



Formulation of Noodles from Malted Millet Composite Flour: A Study on Finger and Barnyard Millet Integration

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ABSTRACT

Background: Noodles, developed from refined wheat flour can pose several health disadvantages. They are often high in sodium, refined carbohydrates and unhealthy fats, while being low in essential nutrients like fiber and protein. This can lead to issues like digestive problems, weight gain and increased risk of vulnerable diseases. The potential of composite malt millet flour as healthy ingredient in noodle development is assessed in this investigation to overcome such health issues.

Methods: Finger and barnyard millet, being minor millets are less utilized as blend of flour for food product development. These millets were malted to improve their digestibility and bioavailability of nutrients, then blended in varying ratios with wheat flour to develop noodles from composite formulations.

Result: The noodle developed from 20% malted millet composite flour was found to be overall acceptable. The incorporation of composite malt flour not only enhanced macronutrients but also shown increase in mineral content (Calcium and iron). This research highlights the feasibility of using malted millet composites in value-added food products and offers a promising approach to promoting millet consumption in modern diets.

Key words: Barnyard millet, Finger millet, Formulation, Malted millet composite flour, Noodles.

INTRODUCTION

Millets, belonging to the Poaceae family, often referred to as "Miracle Grains" or "Nutri-Cereals," are among the ancient, cultivated crops, rank as the sixth highest-yielding grains globally. Millets played a significant role in traditional diets, but their cultivation has declined due to changes in agricultural practices and labour-intensive farming methods (Michaelraj *et al.*, 2013). Finger millet [*Eleusine coracana* (L.)] abundant in mineral like calcium and iron necessary to normal functioning of human body. It has triple calcium comparative to milk and 10 times more than brown rice, wheat, or maize. It is good source of iron, calcium, methionine and other amino acids, slowly digested starch and phytochemical hence, referred as miracle grains. (Kumar *et al.*, 2016). Finger millet contains 162 to 487 mg/100 g calcium, iron 3.61 mg/100 g to 5.42 mg/100 g. The total carbohydrate content is 72 to 79.5%, protein 5.6 to 12.70%, ash 1.7 to 4.13% making it nutritionally high value minor millet. Use of finger millet in daily diet is helpful for the mineral deficiency and also help to avoid disorder of bones and teeth. Barnyard millet (*Echinochloa sapp.*) *Echinochloa Frumentacea* and *Echinochloa Utilis* are two major species of it. It is underutilized grain, has good nutritional profile. It is gluten free and has less glycaemic index (Bangar *et al.*, 2024). Barnyard millet has rich source of micronutrient which are 6.91 mg/100 g iron and 23.16 mg/100 g calcium (Verma *et al.*, 2015). Barnyard millet is helpful for lowering cholesterol and blood sugar level (Rao *et al.*, 2017). The different millet-based food products are made like porridge, infant food, bread, snacks, millet wine and millet nutrition powder (Bhatt *et al.*, 2023). Good iron content of millet valuable for the pregnant and

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lactating women and its high amino acid profile support human health. Barnyard millet has excellent nutritional profile making it superfood to improve consumer health and food security.

Malting is one of the most beneficial processes to upgrade nutritional quality by germination (Baranwal, 2017). During the process the different enzymes get produced. The protease enzyme formed during the germination it degrade the grain proteins and increases the overall quality of the grain by degradation the antinutritional components. It is the biotechnological method useful for predigesting of protein and carbohydrates by increasing in sufficient enzyme activity (Banusha *et al.*, 2013). Malting reduces phytate and tannins (Mbithi-Mwikya *et al.*, 2000).

Noodles, a recognized meal, showcasing increased global demand. This demand is due to taste, nutrition, convenience and affordability to everyone (Gulia *et al.*, 2014). A rapidly expanding segment of the noodle industry

is instant noodles, which people worldwide enjoy. Developing healthier noodles is a need of the hour.

The exploration of composite malt millet flour in noodle development aims to enhance the functional and nutritional parameters of traditional noodles by incorporating malted finger and barnyard millet. By integrating millet into noodle production, this study aligns with global trends in sustainable food systems, functional food innovation and gluten-free product development, offering a nutritious and consumer-acceptable alternative.

MATERIALS AND METHODS

Raw materials

Whole wheat flour, finger millet, barnyard millet, baking powder, Glycerol monostearate, guar gum, oil and salt, were procured from the local market in Pune. The equipment weighing balance, an extruder, a grinder, a hot air oven, a muffle furnace, a centrifuge and other utensils were utilized from the laboratory of School of Food Technology, Pune. The research was exhibited during 2024-25 at Department of Patronage of Traditional and Specialty Foods, School of Food Technology, Pune.

Methodology

Processing technology for malting of millets

The malting of millet was carried by using the procedure outlined by Jain *et al.* (2016). The first step was cleaning of millets followed by washing the millets under tap water. Then grains were soaked in water at 25-30°C for 12 hrs, were subsequently drained and allowed to germinate under a wet cloth for 48 hrs. Then dried in an oven at 50°C for 2-3 hrs and roasted at 73°C for 10 min. Grains were milled to get final flour by using impact mill. The malted millet composite flour was prepared by blending equal proportions of malted finger and barnyard millet flour.

Processing technology for noodles developed from malted millet composite flour

Noodles were developed by the procedure outlined by Jeong *et al.* (2017) with slight modifications. The malted millet composite flour developed with equal proportion (1:1) of finger and barnyard millet. The whole wheat flour is replaced partially by malted millet composite flour as proportions by 10,15,20,25 and 30%. Flours were sieved to ensure uniformity. Baking powder, guar gum, GMS (Glycerol Monostearate), oil and salt were added to the extruder, followed by the addition of water. The extruder was operated in automatic mode, cutting the noodles to a specific length. The noodles were placed in an oven at 60°C for 4-5 hrs for drying. After drying noodles were cooled at room temperature and then packaged in low-density polyethylene pouches.

Proximate analysis

Proximate parameters such as moisture, fat, protein, ash, carbohydrate and micronutrients were determined (AOAC, 2019).

Bulk density

The bulk density was determined using the method laid down by Ishara *et al.* (2018).

Cooking properties of noodles

The qualities of noodles, such as cooking loss, optimum cooking time and water absorption, are calculated using standard equations.

Water absorption capacity

The water absorption is determined by the ratio of the weights of cooked noodles to the uncooked noodles (AACC, 2005).

Optimum cooking time

The OCT was determined using the method described by Kamble *et al.* (2018).

Cooking loss

Cooking loss was measured by assessing the amount of solid substance that was lost to the cooking water.

Sensory evaluation

The noodle samples were evaluated for various sensory attributes: color, appearance, texture, flavor, mouthfeel, taste and overall acceptability, by a semi-trained panel using a 9-point hedonic scale (Lande *et al.*, 2017).

Texture profile analysis

Texture of noodles were determined by Texture analyser from laboratory of Agarkar Research Institute, Pune. The texture of cooked and uncooked noodles was determined using texture analyser (ARI/APEQ/1008/TA-01). The ring prob used was A/SFR. The parameters like springiness, gumminess, cohesiveness, hardness, adhesiveness and chewiness were measured.

Colour determination

Colour of noodles were determined by using Minolta 410 chromameter from laboratory of Agarkar Research Institute, Pune. It is determined in terms of a^* (redness/greenness), L^* (whiteness/brightness) and b^* (yellowness / blueness).

RESULTS AND DISCUSSION

Effect of malting on finger and barnyard millet proximate parameters

Non-malted and malted flours of finger and barnyard millet were subjected to proximate analysis with the goal to assess the impact of the malting process on their nutritional composition. The result obtained are presented graphically in Fig 1 and 2.

The moisture content in malted finger millet flour (12.63%) was slightly lower than that in raw finger millet flour (13.00%), indicating a reduction due to drying process. A similar trend was observed in barnyard millet, where the moisture content decreased from 13.01% in the raw flour to 11.23% in the malted form. This drop in moisture content

can be attributed to the drying process involved in malting, which lowers the water-holding capacity of the grain. These findings are similar to results of Sahoo *et al.* (2024).

Raw finger millet flour exhibited a higher fat content (2.92%) compared to malted finger millet flour (2.71%). In contrast, the fat content in raw barnyard millet flour was 2.85%, whereas it increased to 2.78% in the malted form. Previous studies by Ali *et al.* (2003) recorded similar value. Protein content in raw and malted finger millet flour was 6.77% and 6.92% respectively. The protein content increased in malted flour owing to germination process. This increase might be attributed to degradation of other constituents, which may be due to the formation of enzymes (Murungweni *et al.*, 2024). The similar increase in protein content was recorded by Owheruo *et al.* (2019) in pearl millet.

Finger millet shown a higher total ash content (2.36%) compared to barnyard millet (2.28%) indicated a greater mineral presence. The reported ash content in finger millet was in the range from 1.7% to 4.13% (Rao *et al.*, 1973). The reduction in ash content was recorded in both millets (1.07% in finger millet and 1.09% in barnyard millet) on malting. The similar result indicated by Srilekha *et al.* (2019).

Effect of malting on selective minerals (Calcium and Iron) in finger and barnyard millet

The malting process had a significant impact on the mineral composition, particularly calcium and iron, of both finger millet and barnyard millet flours. The calcium and iron were assessed and values are depicted graphically in Fig 3 and 4 respectively.

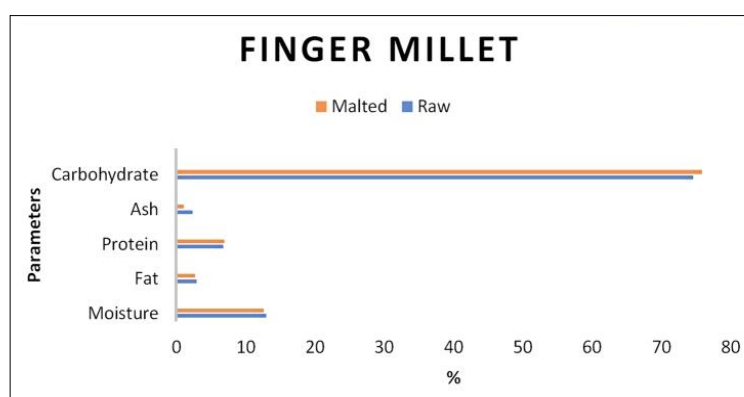


Fig 1: Effect of malting on finger millet nutritional parameters.

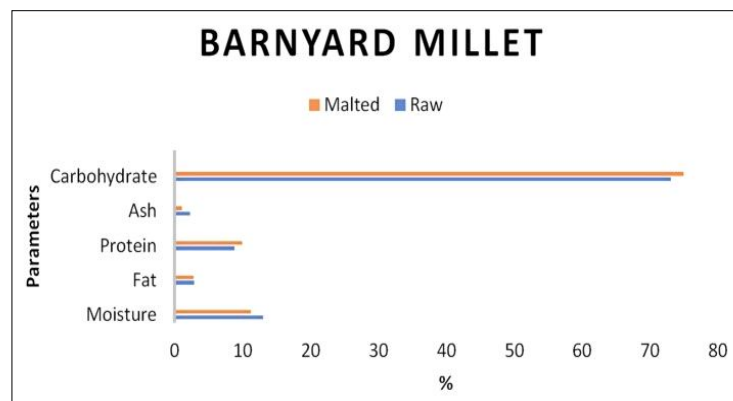


Fig 2: Effect of malting on barnyard millet nutritional parameters.

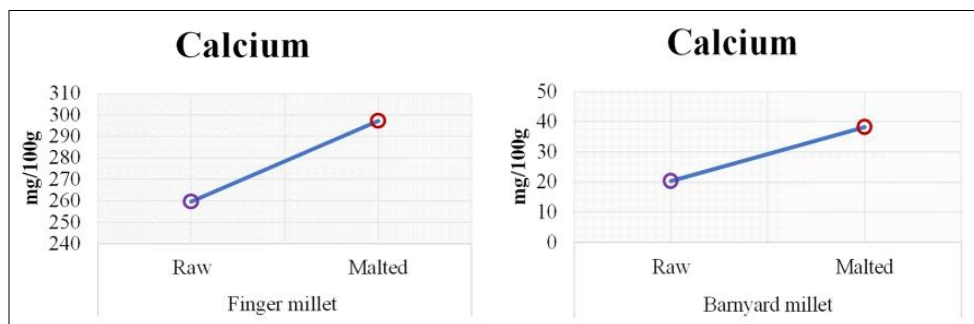


Fig 3: Calcium content of finger and barnyard millet on malting.

In finger millet, calcium content increased from 259.62 mg/100 g to 297.26 mg/100 g in the malted flour indicating an enhancement of approximately 14.5%. Likewise, barnyard millet showed a substantial rise in calcium content from 20.20 mg/100 g to 38.11 mg/100 g after malting recording 88.7% rise. This increase attributed to the degradation of anti-nutritional factors such as phytates and oxalates during germination, which improves mineral bioavailability by releasing bound minerals Meherunnahar *et al.* (2023).

Iron content also shown a moderate increase, with finger millet rising from 4.01 mg/100 g to 4.62 mg/100 g and barnyard millet from 11.07 mg/100 g to 11.48 mg/100 g. Davana *et al.*, (2021) reported the increase in iron content on malting in sorghum.

Overall, malting found to be an effective pre-treatment technique used as intervention that enhances the nutritional quality of millet flours by improving the concentration and bioavailability of essential minerals, making them more suitable for functional food formulations such as health-enhancing noodles (Rao *et al.*, 2017).

Effect of malting on functional properties of finger and barnyard millet flour

Functional properties play a critical role in determining the processing behaviour, structural integrity and textural quality of flour-based food products. The data presented in Table 1 highlights on the effect of malting on these properties in both millet flours.

Water absorption capacity increased from 120.9% to 129.9% in finger millet and 125.9% to 132.9% in barnyard millet. This might be due to partial hydrolysis of starch and proteins, exposing hydrophilic groups and enhancing water-holding capacity, which is beneficial for noodle making.

Malting increased the water absorption capacity of millet flours. Similar results were recorded in refined wheat flour by (Vijayakumar, 2010). The increase in water absorption was recorded in pigeon pea flour on germination by (Onimawo and Asugo, 2004).

Oil absorption capacity (OAC) also exhibited increase in finger millet from 130.9% to 136.1% and barnyard millet from 123.2% to 129.0%, due to protein structural changes that enhance oil entrapment, improving mouthfeel and flavour in products. A similar trend of enhanced oil absorption capacity was recorded by (Vijayakumar, 2010). Bulk density slightly increased from 0.5 to 0.6 g/ml and 0.4 to 0.6 g/ml in finger and barnyard millet respectively, possibly due to reduced porosity and better packing from cell wall breakdown.

Effect of incorporation of malted millet composite flour on sensorial profile of noodles

The sensory evaluation of malted millet composite flour incorporated noodles using the different variations was done in comparison to the control sample. The sensory parameters were evaluated by semi trained panel at School of food technology by using 9point hedonic scale. The scores obtained are presented as graphical representation in Fig 5.

The colour scores recorded by samples T0, T1, T2, T3, T4 and T5 were 8.3, 7.4, 7.4, 7.7, 6.7 and 6.4, respectively. The colour scores recorded increase till T3 samples and further decrease with an increase in malted millet composite flour proportion. T3 had a score near to the control sample. The colour of noodles might have decreased after the T3 sample due to the dark colour of millet flour. The highest flavour score among the treated sample was recorded by T3 as 7.8. Further, as a proportion

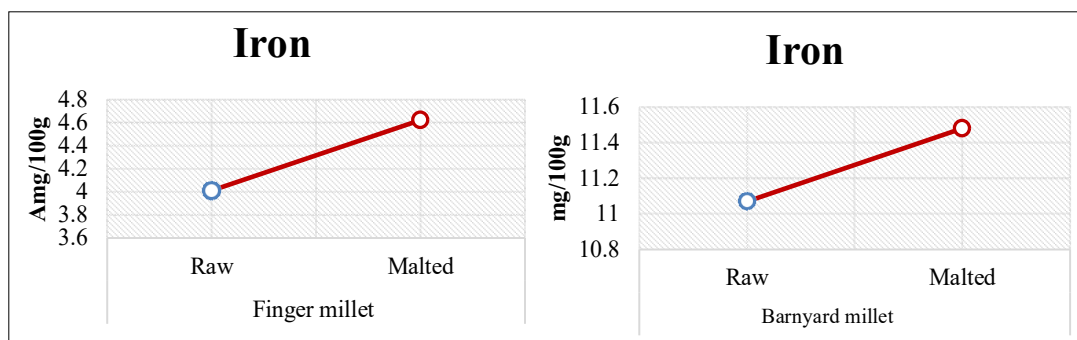


Fig 4: Iron content of finger and barnyard millet on malting.

Table 1: Functional parameters of raw and malted flour.

Parameters	Finger millet flour	Barnyardmillet flour	Finger millet flour	Barnyard millet flour
	Raw	Malted	Raw	Malted
Water absorption capacity (%)	120.9±0.06	129.9±0.06	125.9±0.07	132.9±0.07
Oil absorption capacity (%)	130.9±0.13	136.1±0.04	123.2±0.48	129.00±0.05
Bulk density (g/ml)	0.5±0.00	0.6±0.05	0.4±0.01	0.6±0.01

Values are expressed as mean±S.D.

of composite malt millet flour risen, the score decreased. The addition of finger and barnyard millet malt flour affected the taste of the noodles. T3 sample recorded the best scores for taste (7.9) against the rest of the samples. A similar result impact of malt flour on food product was recorded by Jing *et al.* (2022). Texture, as a promising sensory attribute of noodle, was evaluated by the panellist, which indicated an increasing trend from T1 (7.2) to T3 (7.8) in scores, followed by decrease from T4 (6.9) to T5 (6.5). A similar trend was also recorded for mouthfeel.

This might be due to higher fiber content and altered texture from increased malted flour levels. Despite this, all treatments remained within the acceptable sensory range. The highest (7.7) overall acceptability score was shown by T3 sample, indicating 20 % level as the best incorporation level of composite malt millet flour for noodle development which was formulated with malted 10% finger and barnyard millet. These results suggest that moderate incorporation of malted millets enhances nutritional value without significantly compromising sensory quality. Karthiayani *et al.* (2021) prepared noodles with banana pseudo stem powder at different levels was found to be sensorially acceptable.

Impact of malted millet composite flour on the proximate composition of noodles

The proximate parameters of noodles developed by fortification of malted millet composite flour were evaluated

to understand the nutritional quality. The results recorded are presented in Table 2.

The moisture content of noodles decreased in noodles developed with composite malt flour from 11.93% in the control to a range of 6.8-7.8% in treatments (T1-T5). This reduction was attributed to the lower moisture retention capacity of millet flour. The similar results were shown by Akonor *et al.* (2017) for noodles. Jadhav (2025) reported 8.66% moisture content in noodles developed from multi-millet like Proso, Kodo and Barnyard millet.

The increase in fat content was recorded in noodles with rising replacement of wheat flour with malted millet composite flour from 2.06 to 4.02%. During malting, grains undergo steeping, germination and drying. This results in enhanced lipid concentration as some carbohydrates are broken down into simpler sugars for enzymatic activity, while lipids remain relatively unchanged, increasing their proportion in the final flour. Similar values were recorded by Mepba *et al.* (2021).

The protein percentage was observed to be risen from 10.90% to 11.81% (T1 to T5) as with the increase in malted millet composite flour proportion. Malting enhances protein digestibility and amino acid availability through proteolytic activity. The similar rise is recorded by Shobana and Malleshi (2007). Crude fiber, one of the significant component in aid of digestion, was increased from 1.81% (T0) to 3.90% (T5), as millets are rich in dietary fiber and malting enhances fiber availability by breaking down complex polysaccharides.

Carbohydrate content increased in experimental samples (76.03-73.53%) compared to control (69.16%) due to the high starch content in millets. A slight decrease from T1 to T5 might be due to increased levels of both minor millet flour. Ash content increased from 2.66% (T0) to 3.02% (T5), reflecting higher mineral content and improved bioavailability due to reduced anti-nutrients during malting. The results were in agreement with Zula *et al.* (2021). Overall, malted millet composite flour fortification improved the nutritional profile of noodles, making them an option to incorporate in functional food for potential health benefits.

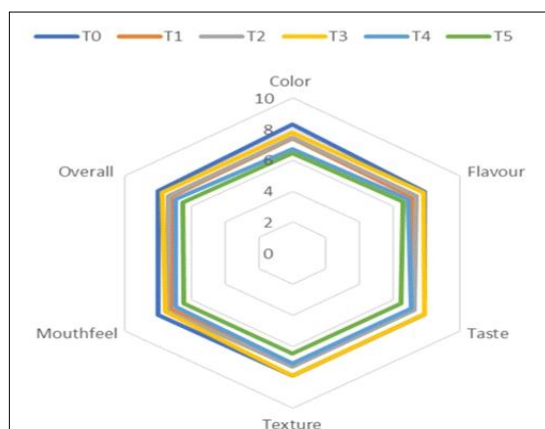


Fig 5: Sensory profile of malted millet composite flour noodles.

Table 2: Effect of malted millet composite flour on proximate composition of noodles.

Parameter (%)	Sample					
	T0	T1	T2	T3	T4	T5
Moisture	11.92	7.60	7.22	6.80	6.74	6.73
Fat	2.06	2.86	3.21	3.62	3.88	4.02
Protein	13.04	10.90	10.96	11.61	11.70	11.81
Crude fiber	1.81	1.91	2.73	3.66	3.80	3.90
Ash	2.66	2.68	2.72	2.74	2.89	3.02
Carbohydrate	69.16	76.03	76.24	74.13	73.71	73.53
SE	1.32	0.53	1.77	11.27	0.53	0.42
CD@5%	3.39	1.37	4.56	28.97	1.37	1.09

Values are the average of three independent experiments.

Calcium and Iron content of noodles developed from malted millet composite flour

The effect of inclusion of composite millet malt flour on calcium and iron content of noodles was evaluated by quantifying it and results illustrated in graphical form in Fig 6.

The calcium content in noodles increased significantly from 40.83 mg/100 g in the control (T0) to 80.75 mg/100 g in T5, mainly due to the high and improved bioavailability from malting. The similar increasing trend was reported by Devi *et al.*, 2014. Iron content rise from 3.82 mg/100 g in T0 to 4.34 mg/100 g in T5 due to the presence of barnyard millet and the enzymatic effects of malting, which increase iron bioavailability (Suma and Urooj, 2014).

Cooking properties of noodles developed from malted millet composite flour

Cooking properties are essential parameters determining the quality, texture and consumer acceptability of noodles. The results obtained are presented in Table 3.

The optimum cooking time decreased from 7.5 min (T0) to 4.5 min (T5) as malted millet composite flour proportion increased from 10% to 30% due to the enzymatic breakdown of starch during malting, which enhanced starch gelatinization and reduced cooking duration. Similar results were reported by Suma and Urooj 2014. The decreasing trend was recorded in water absorption from T0 (198%) to T5 (148%). In control sample highest value was due to better starch availability and gluten presence. The decrease in values was recorded in experimental sample due to increased replacement of flour with malted millet composite flour. A similar decreasing trend was recorded by Elkhailifa *et al.* (2005).

Cooking weight was decreased from 15.4 g (T0) to 11.2 g (T5), attributed to increased fiber and reduced starch content in millet flours, which limit water retention during cooking. Similar values were recorded by Rao *et al.* (2017). Cooking loss increased from 5.80% (T0) to 7.80% (T5) due to weaker structure without gluten and increased solubility of degraded starch and proteins in the malted samples; similar results were recorded by Tanwar *et al.* (2023).

Colour profile of noodles developed from malted millet composite flour

The effect of incorporation of malted millet composite flour on colour profile of standardized is important attribute to decide consumer acceptance. The control (T0) sample and standardized sample (T3) of the noodle were subjected to colour assessment. The graphical representation of colour is displayed in Fig 7. The colour attributes measured and expressed as positive and negative colour space values using a^* (redness/greenness), L^* (whiteness/brightness) and b^* (yellowness / blueness) (Ramashia *et al.*, 2018). The control sample had L value of 52.95, indicating a lighter colour, while the T3 sample exhibited L value of 46.75 indicating slight darkness. This darkness in T3 was likely due to the phenolic compounds in millet flours. The control had a higher red hue ($a = 5.17$) and yellow hue ($b = 11.2$), while T3 shown slightly lower values ($a = 4.75$ and $b = 8.25$), suggesting reduced redness and yellowness. The colour changes in T3 were linked to the composition of millet, which tends to produce a more neutral colour compared to wheat. A similar trend was reported by Gani *et al.* (2012). These findings indicate that millet-based noodles are slightly darker with less pronounced red and

Table 3: Cooking properties of noodles.

Sample	Optimum cooking time (min)	Water absorption capacity (%)	Cooking weight (g)	Cooking loss (%)
T0	7.5	198	15.4	5.80
T1	5.4	190	14.7	6.35
T2	5	183	13.3	6.78
T3	5	169	12.6	6.89
T4	4.7	160	11.4	7.01
T5	4.5	148	11.2	7.80
SE	0.45	27.78	0.73	0.27
CD@5%	1.15	71.45	1.87	0.70

*Values are the average of three independent experiment.

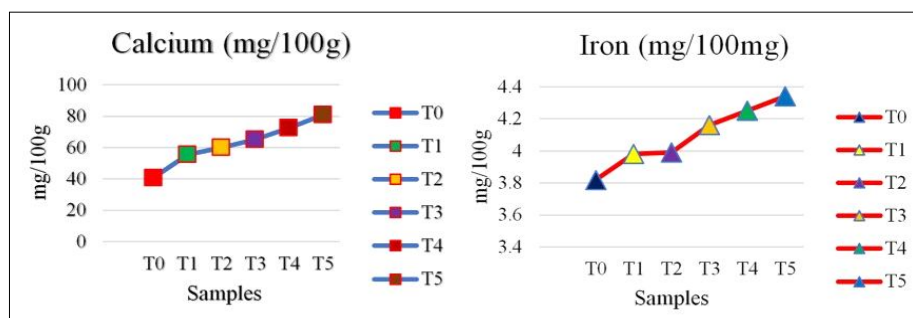


Fig 6: Calcium and Iron content of noodles.

yellow hues but comparable to wheat noodles, exhibiting their visual appeal as an acceptable attribute.

Texture profile analysis (TPA) of standardized noodles developed from malted millet composite flour

Texture profile of a standardized noodle sample developed with malted millet composite flour (20%) and a control sample was assessed. The parameters like springiness,

gumminess, cohesiveness, hardness, adhesiveness and chewiness were measured. The results are depicted in Fig 8 and 9 for control and standardized noodle, respectively.

The texture profile analysis (TPA) revealed the standardized noodle sample's texture is comparable to control. Overall, the results indicate that incorporating malted finger and barnyard millet flours at the 20% level improved textural parameters such as firmness, elasticity

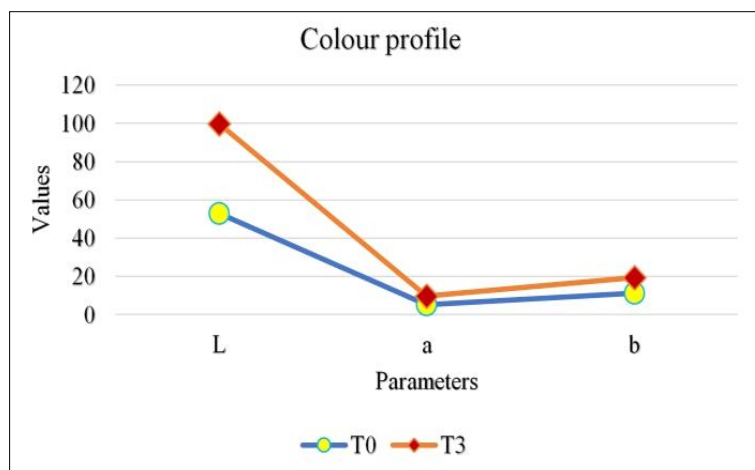


Fig 7: Impact of malted millet composite flour fortification on noodle.

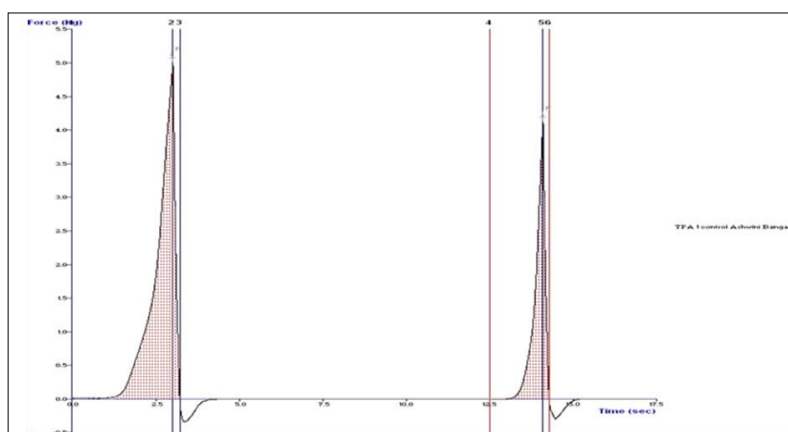


Fig 8: Texture profile of control noodles.

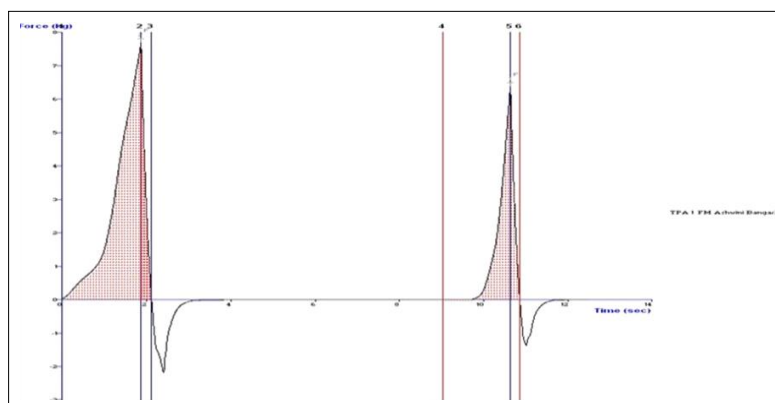


Fig 9: Texture Profile of standardized noodles.

and chewiness, without adversely affecting cohesiveness. These enhancements contribute to better mouthfeel and structural quality of the noodles, demonstrating the potential of malted millet flours in improving functional and sensory properties of noodle products. The similar results trend recorded by Sun *et al.* (2019).

CONCLUSION

The present study successfully demonstrated the potential of using composite malted millets-specifically finger millet and barnyard millet-in the formulation of noodles. Incorporation of malted millet flour improved the nutritional profile, especially in terms of dietary fiber, calcium and antioxidant content, while reducing anti-nutritional factors due to malting. The noodles developed exhibited acceptable sensory attributes, with slight changes in texture and color that were well-received by panelists. The results indicate that malted millet-based noodles can serve as a nutritious alternative to traditional wheat noodles, promoting the utilization of underutilized millets and supporting healthier dietary practices. Further research into optimization of formulation and consumer acceptability could enhance the commercial viability of such functional food products.

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Not Applicable.

Disclaimers

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Informed consent

Not applicable.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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