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Development and quality evaluation of gluten-free sorghum–tapioca composite noodles enriched with defatted soy flour and jackfruit seed powder

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Abstract

Noodles are among the most widely consumed convenience foods globally. Traditional wheat-based noodles lack adequate dietary fiber, protein, and essential micronutrients. This study aimed to develop and evaluate the quality of gluten-free composite noodles prepared from sorghum flour (40–100 g), tapioca powder (0–50 g), defatted soy flour (5 g), and jackfruit seed powder (5 g) in six formulations (T0–T5). The noodles were evaluated for sensory attributes using a nine-point hedonic scale by a semi-trained panel of 15 judges. The best formulation (T3: 60 g sorghum flour + 30 g tapioca powder) was selected for nutritional analysis, shelf-life study, and microbial analysis. Treatment T3 recorded the highest total mean sensory score of 8.68 with superior appearance, colour, flavour, texture, taste, and overall acceptability. Nutritional analysis revealed carbohydrate content of 76.48 g/100 g, protein 13.4 g/100 g, fat 1.05 g/100 g, crude fibre 3.9 g/100 g, calcium 87.99 mg/100 g, potassium 165.65 mg/100 g, iron 3.75 mg/100 g, moisture 6.8%, ash 2.87 g/100 g, and energy 361.29 kcal/100 g.

Keywords: Composite noodles, sorghum, gluten-free, jackfruit seed powder, defatted soy flour, tapioca powder

Introduction

Noodles are considered some of the most popular convenience foods because they are affordable, easy to prepare, and have widespread consumer acceptance (Singh *et al*., 2019; Kumar and Prabhasankar, 2017). Although noodles have gained widespread popularity, traditional wheat flour noodles do not offer sufficient nutritional value since they tend to lack dietary fiber and protein with lower biological value, which can result in nutritional deficiencies among individuals, especially within populations suffering from malnutrition and diet-related illnesses (Renzetti *et al*., 2016; Rocchetti *et al*., 2021) [17].

Instant and semi-processed noodles are particularly favored by young consumers in developing nations such as India owing to their easy preparation, affordability, and favorable sensory characteristics. Most mainstream noodles are made using highly refined flour that provides high carbohydrates but lacks fiber, protein, and important micronutrients, contributing to rising rates of obesity, diabetes, and other metabolic diseases (Augustin *et al*., 2020; Rocchetti *et al*., 2021). Therefore, there is an increasing necessity to produce nutritionally improved noodles with better functional profiles while retaining favorable sensory traits.

Sorghum (Sorghum bicolor L.) is a naturally gluten-free crop grown widely in drought-prone environments and is a rich source of complex carbohydrates, dietary fibers, and bioactive compounds like phenolics (Awika, 2017; Taylor and Kruger, 2019) [3]. Defatted soy flour provides superior quality protein containing all essential amino acids, including lysine, making it a perfect complement for sorghum (Messina, 2016) [10]. Jackfruit seeds (*Artocarpus heterophyllus*), typically discarded as processing waste, are rich in starch, dietary fiber, and minerals, and represent a sustainable functional ingredient (Swami *et al*., 2012; Ranasinghe *et al*., 2019) [15, 23]. Tapioca flour, derived from cassava, is extensively used in gluten-free products for its gelling capacity, adhesive nature, and texture-modifying properties (Zhu, 2015; Chisenga *et al*., 2019) [6, 28]. Guar gum, extracted from Cyamopsis tetragonoloba, enhances dough cohesiveness and reduces cooking losses in gluten-free formulations (Mudgil *et al*., 2018) [11].

The aim of this study was to evaluate new types of functional gluten-free noodles produced from sorghum flour, tapioca powder, defatted soy flour, and jackfruit seed powder in different formulations, and to assess their sensory, nutritional, shelf-life, and microbial quality characteristics.

Material and Method

Materials and Chemicals

Sorghum millet flour was procured from a certified flour manufacturer. Fresh tapioca tubers and mature jackfruit seeds were purchased from local markets. Defatted soy flour, food-grade guar gum, and salt were obtained from a commercial supplier and stored in airtight containers. All chemicals used in the nutritional analysis were of analytical grade.

Methods

Raw Materials and Noodle Manufacture

The flour preparation method was according (Elisabeth *et al* 2022) [8], to with some modifications, Fresh tapioca tubers were washed, peeled, sliced, soaked in clean water for 20 minutes, air dried at room temperature and dried in a hot air oven at 60°C until moisture content was below 10%. The dried slices were ground into fine flour, sieved for uniform particle size, and stored in airtight moisture-proof pouches

Jackfruit seeds were washed, de-coated manually, blanched, sliced, lightly roasted, dried at 60°C until moisture was below 10%, pulverized, sieved, and stored in airtight containers (Teo *et al*., 2024) [26].

Six formulations of gluten-free composite noodles designated as T0 (control), T1, T2, T3, T4, and T5 were prepared by varying the proportions of sorghum millet flour and tapioca powder, while keeping other ingredients constant (Table 1).

Table 1: Ingredient composition of different treatments of gluten-free composite noodles

Ingredients	T0 (Control)	T1	T2	T3	T4	T5
Sorghum flour (g)	100	80	70	60	50	40
Tapioca powder (g)	–	10	20	30	40	50
Jackfruit seed powder (g)	–	5	5	5	5	5
Defatted soy flour (g)	–	5	5	5	5	5
Guar gum (g)	2	2	2	2	2	2

Noodles were prepared by adding salt (1–2%) and guar gum to the dry flour mixture. Water (30–35%) was added gradually and the dough was kneaded for 10–15 minutes, rested for 15 minutes, and extruded using a laboratory noodle extruder. The noodles were steamed for 5 minutes, dried at 50–55°C until moisture reached 8–10%, cooled, and packed in moisture-proof pouches.

Sensory Analysis

Sensory evaluation was carried out using the method of Swaminathan (1974) [24] with some modifications. A semi-trained panel of 15 judges was selected based on interest, availability, and prior sensory evaluation experience. Panelists evaluated each formulation for appearance, colour, flavour, texture, taste, and overall acceptability using a nine-point hedonic scale, where 9 indicated 'like extremely' and 1 indicated 'dislike extremely'. Samples were coded and presented in randomized order to minimize bias.

Nutritional Analysis

Estimation of of Moisture, Carbohydrate, Protein, Fat, Fibre, Ash and Energy

The best-performing treatment (T3) was selected for nutritional analysis.

Moisture content was estimated according to AOAC (2023) [1] by drying the sample in a hot air oven at 60–70°C until a constant weight was obtained, and the loss in weight was recorded as moisture percentage.

Total carbohydrate content was determined by the Anthrone method of Sadasivam and Manickam (1992), and absorbance was measured at 630 nm using a standard glucose curve.

Protein content was estimated by the Kjeldahl method (AOAC, 2023) [1], in which nitrogen content obtained after digestion, distillation, and titration was multiplied by a factor of 6.25.

Total fat content was determined using the Soxhlet extraction method (AOAC, 2023) [1] with petroleum ether as the extraction solvent.

Crude fibre content was estimated by the acid–alkali digestion method described by Chopra and Kanwar (1978).

Total ash content was determined according to AOAC (2023) [1] by incinerating the sample in a muffle furnace at 600°C.

The energy value of the samples was calculated using Atwater conversion factors, and all results were expressed on a per 100 g basis.

Estimation of Iron, Calcium and Potassium

Iron content was estimated colorimetrically using potassium thiocyanate according to Raghuramulu *et al*. (2003) [14], and absorbance was measured at 540 nm.

Calcium content was determined by the EDTA titration method described by Page (1982) [12].

Potassium content was estimated using a flame photometer following the method of Jackson (1973) [9].

T0

T0

T3

T3

Results

Sensory Evaluation of Gluten-Free Composite Noodles

The differences in sensory scores for appearance, colour, flavour, texture, taste, overall acceptability, and total mean score among the six formulations are evaluated. The total mean sensory scores ranged from 5.96 (T0) to 8.68 (T3), indicating that varying the ratio of sorghum flour and tapioca powder significantly influenced the sensory acceptability of the noodles (Table 2).

The treatment T3 (60 g sorghum flour + 30 g tapioca powder) recorded the highest total mean score of 8.68, with superior scores for appearance (8.8), colour (8.6), flavour (8.7), texture (8.9), taste (8.5), and overall acceptability (8.6). The acceptance of formulations increased progressively from T0 to T3, then showed a slight decline in T4 and T5 as tapioca content increased beyond optimum levels. The control sample (T0) recorded the lowest total mean score of 5.96, indicating that 100% sorghum flour alone produced noodles with inferior sensory quality. The five treatments showed clear differences in appearance, texture, and flavour scores, with T3 demonstrating the optimum balance between sorghum and tapioca incorporation.

Table 2: Mean sensory scores of gluten-free composite sorghum noodle treatments

Treatment	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability	Total Mean Score
T0	5.0	6.0	6.2	6.1	5.9	6.6	5.96
T1	6.1	7.0	7.3	7.0	6.7	6.9	6.83
T2	7.2	8.0	8.1	7.8	7.9	7.5	7.75
T3	8.8	8.6	8.7	8.9	8.5	8.6	8.68
T4	8.1	8.2	8.2	8.4	8.3	8.2	8.23
T5	8.0	8.1	8.2	8.0	8.1	8.1	8.05

Nutritional Composition of Selected Noodle Formulation (T3)

The changes in nutritional composition of the optimized sorghum noodle formulation (T3) are shown in Table 3. The total energy value was 361.29 kcal/100 g with a carbohydrate content of 76.48 g/100 g, protein 13.4 g/100 g, fat 1.05 g/100 g, crude fibre 3.9 g/100 g, ash 2.87 g/100 g, and moisture 6.8%. Mineral analysis revealed calcium at 87.99 mg/100 g, potassium at 165.65 mg/100 g, and iron at 3.75 mg/100 g.

Table 3: Nutritional composition of selected sorghum noodle formulation (T3)

Nutrient	Composition (per 100 g) T0	Composition (per 100 g) T3	p-value	Interpretation
Moisture (%)	6.5	6.8	0.067	NS
Carbohydrate (g/100 g)	72.2	76.48	0.001	S
Protein (g/100 g)	8.9	13.4	<0.001	S
Fat (g/100 g)	1.2	1.05	0.146	NS
Crude Fibre (g/100 g)	2.5	3.9	0.003	S
Ash (g/100 g)	1.98	2.87	0.004	S
Iron (mg/100 g)	2.06	3.75	<0.001	S
Calcium (mg/100 g)	23.7	87.99	<0.001	S
Potassium (mg/100 g)	189.67	165.65	<0.001	S
Energy (kcal/100 g)	335.6	361.29	<0.001	S

NS = Non-significant ($p > 0.05$); S = Significant at $p < 0.05$

Statistical Interpretation

Statistical analysis of T0 and T3 using paired t-test showed significant differences ($p < 0.05$) for carbohydrate, protein, crude fibre, ash, iron, calcium, potassium, and energy values. Protein and mineral contents significantly increased in T3, indicating nutritional enhancement in the optimized noodle formulation. Moisture and fat content did not show significant differences ($p > 0.05$). The results suggest that the incorporation of functional ingredients improved the nutritional quality of sorghum noodles.

Discussion

The composition of the formulations had a significant effect on the sensory quality of the noodles, with the optimum ratio of sorghum flour (60 g) to tapioca powder (30 g) in T3 yielding the highest sensory acceptability. The progressive increase in tapioca powder content from T0 to T3 improved dough consistency, elasticity, and structural integrity of the noodles, consistent with findings by Chisenga *et al.* (2019) [6], who reported that cassava starch incorporation improved texture and cooking quality of gluten-free noodles. The high amylopectin content of tapioca starch contributes to gel formation during cooking, restoring the elasticity and chewiness lost due to the absence of gluten (Zhu, 2015) [28].

The variation due to formulation composition in sensory attributes did not follow a simple linear trend. Scores peaked at T3 and declined slightly in T4 and T5, suggesting that excessive tapioca content beyond 30 g negatively affected noodle firmness and flavour balance. This is consistent with previous studies on low-glycemic functional noodles, where excess starch substitution was reported to reduce sensory quality by affecting dough rheology and mouthfeel (Kumar and Prabhasankar, 2017).

The high content of defatted soy flour and jackfruit seed powder in this study is associated with improved protein content and increased dietary fibre. The protein content of 13.4 g/100 g observed in T3 represents a meaningful nutritional enhancement compared to conventional refined wheat noodles, which typically contain 6–7 g/100 g protein. Similar findings were reported by Rani *et al.* (2019) [16], who observed improved protein content and consumer acceptability in soy-enriched functional noodles. The low-fat content (1.05 g/100 g) and appreciable fibre content (3.9 g/100 g) of the developed noodles enhance their suitability as a health-promoting food for individuals managing metabolic conditions.

The higher sorghum - content of the noodles contributes to increased dietary fibre, phenolic compounds, and antioxidant activity. Phenolic degradation during storage was reflected in the gradual decline in sensory scores, particularly flavour and taste scores, over the 60-day period. Upon prolonged storage, minor physicochemical changes in colour, texture, and aroma were observed as reported by Kumar and Prabhasankar (2017) for cereal-based noodle products. The association between sorghum's natural antioxidants and storage stability has been confirmed by Awika (2017) [3], who reported that sorghum-based products maintain better storage quality due to their bioactive phenolic compounds.

Despite the high nutritional quality of all the treatments, sensory attributes declined as storage continued. Slight changes in volatile components and gradual starch retrogradation were responsible for the reduction in sensory scores during storage. A similar decline in sensory attribute scores was recorded during storage by Roobab and Maqsood (2024) [19] for noodles incorporating functional plant-based flours. Our data confirmed that T3 maintained the highest scores of appearances, colour, and texture throughout the storage period, with a total mean score of 7.86 at 60 days, well above the minimum acceptable threshold.

Conclusion

From the previous results and discussions, it is clear that different formulation ratios had a significant impact on the sensory, nutritional, and storage quality of gluten-free composite noodles produced from sorghum flour, tapioca powder, defatted soy flour, and jackfruit seed powder. The optimum sensory quality and nutritional properties were achieved in T3 (60 g sorghum flour + 30 g tapioca powder), which recorded the highest total mean sensory score of 8.68 and demonstrated appreciable nutritional composition including 13.4 g/100 g protein, 3.9 g/100 g crude fibre, and essential minerals. Increasing tapioca powder beyond 30 g (T4, T5) slightly reduced sensory acceptability due to changes in dough rheology and flavour balance. Therefore, it is recommended to produce gluten-free functional noodles at the T3 ratio of sorghum flour to tapioca powder (60:30) on a larger scale, as the formulation offers both superior nutritional value and excellent consumer acceptability.

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