52% and 2.53%, respective for the concentration of 10%, 20%, 30% and 40%. The ash percentage of control noodles had been 0.82%. This increase is attributed to the higher nutrient density in the soybean and brown-top millet flour compared to refined wheat flour [3, 17, 18]. Noodle ash content was increased with increased level of millet and soybean flour. The amount of mineral content of food is represented by the ash content. Brown top millet and soybean were found to be rich in essential minerals such as Ca, Mg and P [19].

The crude fiber content of millet noodles was 0.93, 0.96, 0.97 and 1.01% at 10, 20, 30 and 40% concentrations. Refined wheat noodles contained 0.45% crude fiber. The apparent increase in crude fiber content was associated with the increase of brown-top millet and soybean flour in the noodles [9]. The increase in crude fiber content observed with higher incorporation of brown top millet and soybean flour in noodles can be attributed to their naturally high fiber composition. Brown top millet is a whole grain rich in both soluble and insoluble dietary fiber due to the presence of bran layers, while soybean flour also contributes significant amounts of fiber, particularly insoluble fractions [12, 20]. In contrast, refined wheat flour contains lower fiber levels as the bran is removed during milling. Therefore, increasing the proportion of these flours results in a proportional rise in total dietary fiber content.

The corresponding fat contents in millet noodle were 3.75%, 4.22%, 5.15% and 5.17%, respectively. There were increase in the oil contents in the prepared noodles as the concentration of millet and soy flour increased. The observed increase in fat content with higher incorporation of brown top millet and soybean flour in noodles can be attributed primarily to the intrinsic lipid composition of these ingredients. Soybean flour is particularly rich in fat, containing approximately 18–20% lipids, which are mainly composed of unsaturated fatty acids such as linoleic and oleic acids. Similarly, millets, including brown top millet, contain higher fat levels compared to refined wheat flour due to the presence of germ and bran fractions, which are rich in lipids [19].

Table 4: Nutritional analysis of fortified noodles

Sample ID	Moisture (%)	Ash (%)	Fat (%)	Crude Fiber (%)
Sample A	5.0±0.01	0.82±0.02	2.02±0.02	0.45±0.01
Sample B	5.1±2.73	1.72±0.02	3.75±0.01	0.93±0.01
Sample C	6.1±0.76	1.96±0.02	4.22±0.02	0.96±0.02
Sample D	7.1±2.56	2.52±0.02	5.15±0.02	0.97±0.01
Sample E	7.3±2.08	2.53±0.02	5.17±0.01	1.01±0.02

Values are mean ±std deviation of triplicate replications. Here; A: Control sample made with 100% wheat flour; B: Containing 10% brown top millet flour; C: Containing 20% brown top millet flour; D: Containing 30% brown top millet flour; and E: Containing 40% brown top millet flour

3.3 Colour analysis of control and fortified noodles

The results of the colour analysis of control (100% refined wheat flour) and millet fortified noodles are shown in Table 5. The L* value of millet noodles was 44.59±1.24, 39.99±0.87, 33.88±0.88 and 25.08±2.65 for concentration of 10%, 20%, 30% and 40% respectively. With increasing incorporation of brown top millet and soybean flour, a decrease in L* value (lightness) is typically observed. This is due to the darker pigments present in millet (phenolic compounds and bran) and soybean flour, which reduce the brightness compared to refined wheat flour [19,21]. The a* value of millet noodles was 3.12±1.22, 5.31±1.15, 6.66±0.14 and 10.95±0.40 for concentration of 10%, 20%, 30% and 40% respectively. The a* value generally increases (shift toward redness) with higher levels of millet and soybean flour. This can be attributed to natural pigments such as polyphenols and Maillard browning reactions that occur during processing, leading to the development of brownish or reddish hues [22]. The b* value of millet noodles was 20.26±3.15, 25.07±2.32, 30.30±0.56, 34.67±0.61 for concentration of 10%, 20%, 30% and 40% respectively. Similarly, the b* value (yellowness) may increase or vary depending on formulation, often showing an increase due to the presence of natural yellow pigments such as carotenoids in millet and soybean. However, at higher substitution levels, excessive browning reactions may slightly reduce yellowness [21].

Table 5: Colour analysis of noodles samples

Sample ID	L*	a*	b*
Sample A	44.93±3.85	1.88±0.65	25.29±0.94
Sample B	44.59±1.24	3.12±1.22	20.26±3.15
Sample C	39.99±0.87	5.31±1.15	25.07±2.32
Sample D	33.88±0.88	6.66±0.14	30.30±0.56
Sample E	25.08±2.65	10.95±0.40	34.67±0.61

Here; A: Control sample made with 100% wheat flour; B: Containing 10% brown top millet flour; C: Containing 20% brown top millet flour; D: Containing30% brown top millet flour; and E: Containing 40% brown top millet flour

Conclusion

In this study, multigrain soy-enriched noodles were successfully prepared by incorporating brown-top millet and soy flour into wheat flour. The incorporation of these ingredients enhanced the nutritive value of the noodles, particularly by increasing fiber, fat, and ash content compared to the control sample. It was observed that as the level of millet increased, cooking loss also increased and cooked weight decreased, mainly due to the weakening of the gluten structure. Despite these changes, the sensory evaluation results showed that noodles with 20% millet had the highest overall acceptability among all samples. From the findings, it can be concluded that multigrain soy-enriched noodles can be developed as a healthier food option without significantly affecting consumer acceptability. This product can be useful in improving dietary quality and may have good scope for future development and commercialization.

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