

Nutritional and Rheological Enhancement of Peanut Milk Yogurt Fortified with Browntop (*Brachiaria Ramosa* L.) Millet Starch, Jackfruit (*Artocarpus Heterophyllus* L.) Seed and Apple (*Malus Domestica* L.) Powder

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Abstract

Purpose: In response to the increasing demand for plant-based dairy alternatives, this study investigates the enhancement of peanut milk yogurt by fortifying it with browntop millet starch, jackfruit seeds and apple powder to improve its texture and nutritional profile. **Methods:** Formulations were optimized based on the preliminary trials of various compositional analyses. **Results:** Variant PYY comprising of 70% peanut milk, 10% each of browntop millet starch, jackfruit seed and apple powder was found to be the most preferred sample by the sensory panelists with 8.1 ± 1.11 as the average overall acceptability score. It exhibited characteristic nutritional composition of 13.4 g/100 g fat, 6.4 g/100 g protein and 58.7 mg/100 g calcium content. Physico-chemical attributes revealed considerable similarity among the standard and other samples of fortified peanut yogurt. **Conclusions:** The combined fortification with functional ingredients not only supports the nutritional enhancement of the yogurt but also promotes improved gut health, anti-oxidant activity and weight management. Furthermore, the addition of millet starch prevented phase separation thereby improving its shelf-life and giving a desirable mouth feel.

Keywords: Plant-based dairy, Functional, Gut health, Weight management, Shelf-life.

Introduction

In recent years, the global demand of non-dairy alternatives has witnessed a significant surge due to veganism, lactose intolerance, dairy allergies and certain environmental concerns. The concept of plant-based yogurts has emerged as promising substitute because of their cost-effectiveness, functional versatility, health aspects and nutritional equivalence with dairy based yogurts. The rise of plant-based yogurts marks a characteristic turning point in the global food landscape thereby advocating probiotic benefits and its comprehensive nutritional profile.

Peanuts (*Arachis hypogaea* L.) commonly known as groundnuts are nutrient-dense legumes widely recognized for its rich protein content and good fats. This sustainable ingredient is rich in monounsaturated fatty acids (MUFA), vitamin B-complex and E, flavonoids, alkaloids, phytosterols, resveratrol, dietary fiber, magnesium, phosphorus, copper and selenium (Ciftci & Suna, 2022). Peanut milk, among the other available dairy substitutes, has garnered significant attention due to its rich creamy texture, affordability and higher protein content. It is an oil-seed legume having low-glycemic index, making it suitable for diabetic patients as well. Regular and moderate consumption of peanuts contribute in prevention of non-communicable diseases (Arya et al. 2016).

Browntop millet (*Brachiaria ramosa* L.) also known as Sridhanya or Choti kangni is a functional nutri-cereal composed of complex carbohydrates, dietary fiber, iron, phosphorus, magnesium, zinc, potassium, phenols and flavonoids (Srivastav and Chauhan, 2024). Browntop millet (BTM) starch comprises of amylose and amylopectin owing to slow digestibility and noticeable prebiotic activity. Despite the rigorous extraction process of starch from the millet grains, it exhibits excellent physico-chemical properties such as water absorption, gelling ability, swelling power, thickening and stabilization that improves the texture and mouth feel of food product into which it is added (Mounika et al. 2024).

Jackfruit (*Artocarpus heterophyllus* L.) seeds are round shaped, light-brown in colour; rich in protein, starch, fiber, iron, calcium and vitamin B complex. Being a starchy source, it serves as a low-fat natural energy booster that aids in digestion, weight management and regulating blood sugar levels. Although these seeds are considered as agricultural waste, they are packed with flavonoids, isoflavones, saponins that targets comprehensive utilization in various food products (Fabil et al. 2024). It is a promising functional ingredient for incorporating it in recipe formulations like yogurt, bakery foods and beverages. The flour of the dried seeds offer diverse phyto-chemical attributes and at the same time can withstand high temperatures and still be potent in its efficacy (Suzihaque et al. 2022).

Apple (*Malus domestica* L.) is a distinguished fruit known for its rich nutrient profile, phytochemical content and efficacious health-promoting properties. It is a low-calorie, functional fruit high in dietary fiber, vitamin C, potassium, magnesium, flavonoids, polyphenols and triterpenoids. Consumption of apples has known to prevent and treat degenerative diseases, cholesterol management, metabolic syndromes, inflammatory bowel disease, cardiovascular health and hepatic steatosis (Patocka et al. 2020). Apple pomace or its powder is gaining much importance nowadays due to its efficiency in getting utilized as food fortificant as well as being valorized to produce sustainable foods.

Method and Materials

Procurement and Processing of Raw Materials

Peanuts, BTM grains, Jackfruit and Apples were collected from the local market of Varanasi, Uttar Pradesh, India. Each ingredient underwent specific pre-processing to ensure suitability for further usage. The peanuts were washed and soaked for 10-12 hours in water at 1:2 (w/v) ratio. The soaked peanuts were de-husked and millet grains were sun-dried for 48-72 hours. BTM was subjected to soaking in distilled water at 1:3 (w/v) ratio for 12 hours at room temperature. Apples were washed, sliced and subjected to dehydration at 65 °C for 5-7 hours. Jackfruit was peeled, cut and the seeds were separated to dry them in the oven to eliminate moisture at 60 °C for 6 hours.

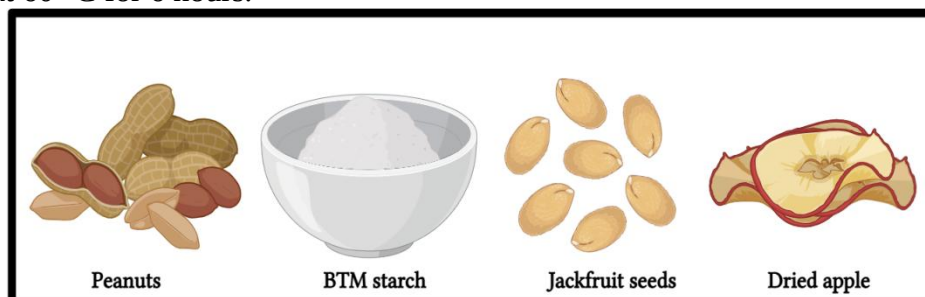


Figure 1: Raw materials for the preparation of fortified yogurt

Extraction of BTM Millet Starch

The softened BTM grains were ground in a high speed blender with minimal water to form slurry. It was then filtered through a double-layered muslin cloth to remove fibrous residues. The filtrate underwent sedimentation for 6-8 hours followed by the decantation of clear

supernatant and collection of starch layer. The obtained starch further was washed 4 times with distilled water to enhance purity. The washed starch was subjected to oven-drying at 45 °C until a constant weight was achieved for two concurrent readings. The dried starch was ground into fine powder in a mortar-pestle and then was passed through a 60-mesh sieve to ensure uniform particle size.

Sample Preparation

The de-husked peanuts were transferred to a blender along with water at 1:1 (w/v) ratio to obtain the milk. It was then filtered using a muslin cloth, which was then boiled for 5 minutes to ensure microbial safety. The dehydrated apple pieces and jackfruit seeds were grounded separately in a mixer to obtain fine powder of both the ingredients. These powders were subsequently sieved using a 60-mesh sieve to remove coarse particles, ensuring a uniform texture for further formulation. They were stored in airtight container at room temperature in cool, dry place until further use.

Formulation of Fortified Peanut Yogurt

The extracted peanut milk was taken into a clean glass bowl along with an appropriate quantity of BTM extract. Dried jackfruit seed and apple powder were then incorporated as per the formulation detailed in figure 2 to develop three variants of the yogurt. For the standard sample, 100 ml of peanut milk was used for yogurt preparation. To prepare the fortified yogurt, 4-5 green chilli stalks were also utilized in the preparation process. The prepared samples were coded as Standard, PYX, PYY and PYZ.

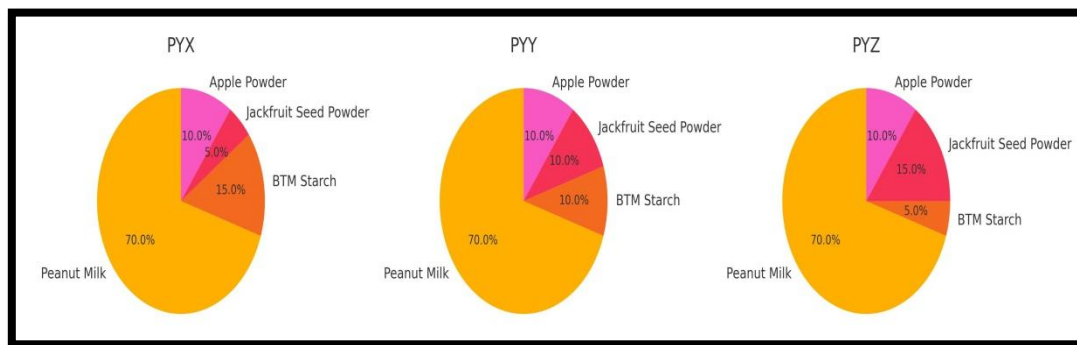


Figure 2: Composition of ingredients of fortified peanut yogurt

Nutritional and Physico-chemical Analysis

The prepared variants of fortified vegan yogurt and standard sample were tested for their proximate profile as per the standardized procedures given by AOAC 2016. The physico-chemical evaluation was conducted for pH, syneresis and specific gravity (Ares et al., 2007).

Sensory Analysis

A total of 20 sensory panelists were identified by conducting a triangle test using different concentrations of mango juice. They were provided with three fortified peanut yogurt samples along with a standard vegan yogurt and were further required to mark their preferences on a 9-point hedonic scale proforma on the parameters like taste, texture, appearance, aroma and overall acceptability (Srivastav et al., 2022).

Results and Discussion

The present study evaluated the effect of incorporating jackfruit seed and apple powder along with browntop millet starch on nutritional, physico-chemical and organoleptic properties.

Proximate Analysis of Fortified Peanut Yogurt

Table 2 illustrates the proximate composition of the standard and experimental samples of fortified peanut yogurt. The highest moisture content was recorded in the standard sample and the lowest in Sample PYX. Ash content increased in the fortified samples with PYX showing highest proportion. The protein content showed a slight decrease in PYX (6.0 ±

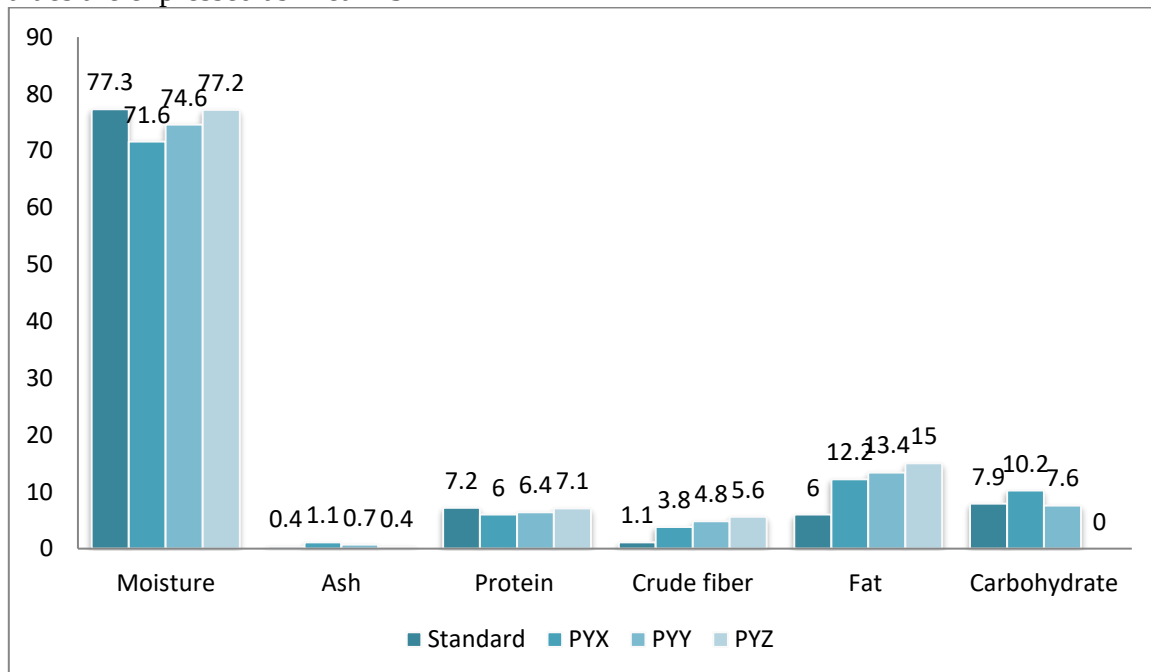
0.70) and PYY (6.4 ± 0.82) compared to the standard variant. A notable increase in crude fiber was observed in experimental samples, particularly in sample PYZ (5.6 ± 0.10), suggesting improved dietary fiber content. Fat content significantly increased in all formulations, with sample PYZ exhibiting highest concentration. Carbohydrate content, however, showed an inverse trend of decrement, possibly due to lower lactose content or microbial utilization during fermentation.

Sengupta et al., (2016) in their study explained that the consumption of soy yogurt fortified with sesame oil had a positive impact on lowering blood cholesterol levels on albino mice on its consumption of about 8 weeks. Ahmed et al., (2021) propagated the concept of addition of apple pomace and pomegranate peel powder after the process of freeze-drying to develop a functional yogurt. They also reported that the variation in the amounts of pomegranate peel did not affect the nutritional profile to a significant extent. A similar moisture reduction was reported by Mohamed et al. (2021) in oat and chickpea fortified yogurts as the present study. Additionally, Ali et al., (2023) observed comparable effects in starch-enriched yogurt, where higher dry matter reduced the total moisture content. The most evident increase was reported in crude fiber content, which rose significantly from 1.1 to 5.6 g/100 g approximately, which demonstrated the dietary fiber potential of the plant-based additives that resists breakdown during fermentation. There was a marked increase in fat content across all the fortified samples that may be attributed to the lipid-rich nature of jackfruit seeds powder.

Table 2: Nutritional composition of standard and fortified peanut yogurt

Nutrients (g/100 g)	Standard	PYX	PYY	PYZ
Moisture	77.3±0.25	71.6±1.57	74.6±1.42	77.2±0.44
Ash	0.4±0.01	1.1±0.31	0.7±0.08	0.4±0.03
Protein	7.2±0.11	6.0±0.70	6.4±0.82	7.1±0.12
Crude fiber	1.1±0.00	3.8±0.34	4.8±1.07	5.6±0.10
Fat	6.0±0.24	12.2±0.31	13.4±0.77	15.0±0.22
Carbohydrate	7.9±0.27	10.2±1.04	7.6±0.84	5.1±0.50

Values are expressed as Mean±SD



Mineral profile of Fortified Peanut Yogurt

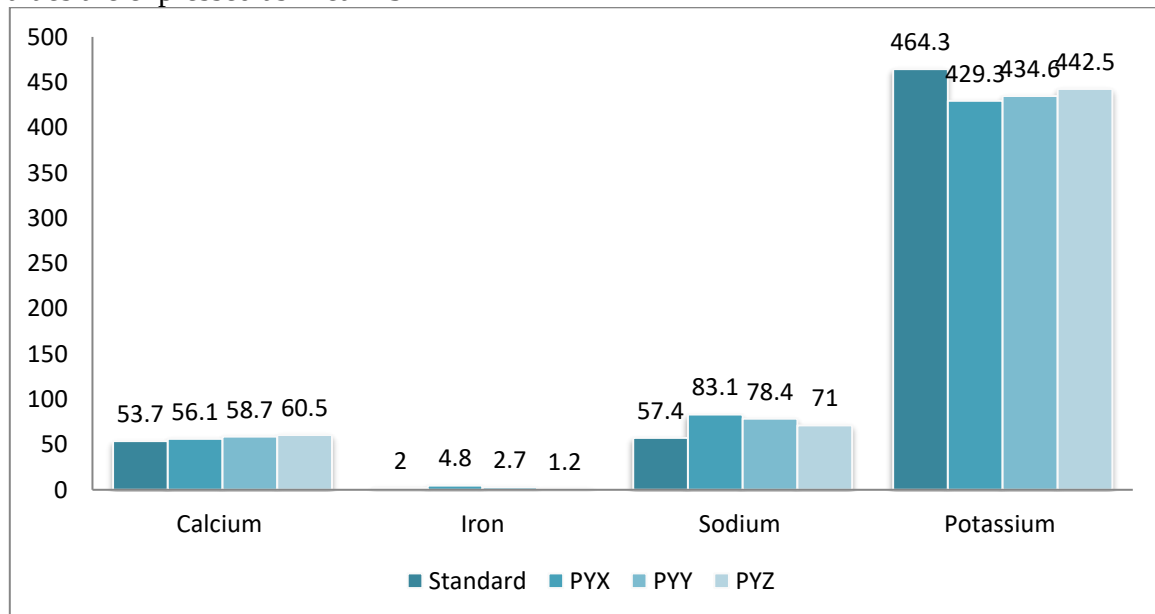
The mineral analysis revealed notable differences among the standard and experimental samples as shown in Table 3. Calcium content increased in all formulations, with PYZ showing the highest amount, indicating improved mineral content due to fortification. Iron was significantly higher in PYX, more than twice that of standard variant. Sodium levels also rose across all formulations with sample PYX leading and suggesting higher added sodium from the used ingredients. On the contrary, potassium content slightly declined in the experimental samples compared to the standard. Overall, the experimental formulations, especially samples PYX and PYZ showed enhanced mineral profiles, supporting their nutritional improvement over the standard formulation.

The addition of roasted date seed powder prior to fermentation significantly enhanced the mineral content of the yogurt, contributing to the fulfillment of recommended dietary allowance (RDA) for each mineral present, especially calcium (Hossain et al., 2023). Iron content was notably highest in PYX (4.8 ± 0.25), more than double that of the standard, supporting the observations elucidated by Mohamed et al. (2021), where legume-enriched yogurts contributed to a substantial rise in iron concentrations due to the natural richness of chickpea powder. Sodium levels too surged across all treated samples, with PYX containing the highest amount (83.1 ± 1.74 mg/100 g), likely due to inherent sodium in the added plant materials, similar to the results reported by Saleh et al. (2023) in starch-fortified yogurts.

Table 3: Mineral composition of standard and fortified peanut yogurt variants

Minerals	Standard	PYX	PYY	PYZ
Calcium	53.7±0.64	56.1±1.20	58.7±0.75	60.5±0.31
Iron	2.0±0.04	4.8±0.25	2.7±0.04	1.2±1.01
Sodium	57.4±0.29	83.1±1.74	78.4±0.32	71.0±0.65
Potassium	464.3±0.67	429.3±0.61	434.6±2.05	442.5±0.14

Values are expressed as Mean±SD



Physico-chemical Evaluation of Fortified Peanut Yogurt

The physico-chemical analysis of the developed fortified peanut yogurt reveals increasing pattern of pH values whereas decreasing scores of syneresis and specific gravity for all the three variants. Sample PYX exhibited the lowest pH, indicating slightly higher acidity, while PYZ showed the highest pH value, suggesting greater stability in neutral conditions. Syneresis, an indicator of water separation in the product matrix was highest in PYX and

lowest in PYZ, implying better water-holding capacity and structural stability in the same. Specific gravity values ranged from (0.8 ± 0.02) to (1.06 ± 0.1) kg/m³. PYX recorded the highest specific gravity, while PYZ had the lowest value indicating a lighter texture in PYZ, which may contribute to a smoother mouth feel.

As suggested by Dhakal et al., (2023), yogurt samples with lower fat content exhibit a greater degree of syneresis, which was not in support of the above stated results. Similarly, a study conducted by Misz et al., (2024), also mentioned 43.2 ± 0.71 as the range of syneresis of white lupin based yogurt, confirming its lower fat content. The addition of plant-based starch in different yogurt samples significantly reduced syneresis and improved yogurt firmness and consistency (Saleh et al., 2020). Arshad et al., (2022) in their study mentioned about the importance of presence of protein in the yogurt mixture. Higher the amount of protein better is the consistency of the yogurt, as it favorably supports the results of the present study that involves browntop millet starch as a component. Syneresis significantly decreased in sample PYZ ($20.0 \pm 0.14\%$) compared to the control ($27.6 \pm 0.88\%$), indicating improved water-holding capacity which corroborates with findings by Mohamed et al. (2021), who reported reduced whey separation in yogurts fortified with dietary fibers and resistant starches. Also, the specific gravity of PYZ () was markedly lower than other samples, which may be attributed to differences in total solids or air incorporation during the process of fermentation.

Table 4: Physico-chemical evaluation of standard and fortified peanut yogurt variants

Properties	Standard	PYX	PYY	PYZ
pH	6.0±0.30	5.6±0.03	5.9±0.03	6.2±0.02
Syneresis (%)	27.6±0.88	29.2±0.04	25.0±0.56	20.0±0.14
Specific gravity (kg/m ³)	1.03±0.53	1.06±0.1	1.02±0.37	0.8±0.02

Values are expressed as Mean±SD

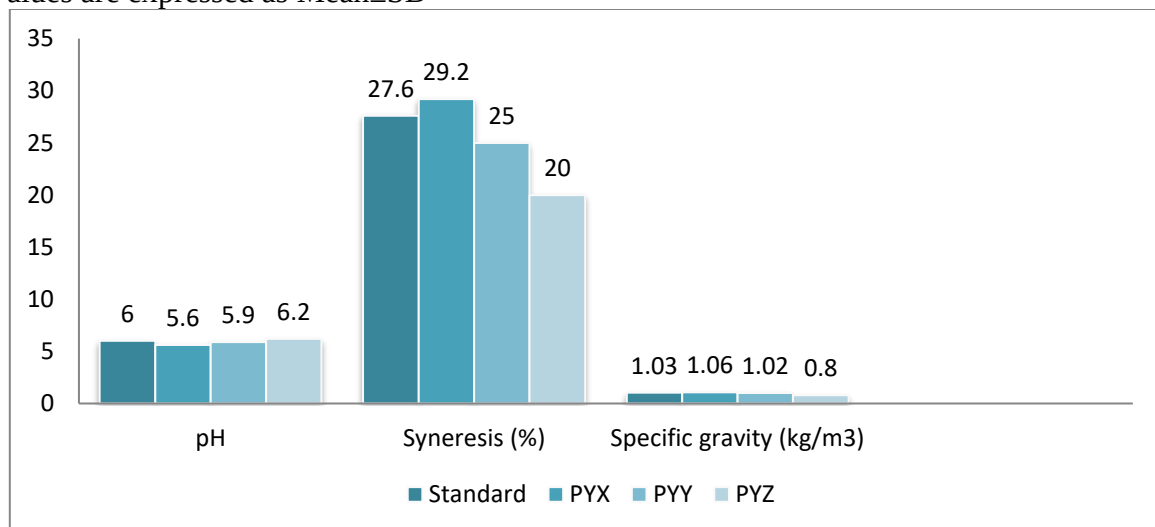


Figure 5: Physico-chemical evaluation of standard and fortified peanut yogurt variants

Sensory analysis of the Fortified Peanut Yogurt

The sensory attributes of the standard and experimental samples (PYX, PYY, PYZ) were evaluated by a panel using a 9-point hedonic scale. Among these variants, PYY consistently received the highest scores across most of the stated attributes, indicating its favorable sensory profile. Texture or Mouth feel was best rated in PYX, while PYY and PYZ scored moderately. The findings suggest that the modifications made in the PYY formulation significantly enhanced the product's sensory profile, making it more appealing to the panelists.

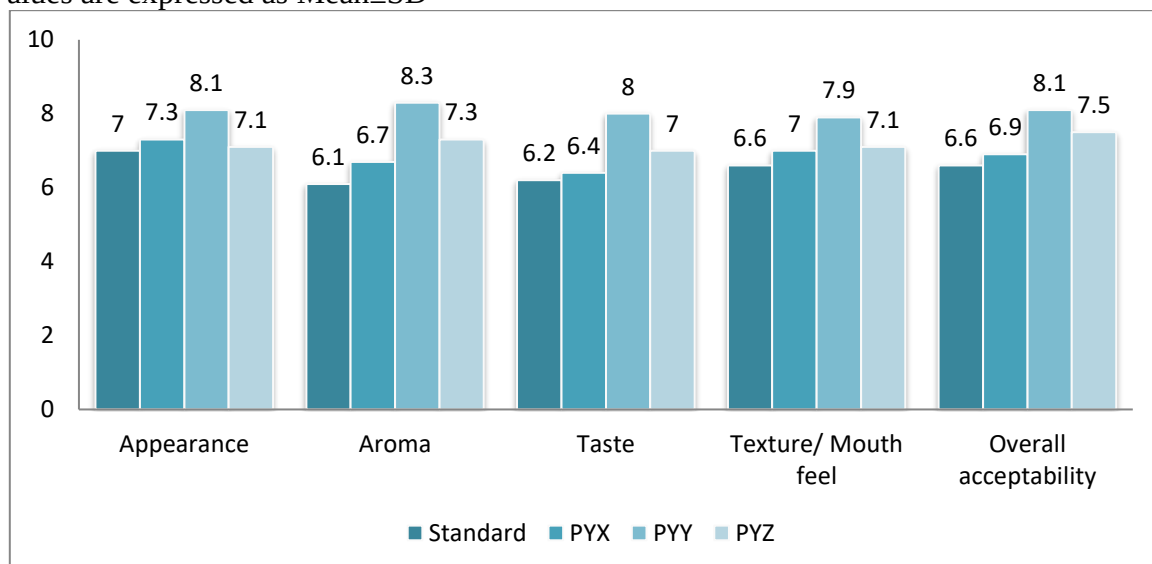
Higher content of BTM starch gave a better texture/mouth feel to the yogurt as compared to lower concentrations of the starch. It was in sync with the study results compiled by Mohd

Fazla et al., (2023). The addition of strawberry and peach flavors enhanced the aroma and taste of the yogurt (Misz et al., 2024). The desired sensory acceptability was achieved by incorporation of tuber starch to the yogurt samples (Sameen et al., 2016). Inclusion of soybean and jackfruit seed powder compromised the sensory attributes of the yogurt, particularly color, aroma and appearance (Jimoh and Kolapo 2007). The sensory profile of the functional yogurt was negatively affected on the enrichment of jackfruit seed protein isolate as it made the sample appear darker than the standard variant (Hossain et al., 2023).

Table 5: Organoleptic scores of standard and fortified peanut yogurt variants

Attributes	Standard	PYX	PYY	PYZ
Appearance	7±1.22	7.3±1.13	8.1±0.88	7.1±1.02
Aroma	6.1±1.87	6.7±0.92	8.3±0.96	7.3±1.02
Taste	6.2±1.75	6.4±1.02	8.0±0.94	7.0±1.28
Texture/ Mouth feel	6.6±0.92	7.9±1.03	7.5±1.08	7.1±1.25
Overall acceptability	6.6±1.68	6.9±0.99	8.1±1.11	7.3±1.19

Values are expressed as Mean±SD



Conclusion

The fortified peanut yogurt prepared is a nutritious, plant-based alternative suitable for vegan and lactose-intolerant individuals. It demonstrated high levels of protein, fat and fiber along with essential minerals such as iron and potassium. Variant PYY emerged as the most preferred fortified peanut yogurt which also had desirable consistency and mouth feel. The incorporation of BTM starch not only improved the yogurt's consistency and stability but also contributed to protein and functional bio-actives enrichment. The study underscores the potential of underutilized millets, seeds and fruit in developing innovative and sustainable dairy alternative suitable for health-conscious consumers.

Future Scope

The present study is an introductory exploratory research that utilizes starch of browntop millet as a setting agent and jackfruit seeds and apple pomace, which is a food waste to enhance the functional properties of the yogurt. Future studies may emphasize on using other underutilized millets, seeds, vegetable and fruit wastes to enhance the health-promoting potential of the prepared yogurt. Additionally, increasing the consumer acceptance by

marketing it as per the consumer demands would establish the concept as a sustainable trend among the people of varied age groups.

Conflict of Interest

The authors declare no conflict of interests.

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