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Research Article

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Effect of sprouting on reduction of anti-nutritional factor in pearl millet and its potential application in food industry

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ABSTRACT

Pearl millet (*Pennisetum glaucum*) is a nutritionally rich, gluten-free grain with numerous health benefits, including high levels of essential amino acids, iron, zinc, and proteins. In addition, gluten-free foods made from pearl millet can help improve digestion and reduce inflammation for those sensitive to gluten. Despite its high nutritional potential, pearl millet remains underutilized in the food industry. This is partly due to the presence of anti-nutritional factors such as tannins and phytates, which lower nutrient digestibility and bioavailability. This study aimed to optimize sprouting conditions in three pearl millet genotypes *viz*., CO (Cu) 9, TNAU cumbu hybrid CO 9 and CO 10 to enhance nutrient availability and reduce these anti-nutritional factors. Results indicated that 12 hr soaking and 24 hr sprouting significantly reduced tannin and phytate levels while increasing nutrient bioavailability, particularly in TNAU cumbu hybrid CO 9 and CO 10. Sprouted flour of TNAU cumbu hybrid CO 9 and CO 10 recorded an increase in iron of 73.60 and 72.58 ppm and zinc of 46.56 and 46.34 ppm respectively. Besides sprouted flour had less than 1.00 Na/K ratio which might favour the regulation of blood pressure. These sprouted flour samples were then used to formulate gluten-free noodles, with different composite flours using corn flour and tapioca starch in different ratios, further texture and sensory evaluation was conducted and a 50:50 ratio of sprouted pearl millet flour and corn flour was found to be desirable. The research highlights pearl millet's potential as a valuable, gluten-free food source with broader applications in health-conscious and specialty food markets.

KEYWORDS: Pearl millet, Sprouted flour, Iron, Na/K, Noodles

INTRODUCTION

Pearl millet (*Pennisetum glaucum*), also known as Bajra, is recognized as one of the four most important cereals - alongside rice, maize, and sorghum. It is cultivated in tropical semi-arid regions, primarily in Africa and Asia (Vijayakumari *et al*., 2007). It has garnered increased attention in recent years, particularly following the global recognition of 2023 as the "Year of Millets". This surge in interest stems from its numerous nutritional benefits and versatility in food applications. It is nutritionally superior than other cereals due to its high level of zinc, calcium, iron, lipids and high- quality proteins (Dendy, 1995). When it comes to protein content, pearl millet has a greater percentage (around 11.6%) than other staple grains including rice, barley, maize, and sorghum. Essential amino acids including lysine, threonine, methionine, and cysteine are included in its protein composition (Slama *et al*., 2020). Pearl millet has emerged as a valuable source of gluten-free flour, catering to the dietary needs of individuals seeking alternative options for baby food and diabetic-friendly consumables. Pearl millet has been recommended for the treatment of celiac disease, constipation, and several non-communicable diseases. It is one of the primary components in many African meals and is consumed as steam-cooked products and porridges, which can be also be used to brewing beer and as a supplemental diet for babies and small children (Sade, 2009). In India, pearl millet is cultivated over 6.93 m ha area with an average production of 8.61 mt and productivity of 1243 kg ha^{-1} (Naorem *et al*., 2023). Inspite of its nutritional benefits, nutritional quality and digestibility of carbohydrates, proteins and minerals of pearl millet is reduced due to the presence of anti-nutritional factors which lead to poor digestion. The main anti-nutritional compounds present in pearl millet includes tannins, polyphenols and phytates. Tannins and polyphenols limit the utilization of pearl millet as food or feed (Duhan *et al.*, 2002), whereas phytate reduces the bio-availability of iron and zinc (Cámara & Amaro, 2003). Studies by Gabaza *et al.* (2018) and Slama *et al.* (2020) also suggested that presence of phytates, oxalates, and polyphenols in PM might affect the bioavailability of its iron. Hence to improve the nutritional value of grains various processing methods like soaking, sprouting and cooking are available (Devi *et al.*, 2015). Studies by Pushparaj and Urooj (2011), Devi *et al.* (2015) and Majid and Nanda (2017) highlighted the importance of sprouting in improving the nutritional quality and bioavailability. Despite the nutritional benefits of sprouted flour, its applicability in value added products like noodles are limited. In this study, optimal sprouting conditions for pearl millet was optimized to enhance its nutrient content. The sprouted pearl millet flour was then used to produce noodles in various formulations. These noodles were evaluated for their textural and sensory properties to determine the best composition, with the goal of developing a gluten free, nutritious and consumer-acceptable product suitable for the food industry. Hence, the present study focussed on evaluating the effect of nutritional and anti-nutritional properties with its potential for food industry.

MATERIAL AND METHODS

Pearl millet varieties *viz.*, CO (Cu) 9, TNAU Cumbu hybrid 9, CO 10 were obtained from Department of Millets, Tamil Nadu Agricultural University, Coimbatore. Grains of all the three varieties were grinded using pestle and mortar. About 20 g of grounded samples from each of the three varieties were subjected to two different treatments as given below to increase the nutrient availability (Table 1 & Figure 1).

The samples after treatment were assessed for its tannin level (mg/g), phytate (mg/g), inorganic phosphorous (mg/g) and iron content (mg/g) along with control using factorial completely randomized design. Two factors *viz.*, treatment (factor A) and varieties (factor B) with three levels *viz.*, control (A1), treatment 1 (A2) and treatment 2 (A3) and three genotypes (B1, B2, B3) were used in three replicates.

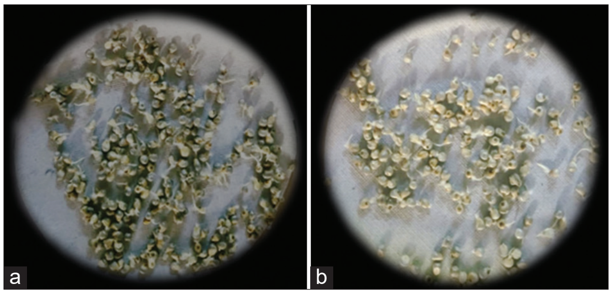

Figure 1: Sprouted Pearl millet grains. (a) Sprouted grains with 24 hrs soaking and 12 hrs sprouting and (b) Sprouted grains with 12 hrs soaking and 24 hrs sprouting

Tannin Estimation Using Folin-Deni's Method (Dykes & Rooney, 2006)

About 0.25 g of the sample was weighed and transferred in to a 50 mL conical flask. Then 10 mL of water was added to it, heated, and then boiled for 30 min. Afterward, centrifuged at 5000 rpm for 20 min then the supernatant was collected, after collection the volume was made up to 10 mL then 0.2 mL of the sample was transferred to a tube and the volume was made up to 7.5 mL. Following that, 0.5 mL Folin Denis reagent and 1mL sodium carbonate was added, and mixed well.

Phytate Estimation Using Davis & Reid method (Davies & Reid, 1979)

About 500 g of the sample was measured, and 10 mL of 0.5 M HNO_3 was added and centrifuged overnight. The solution was then extracted through Whatman no. 1 filter paper. From 0.2 mL of the extract, 200 μL were transferred into a 1.5 mL tube and then 200 μL of FAS was added, then the sample was left in a water bath for 20 min, then cooled to room temperature. The following steps were completed in 15 min. 1 mL isoamyl alcohol and 20 μL of ammonium thiocyanate were added, after which the color development began instantly. Then the sample was centrifuged for 10 min at 3000 rpm at 4 °C, and then 300 μL of the supernatant was collected and transferred into a microliter plate.

$$PAP = \frac{Y\,value \times Amount\,of\,acid\,taken\,for\,extraction \times 1000}{weight\,of\,sample\,taken(g)}\ \text{mg/g}$$

Inorganic Phosphorous Estimation Using Hip Assay (Raboy, 2003)

Around 100 g of sample was soaked in HCl overnight at 4 °C. Then the sample was centrifuged at 8000 rpm for 5 min, and 30 μL of the sample was transferred into a tube and 270 μL of Chen's reagent was added.

$$P_i = \frac{Y\,value \times Amount\,of\,acid\,taken\,for\,extraction \times 1000}{weight\,of\,sample\,taken(g)}\ \text{mg/g}$$

Table 1. Treatment types used in the present study

Treatment	Soaking time (hr)	Sprouting time (hr)	Soaking medium	Sprouting medium
Control	Without soaking and sprouting		Distilled water	Blotting paper
Treatment (T1)	12	24		
Treatment (T2)	24	12		

Table 2. Visual scoring scale used in iron range classification

Score (colour intensity)	Range (mg/kg)
High	51.7-74.7
Medium	40.3-40.8
Low	30.8-35.7

Iron Estimation Using Prussian Blue Method (Velu *et al.*, 2014)

0.5 g of the sample was transferred into petri plates, then 10 mL of Prussian blue solution was poured onto the samples, after which color development was observed in 10 min. Visual scoring scale used is presented below in Table 2.

Micro and Macro - Nutrient Analysis

Whole flour and treated flour of TNAU Cumbu hybrid 9 and CO 10 were assessed for its micro-nutrient *viz.*, iron (Fe), zinc (Zn) & manganese (Mn) and macro nutrient *viz.*, calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), and phosphorous (P) using ICPMS (iCAP RQ ICP-MS).

Composite Flour Development for Noodles Making

Pearl millet grains were soaked for 12 hr and drained the water. Then transferred onto a blotting paper and made to sprout for 24 hr. After 24 hrs, it was grinded into a fine powder using a blender. Flour composition used in present study given in the following Table 3.

Preparation of Noodles

Noodles were prepared by mixing the composite flour of different combinations with the mentioned quantities of Xanthan gum and water. The flour was first measured and mixed according to the combination and then sieved through a 200 mm sieve, then the flour was hydrated with 30% water and steamed for 10 min. The steamed flour was kneaded for 15 min by adding the remaining water. The dough was extruded into noodles and steamed for 10 min, finally, the noodles was dried at 60 °C for 4 hr.

Evaluation of Noodles

Textural analysis was done using a texture analyser for eight different characteristics *viz.*, force, hardness, fractur ability, gumminess, chewiness, springiness, cohesiveness and resilience. Sensory acceptability evaluation was done by a panel of 8 members using the 9-point hedonic scale indicating characters such as texture, appearance, chewiness, and overall acceptability from 1-non desirable, 5-neither and 9-desirable as reference scores (Hymavathi *et al.*, 2019).

Table 3. Different types of flour composition used in the present study.

Sample	Pearl millet flour (g)	Corn flour (g)	Tapioca starch (g)	Xanthan gum (g)	Water (mL)	Salt (g)	Total weight (g)
Sample 1 (TNAU Cumbu hybrid 9)	50	50	-	2	40	2	100
Sample 2 (TNAU Cumbu hybrid 9)	60	20	20	2	40	2	100
Sample 3 (CO 10)	50	50	-	2	40	2	100
Sample 4 (CO 10)	60	20	20	2	40	2	100

RESULTS AND DISCUSSION

Tannins and phytates are recognized as major anti-nutritional factors that interfere with the digestibility and bioavailability of nutrients in pearl millet (Butler, 1992). Reducing these compounds through effective treatments can significantly enhance the nutritional quality of millets (Raboy, 2003; Shahidi & Naczk, 2003). Mechanical, thermal, and biological processes are among the methods that can enhance the nutritional availability in millets. Specifically, wet processing methods such as soaking, germination, and fermentation have been shown to decrease phytic acid content and improve mineral solubility, thereby enhancing mineral bioavailability (Nehir El & Simsek, 2012). Among various household processing techniques, pre-soaking and germination are particularly effective for boosting the nutritional content of millets (Kayodé *et al.*, 2007). These techniques promote the bioavailability of minerals by transitioning grains from a dormant state to an active state, thereby improving their nutritive levels. They also reduce the levels of anti-nutrients such as oxalic acid, phytic acid, trypsin inhibitors, and tannins, while increasing the amount of absorbable nutrients.

In present study, analysis of variance revealed that factors and its interaction were significant. It depicted that three varieties taken in present study had significant difference on the treatments *viz.*, 12 hr soaking 24 hr sprouting and 24 hr soaking and 12 hours sprouting for tannin, phytate and inorganic phosphorous (Table 4). Tannin content was significantly affected by the treatments across all varieties. As shown in Table 5, the control group exhibited the highest tannin levels in TNAU Cumbu hybrid 9 (5.46 mg/g), followed by CO 10 (4.73 mg/g) and CO (Cu) 9 (4.50 mg/g). Following Treatment 1, tannin content was reduced substantially, with TNAU Cumbu hybrid 9 showing the greatest reduction to 3.51 mg/g, followed by CO 10 (3.30 mg/g) and CO (Cu) 9 (4.08 mg/g). Treatment 2 resulted in a moderate reduction of tannins, where TNAU Cumbu hybrid 9 decreased to 4.90 mg/g, CO 10 to 3.38 mg/g, and CO (Cu) 9 to 4.37 mg/g. Treatment 1 that is 12 hr soaking and 24 hr sprouting led to a significant reduction in tannin content across all varieties, especially in CO 10, where tannin levels decreased from 4.73 mg/g (control) to 3.30 mg/g. Similarly, TNAU Cumbu hybrid 9 exhibited a higher reduction in tannins, from 5.46 mg/g

Table 4: Analysis of variance under factorial completely randomized design

Sources of variation	Degrees of freedom	Tannin	Phytate	Pi
Factor A	2	397.4*	1023.6*	24.82*
Factor B	2	943.9*	268.40*	76.08*
Interaction (A×B)	4	292.2*	181.10*	22.71*
Error		27		
Total		36		

Factor A-Treatment, A1-Control, A2-Treatment 1, A3-Treatment 2, Factor B-Three genotypes to 3.51 mg/g. By effectively reducing tannin content through Treatment 1, especially in CO 10, the potential for improving the nutritional value of food products will be significant. The results and treatment chosen align with the previous study in which 12 hr soaking and 24 hr sprouting has shown effective reduction in the levels of tannin in multiple millet crops including pearl millet (Bhuvaneshwari *et al.*, 2020). These results suggest that Treatment 1 was more effective in reducing tannin content across all varieties compared to Treatment 2.

Phytates are considered potent antinutritional factors because they can chelate minerals such as calcium, iron, and zinc, reducing their bioavailability (Thompson, 1993; Raboy, 2003). A similar pattern of reduction was observed in phytate content across treatments. In the control group, phytate levels were highest in TNAU Cumbu hybrid 9 (2.00 mg/g), followed by CO 10 (1.48 mg/g) and CO (Cu) 9 (1.23 mg/g). Treatment 1 resulted in a notable reduction in phytate content, with TNAU Cumbu hybrid 9 decreasing to 1.93 mg/g, CO 10 showing a more substantial drop to 0.67 mg/g, and CO (Cu) 9 reducing to 0.92 mg/g. Treatment 2, while effective, was less impactful, with TNAU Cumbu hybrid 9 having 2.03 mg/g, CO 10 decreasing to 1.36 mg/g, and CO (Cu) 9 reducing to 1.18 mg/g. Overall, Treatment 1 was more effective in reducing phytate content, especially in CO 10, which experienced the greatest reduction.

Table 6 depicted the effect of treatments on Pi (inorganic phosphate) availability across the three varieties. In the control group, Pi availability was lowest, with values ranging from 0.46 mg/g in TNAU Cumbu hybrid 9 to 0.58 mg/g in CO 10. After applying Treatment 1, Pi availability increased across all varieties, reaching 0.72 mg/g in TNAU Cumbu hybrid 9, 0.68 mg/g in CO 10, and 0.57 mg/g in CO (Cu) 9. Treatment 2, while less effective than Treatment 1, still resulted in an improvement in Pi availability over the control, with values of 0.62 mg/g in TNAU Cumbu hybrid 9, 0.60 mg/g in CO 10, and 0.54 mg/g in CO (Cu) 9. The availability of iron (Fe) also improved significantly with treatment (Table 6). In the control group, Fe availability was reported as low in TNAU Cumbu hybrid 9 and CO 10, and medium in CO (Cu) 9. After Treatment 1, Fe availability increased to medium in TNAU Cumbu hybrid 9 and high in both CO 10 and CO (Cu) 9. Treatment 2 also improved Fe availability, but to a lesser extent, resulting in medium Fe availability across all varieties. The improvement in Fe availability under Treatment 1 aligns with the reduction in tannin and phytate levels, particularly in CO 10. Tannins and phytates are well-documented inhibitors of iron absorption, as they bind to iron and prevent its bioavailability (Reddy *et al.*, 1982; Thompson, 1993). The combined results from Tables 5 and 6 demonstrated that Treatment 1 consistently outperformed Treatment 2 in improving the bioavailability of both Pi and Fe (Figure 2). The significant reduction in phytate levels (Table 5) under Treatment 1 is particularly relevant to Pi availability, as phytates strongly bind inorganic phosphate, making it unavailable for absorption (Kumar & Singh, 1998; Raboy *et al.*, 2000). Therefore, the increased Pi availability in TNAU Cumbu hybrid 9 and CO 10 following Treatment 1 can be attributed to the reduced phytate content in these varieties. Similarly, the reduction of tannins (Table 5), which is known to bind and inhibit iron absorption, contributed to the improved Fe availability in CO 10 and CO (Cu) 9 under Treatment 1 (Butler, 1992; Chung *et al.*, 1998).

The results suggests that Treatment 1 is not only effective in reducing antinutritional factors but also in enhancing the bioavailability of essential minerals such as iron (Shahidi & Naczk, 2003). Thus, these studies clearly demonstrated the effectiveness of 12 hr soaking with 24 hr sprouting in improving nutritional quality. According to study of (Singh *et al.*, 2024), sprouting increased the bioavailability of several minerals and vitamins antioxidant activity and reduced anti-nutrients like metal chelating phytates and enzyme inhibitors. Sprouted pearl millet flour had low setback, paste viscosity, phytate content, and high protein and dietary fiber content. Asiedu *et al.* (2024) also reported that duration of sprouting significantly affects the quality parameters of millet and sorghum flours. Physiochemical properties *viz.*, energy content (377.58-412.18 kcal), fat (1.69-10.55%), and ash (1.05-2.55%) of malted millet and sorghum showed an increasing trend, while the percentages of fiber (1.98-1.68%) and carbohydrates (89.10-78.67%) declined as the number of sprouting days increased. In this context sprouted flours along with whole flour assessed for its micro and macro nutrients. TNAU Cumbu hybrid 9 and CO 10 recorded increase in iron, zinc, manganese, magnesium, calcium and sodium content, and decrease in potassium and phosphorus in sprouted flour.

Table 5: Effect of treatment on anti-nutritional factors

Treatment	Tannin (mg/g)			Phytate (mg/g)		
	TNAU Cumbu hybrid 9	CO 10	CO (Cu) 9	TNAU Cumbu hybrid 9	CO 10	CO (Cu) 9
Control	5.46±0.01	4.73±0.04	4.50±0.03	2.00±0.03	1.48±0.03	1.23±0.01
Treatment 1	3.51±0.02	3.30±0.02	4.08±0.03	1.93±0.05	0.67±0.02	0.92±0.02
Treatment 2	4.90±0.03	3.38±0.03	4.37±0.03	2.03±0.04	1.36±0.03	1.18±0.02

Table 6: Effect of soaking and sprouting in different time interval on nutrient availability

Treatment	Pi (mg/g)			Fe (mg/g)		
	TNAU Cumbu hybrid 9	CO 10	CO (Cu) 9	TNAU Cumbu hybrid 9	CO 10	CO (Cu) 9
Control	0.46±0.01	0.58±0.01	0.54±0.01	low	Low	medium
Treatment1	0.72±0.01	0.68±0.009	0.57±0.01	medium	high	high
Treatment 2	0.62±0.009	0.60±0.007	0.54±0.009	medium	medium	medium

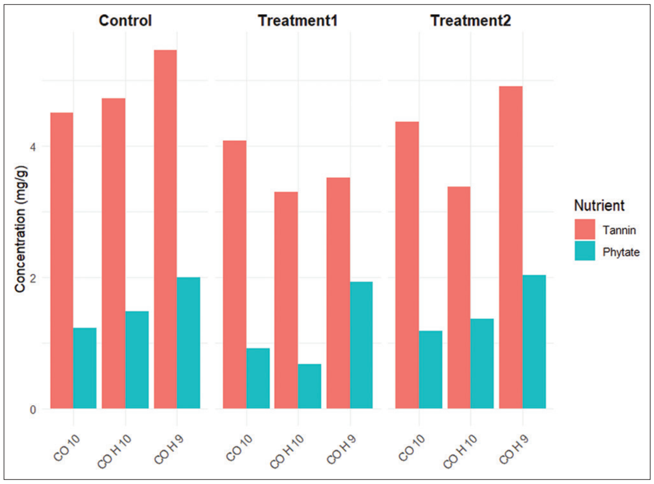

Figure 2: Comparative representation of effect of anti-nutritional factors and nutrient availability on treatments over three varieties of pearl millet

Iron biofortified pearl millet consumption among school children contributed to healthier cognitive and motor development (Pompano *et al.*, 2022). Besides it had role in improving haemoglobin levels by 13.20 % on regular consumption (Anitha *et al.*, 2021). Iron content in sprouted flour in present study increased from 67.41-73.60 ppm and 69.66-72.58 ppm in TNAU Cumbu hybrid 9 and CO 10 respectively. Sodium has reported to increase in treated sample. Zinc had higher impact on immune system, cell growth and division, wound healing and very important for pregnant women, infants and growing children. Sprouted flour in present study recorded 1.5-2.5 ppm increase in zinc content compared to controls. Besides calcium bioavailability had its important role in forming the basic structural frame work of bones and teeth, insufficient intake of calcium leads to osteoporosis (Singh *et al.*, 2024). In present study, sprouted flour recorded an increase in calcium from 114.99-166.84 and 82.00- 94.07 ppm in TNAU Cumbu hybrid 9 and CO 10 respectively (Table 7). The Na/K ratio of sprouted/treated flour was 0.17 and 0.22 in TNAU Cumbu hybrid 9 and CO 10 respectively which was below 1.0 as recommended by National Research Council which implied that pearl millet flour may be considered as a diet to regulate blood pressure and nerve functions in the body (Owheruo *et al.*, 2019). It has increased due to sprouting of millets.

Table 7: Micro and macro nutrient levels in control and treated pearl millet flour

Micro and macro - nutrients (ppm)	TNAU Cumbu hybrid 9		CO 10	
	Control	Treated	Control	Treated
Iron	67.41	73.60	69.66	72.58
Zinc	44.37	46.57	44.66	46.34
Magnesium	8.53	9.09	9.97	10.70
Manganese	658.59	848.23	610.14	733.89
Calcium	114.99	166.84	82.00	94.07
Sodium	321.04	330.57	315.69	337.68
Potassium	2700.93	1869.6	2514.55	1504.80
Phosphorus	1768.62	1751.52	1613.68	1417.96
Na/K ratio	0.11	0.17	0.12	0.22

Table 8: Textural characteristics of uncooked noodles in four samples

Sample	Force	Hardness	Fracturability	Gumminess
Sample 1	4633.86	5026.51	1568.09	3169.19
Sample 2	7377.48	160.51	1517.102	134.67
Sample 3	2378.48	1439.57	2414.96	643.37
Sample 4	2067.49	2041.05	2236.99	805.35
Sample	**Chewiness**	**Springiness**	**Cohesiveness**	**Resilience**
Sample 1	2662.65	0.835	0.554	0.276
Sample 2	65.19	0.465	0.332	0.246
Sample 3	1166.71	0.929	0.897	0.418
Sample 4	402.37	0.608	0.469	0.218

It is critical to investigate the potential of these sprouted flours in functional food. Thus, the use of sprouted grains in food formulations is a growing trend in health foods and is getting more and more popular in the market. In this context, Pearl millet flour of TNAU Cumbu hybrid 9 and CO 10 after 12 hr soaking and 24 hr sprouting was mixed in different composition/ratios with corn flour and tapioca starch to make gluten-free noodles and evaluated for its texture and consumer preference as follows. The texture profile analysis (TPA) results highlighted key differences in the physical properties of the gluten-free noodles, focusing on force, hardness, fracturability, gumminess, chewiness, springiness, cohesiveness, and resilience. The results from the texture profile analysis (TPA) of gluten-free noodles demonstrated significant variation across the samples in terms of force, hardness, fractur ability, gumminess, chewiness, springiness, cohesiveness, and resilience (Table 8). These properties are crucial in determining the texture and overall sensory experience of the noodles.

Force and hardness are closely related, as both indicate the firmness of the noodles. These characteristics provide essential insights into how the noodles behave under pressure (Mudgil *et al.*, 2016). Sample 2 had the highest force (7377.48 g), making it the firmest noodle, while Sample 1 had the highest hardness (5026.51 g), indicating a dense and strong structure. Conversely, Sample 4 reported the lowest force (2067.49 g), resulting in a softer and less resistant noodle. Fracturability refers to how easily the noodle breaks and gumminess refers to the perceived stickiness of the product during chewing. Sample 3 had highest fracturability (2414.96 g), and gumminess was highest in Sample 1 (3169.19 g), suggesting that this sample is denser and requires more chewing effort. These two factors are inversely related, as noodles that break easily (high fracturability) tend to have lower gumminess, whereas denser, chewier noodles maintain their structure for a longer time. According to Obadi & Xu (2021), resilience refers to the rubbery state of the noodles and is a measure of recoverable energy after compression. Chewiness is the energy required to break down the noodles to the swallowing state. Springiness is an important factor that measures the ability of the noodles to return to their original shape after being compressed.

Sample 1 had highest chewiness value (2662.65 g), making it the most substantial and long-lasting during eating. This is complemented by its high gumminess, creating a firm and robust bite. Sample 2, with the lowest chewiness (65.19 g),

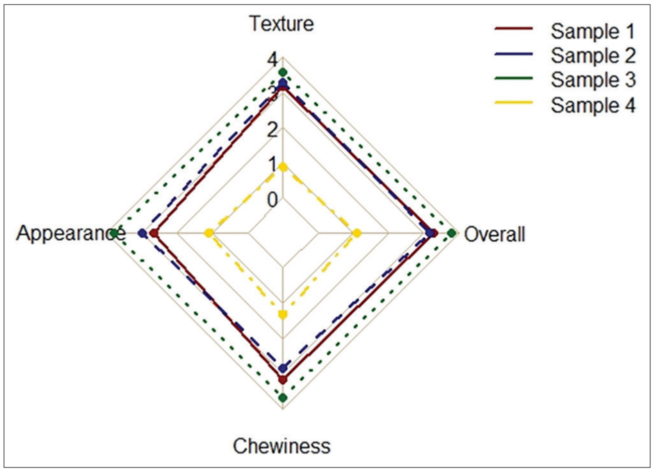

Figure 3: Sensory evaluation of cooked noodles from four samples using hedonic scale

Figure 4: (a-d) Dried and uncooked noodles made from four different flour compositions

Figure 5: (a-d) Cooked noodles made from four different flour compositions

breaks down quickly in the mouth, resulting in a softer and less resistant texture. Sample 3 had the highest springiness (0.929), indicating a bouncy and elastic texture. This characteristic is closely related to cohesiveness, which reflects how well the noodles hold together during chewing. Sample 3's high cohesiveness (0.897) suggests that it retains its structure well throughout the eating process, providing a consistent texture. Finally, resilience is the ability of the noodle to recover its shape after deformation, and it was also highest in Sample 3 (0.418). This indicates that this sample has a strong capacity to bounce back after compression, maintaining its integrity through multiple bites. Lower resilience in Sample 4 (0.218) suggests that it is more pliable and less likely to recover after being compressed, creating a softer texture. Wheat-based noodles had more desirable texture than gluten-free noodles. However, texture of gluten free noodles made of pearl millet flour from the present study was improved by addition of xanthan gum. The best results with improved texture were found in the gluten-free tiger nut noodles prepared with 0.5% xanthan gum 1990 (Gasparre & Rossel, 2019).

Further sensory evaluation was done using hedonic scale test and results were discussed as follow (Figure 3). The analysis was conducted on cooked noodles. The results revealed that on a 9-point hedonic scale, all noodles sample received a minimum score of 7, which is considered acceptable whereas sample 4 had a minimum score of 2 which is non-desirable. Due to the higher composition of binding agents the flour was not able to hold its stretchable dough form after steaming which lead to shorter noodle strands which were not texturally appealing during evaluation. As per the study, the addition of different percentage of corn flour and tapioca starch in the formulation to make noodles had a significant difference on all the sensory parameters. Noodles with the 50% corn flour showed the best sensory results in terms of texture (7.62), appearance (7.87), chewiness (7.75), and overall acceptability (7.87) attribute (Figures 4 & 5).

CONCLUSION

Thus, this study revealed that 12 hr soaking 24 hr sprouting was effective in reducing anti-nutritional factors and increasing bioavailability. Sprouted pearl-millet flour with enhanced nutrient availability and corn flour with 50:50 ratio found to be optimum in making gluten-free noodles due to its desirable sensory characteristics. It was attributed by its moderate hardness, and chewiness, with higher springiness, cohesiveness and resilience. Besides, sprouted flour noodles would be easier to digest since sprouting increased the reduction of anti-nutritional factors and Na/K ratio below 1.00 in sprouted flour would be useful in regulating blood pressure and nerve functions.

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