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Process optimisation and quality evaluation of mango pulp incorporated plant-based milk substitute

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ABSTRACT: Consumers are increasingly turning to alternatives to cow's milk due to health concerns such as lactose intolerance, cow's milk allergies, calorie control, high cholesterol and a growing preference for vegan diets. This study aimed to develop a plant-based milk substitute using a blend of red rice milk, groundnut milk and ragi milk, with mango pulp added for flavour. The formulation consisted of 50% red rice (*Jyothi*), 40% groundnut milk and 10% ragi milk to approximate the composition of cow's milk. Mango pulp was added in varying amounts (10%-30%) and sensory evaluation using a nine-point hedonic scale determined the optimal formulation. The blend containing 70% plant-based milk and 30% mango pulp received the highest score of 8.30 for overall acceptability. Nutritional analysis of the selected formulation showed it contained 69.98 kcals of energy, 6.54 g carbohydrates, 5.78 g protein, 2.3 g fat, 4.10 g starch, 94.2% moisture, pH 4.28 and TSS 10°Brix. Microbial analysis indicated no bacterial, fungal, or yeast growth during storage. This plant-based milk offers a promising alternative for those with lactose intolerance or milk allergies, as well as a flavourful, nutritious option for children with digestive issues related to dairy products.

Key words: Groundnut, lactose intolerance, mango pulp, plant-based milk, rice, ragi

Plant-based milk alternatives are liquids that are derived from crop products such as cereals, pseudocereals, legumes, nuts and oilseeds. These ingredients are extracted in water and homogenized to achieve a particle size reduction of 5–20 µm, resulting in a fluid that mimics the appearance and texture of cow's milk. Traditionally, these alternatives are produced through wet milling, a process involving the grinding of raw materials into a slurry, which is then strained to remove larger particles (Sethi *et al.,* 2016).

Compared to animal-derived milk, plant-based alternatives offer several advantages, including lower levels of saturated fats and calories while still providing essential nutrients. However, the nutritional profile of these substitutes can vary significantly depending on the raw materials, processing techniques, fortification and additional ingredients used (Valencia-Flores *et al.*, 2013). Consequently, the specific nutritional content of plant-based milk alternatives can differ across various types.

In recent times, plant-based milk alternatives have gained recognition as functional beverages due to their rich content of beneficial biological compounds such as vitamins, minerals, dietary fibre and antioxidants. The use of ingredients like cereals, millets, legumes and nuts allows for the creation of plant-based milks that not only promote health and nutrition but are also affordable and flavourful. This adaptability supports the development of a wide array of plant-based milk products, catering to diverse dietary preferences and nutritional needs (Mäkinen *et al.*, 2016).

Rice (*Oryza sativa*) is one of the most commonly used staple grains in the development of dairy substitutes. While rice is rich in starch, it contains lower levels of protein, lacking essential amino acids like threonine and lysine, but is a good source of ferulic acid, sinapic acid and p-coumaric acid. Rice milk is a non-dairy beverage made primarily from milled rice and water and is often marketed as a vegan alternative to cow's milk that is allergy-friendly and easy to digest. It's opaque white or beige colour and creamy texture make it a suitable option for individuals, including children, with milk protein allergies. (Saini and Morya, 2021).

According to Isanga and Zhang (2009) groundnut milk (*Arachis hypogea* L.) is an important source of edible oil and protein, highly regarded for its nutritional value in human diets. It is produced by soaking and grinding full-fat raw peanuts with water, followed by filtration. Peanut milk and its related products provide significant nutritional benefits for individuals of all ages, owing to their high protein content, minerals and essential fatty acids such as linoleic and oleic acids.

Ragi or finger millet (*Eleusine coracana*) milk is a gluten-free and lactose-free colloidal system containing dispersed particles such as proteins, starch granules and other solid components, making it a rich source of nutrients, particularly calcium, other minerals and fibre. This makes finger millet milk an excellent alternative to cow's milk. As a plant-based product, it provides a vegan source of calcium and is a cost-effective option compared to other calcium-rich plant-based alternatives (Selvamuthukumaran, 2019).

Mango (*Mangifera indica* L.) is one of the most important tropical fruits worldwide, both in terms of production and consumer preference. Its edible portion is pulpy, varying in texture from firm to tender, with a distinctive flavour. Mangoes are rich in antioxidants, which help reduce cholesterol levels due to their high fibre content and promote eye health thanks to their high vitamin A content. Typically sweet, mangoes are versatile and can be used in the preparation of a wide range of products (Ramya and Anitha, 2020).

The present study seeks to optimize formulations for producing fruit flavoured milk by combining red rice, peanut and ragi milk, offering a viable alternative to dairy-based products. By leveraging the distinct attributes of each ingredient such as the creamy texture of rice milk, the nutritional benefits of ragi milk and the versatility of peanut milk enhanced by the richness of mango, this research aims to develop a non-dairy milk option that aligns with consumer preferences and dietary needs.

Table 1: Combinations of mango pulp incorporated plant milk substitute

Treatments	Combinations
T1	100% PMS (Control)
T2	90% PMS + 10% MP
T3	85% PMS + 15% MP
T4	80% PMS + 20% MP
T5	75% PMS + 25% MP
T6	70% PMS + 30% MP

*PMS – Plant Milk Substitute, MP – Mango Pulp

MATERIALS AND METHODS

The red rice variety chosen for this study was *Jyothi*, sourced from local farmers, while groundnuts, ragi and mangoes were procured from the local market. The red rice milk preparation followed the procedure recommended by Wijaya and Romulo (2021), with modifications. Specifically, 100 grams of red rice were rinsed and soaked in water for one hour. The rice was then cooked at 80°C for 15 minutes. After cooking, the rice was blended with lukewarm water in a 3: 10 ratio for two minutes to form a slurry. The slurry was filtered through muslin cloth to extract the rice milk, which was stored in a sterile glass bottle and cooled to room temperature.

Groundnut milk was prepared by soaking 100 grams of peanuts overnight, followed by washing and grinding. The resulting pulp was filtered through a double-layered muslin cloth two to three times to obtain the peanut milk. This milk was then pasteurized and cooled to a lukewarm temperature, following the method of Sharon *et al.* (2021).

To enhance the nutritional value of ragi milk, the ragi was germinated prior to processing. Following Kokani *et al.* (2018), 100 grams of ragi was rinsed and soaked in 500 ml of water for eight hours. After soaking, the ragi was cleaned and allowed to sprout for 72 hours at 20°C. The sprouted ragi was then dried at 60°C for two hours and milled into a powder, which was subsequently used to produce the ragi milk.

The individually prepared plant-based milks were combined in specific proportions to formulate the standard plant-based milk substitute. Red rice milk constituted 50% of the blend, while 40% groundnut milk and 10% ragi milk were added to enhance nutritional content and achieve a closer resemblance to dairy milk. This mixture was then flavoured with mango pulp to improve taste and consumer appeal.

Standardisation of mango pulp incorporated plant-based milk substitute

The enriched plant-based milk substitute (PMS) was blended with mango pulp to develop and standardise mango-flavoured plant-based milk substitute. The mango pulp was incorporated in varying proportions, ranging from 10% to 30% (T2–T6), as detailed in Table 1, with the 100% plant-based milk substitute serving as the control (T1). The experiment was conducted using a Completely Randomized Design (CRD), consisting of six treatment combinations and three replications for each treatment.

Organoleptic evaluation and selection of mango pulp incorporated plant milk substitute

The sensory and organoleptic evaluation of the mango-flavoured plant-based milk was conducted using a 9-point hedonic scale by a panel of 20 judges. Acceptability trials were performed at the laboratory level using a simple triangle test, following the guidelines of Jellinek (1985). The panel, consisting of individuals aged 18-35, assessed the organoleptic attributes of the plant milk substitute with incorporated mango pulp. The evaluation focused on appearance, colour, flavour, texture, taste and overall acceptability across five treatment variations. The data was analysed using Kendall Wallace's Analysis of Variance (ANOVA) to determine the most preferred product.

Nutritional analysis

The nutritional qualities of the selected plant-based milk substitute, along with the control, were determined by analysing various parameters. These included energy, carbohydrate, protein, fat, moisture and starch content, following the methods of Sadasivam and Manickam (1997). Additionally, the pH and total soluble solids (TSS) of the plant-based milk substitutes were evaluated to provide a comprehensive assessment of their nutritive value.

Microbial enumeration

After organoleptic evaluation, the selected mango flavoured plant-based milk substitute (PMS), along with the control sample, was subjected to microbial evaluation for the detection of bacteria, fungi and yeast. The evaluation was conducted using the serial dilution and plate count method. Initially, 10 ml of the sample was added to 90 ml of sterile water and agitated for 20 minutes. Subsequently, 1 ml of this solution was transferred into a test tube containing 9 ml of sterile water to achieve a 10^{-2} dilution, with additional dilutions of 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} prepared similarly. Enumeration of the total microbial population was performed using Nutrient Agar medium for bacteria, Potato Dextrose Agar medium for fungi and Sabouraud's Dextrose Agar medium for yeast (Agarwal and Hasija, 1986).

Statistical analysis

The nutritional analysis of the control and the optimal treatments were statistically evaluated using a T-test in SPSS software. Organoleptic evaluation scores were analysed using Kendall's Coefficient of Concordance (W). All analyses were conducted in triplicate to ensure the reliability and consistency of the results.

RESULTS AND DISCUSSION

Organoleptic evaluation of mango pulp incorporated plant-based milk substitute

An organoleptic evaluation was conducted on a plant-based milk substitute (PMS) formulated with the incorporation of mango pulp. In this study, white rice milk (WRM), enriched with groundnut milk (GM) and ragi milk (RM), constituted the base for the plant-based milk substitute. Various concentrations of mango pulp were incorporated to determine the optimal formulation. The treatment T6, comprising 70% PMS and 30% mango pulp (MP), achieved the highest mean scores across all sensory attributes, including appearance (8.27), colour (7.82), flavour (8.22), consistency (8.42), taste (8.25) and overall acceptability (8.30). These results suggest that the formulation with 30% mango pulp was the most preferred due to its balanced sweetness, appealing appearance and flavour. The total mean scores for the organoleptic evaluation are detailed in Table 2.

Atwaa *et al.* (2019) reported that the highest mean value for a fruit-flavoured probiotic rice milk beverage was obtained from a sample containing 20% mango pulp. Their findings indicated that the inclusion of mango pulp significantly improved consumer acceptability of the rice milk beverage. These results are consistent with those of Jayalalitha *et al.* (2015), who found that adding mango pulp to yoghurt enhanced the sensory evaluations of the product.

Physico-chemical composition of mango pulp incorporated plant based milk substitute

The physicochemical composition of the plant-based milk substitute incorporating mango pulp was analysed, with detailed results provided in Table 3. Based on sensory evaluations, the treatment T_6, consisting of 70% plant-based milk substitute (PMS) and 30% mango pulp (MP), was identified as the most preferred formulation. Nutritional analysis of the selected treatment revealed the following composition: moisture content at 96.6%, an energy value of 85.48 Kcal per 100 ml, carbohydrate content of 10.11 g per 100 ml, protein content of 6.31 g per 100 ml and fat content of 2.3 g per 100 ml. Additionally, the pH value of the flavoured plant milk was found to be 4.28, with a total soluble solids (TSS) value of 10°Brix.

Sreelakshmi *et al.* (2024) found that the developed plant based milk substitute had similar results to the developed plant based milk substitutes in terms of energy (85.48 kcals), carbohydrate (10.11g per 100ml), protein (6.31g per 100ml), fat (4.2g per 100ml) and moisture (96.6%). The findings of the present study are also consistent with the study by Sakhale *et al.* (2012), which reported that mango-incorporated soy milk ready-to-serve (RTS) beverages had a total soluble solids (TSS) of 14.0, a pH of 5.2 and significantly lower protein, fat and carbohydrate content. Lavudi *et al.* (2021) conducted a study and found that the peanut milk prepared by the normal soaking method had a pH value of 6.52 and TSS of 10.12°Brix, which supports the present study as well.

The observation described in Table 3 shows that the addition of mango pulp lowers the pH in plant-based milk formulations. Fruit pulp, being naturally rich in organic acids such as citric and malic acids, contributes to a decrease in pH, making the formulation more acidic. This increased acidity is particularly evident as the percentage of fruit pulp rises. In a study done by Roy *et al.* (2015), similar behaviour was observed in yogurt, where the incorporation of fruit pulps like banana, papaya and watermelon resulted in increased acidity. This change in acidity is attributed to the organic acids present in the fruits, which lower the pH and create a more acidic environment. Such acidity impacts not only the taste but also the shelf life and microbial stability of the product, as higher acidity can inhibit spoilage organisms while fostering the growth of beneficial microbes, especially in fermented products like yogurt. This observation highlights the dual role of fruit pulp addition: enhancing flavour while also potentially improving the safety and longevity of the product through increased acidity.

The findings show that the plant-based milk substitute enriched with mango pulp is highly

Table 2: Mean scores for organoleptic evaluation of mango pulp incorporated plant-based milk substitute

Treatments	Appearance	Colour	Flavour	Consistency	Taste	Overall acceptability
T_1Control - 100% PMS	7.16(1.90)	7.29(2.40)	7.22(2.83)	7.40(3.73)	6.92(4.57)	6.80(5.57)
$T_2$90% PMS+ 10% MP	7.33(2.10)	7.33(2.30)	7.24(3.40)	7.58(3.77)	7.22(5.53)	7.28(3.30)
$T_3$85% PMS+ 15% MP	7.40(2.53)	7.58(2.83)	7.40(2.83)	7.71(3.23)	7.10(3.93)	7.27(5.63)
$T_4$80% PMS+ 20% MP	7.58(1.97)	7.71(2.80)	7.47(3.13)	7.84(3.63)	7.05(3.77)	7.32(5.70)
$T_5$75% PMS+ 25% MP	7.82(2.48)	8.22(3.48)	7.67(3.18)	7.89(3.03)	7.10(3.03)	7.65(5.83)
$T_6$70% PMS+ 30% MP	8.27(1.60)	7.82(3.03)	8.22(3.15)	8.42(3.20)	8.25(4.25)	8.30(5.78)
Kendall's W**	.602	.491	.404	.484	.421	.613

PMS – Plant Milk Substitute MP – Mango Pulp

** Values in parentheses are mean rank score based on Kendall's W and significant at 1% level

Table 3: Physico-chemical composition of mango pulp incorporated plant-based milk substitute

Parameters (100 ml)	Treatments		t value
	T_1(Control)	T_6(70% PMS+ 30% MP)	
Moisture (%)	95.6	94.2	7.24*
Carbohydrate (g)	8.48	6.54	15.86*
Protein (g)	5.43	5.78	0.481**
Fat (g)	2.6	2.3	0.509**
Energy (kcal)	79.04	69.98	23.15*
pH	6.52	4.28	40.36*
TSS (°Brix)	5.5	10	-7.9*

nutritious, providing a good source of carbohydrates, proteins, fats and essential minerals such as calcium, phosphorus, sodium, potassium, magnesium and iron as it improves the nutritional quality. Rice, a widely available staple grain, can serve as an excellent carbohydrate source, while groundnut contributes valuable protein and fat. Ragi, an affordable source of calcium and iron, further enhances the nutritional value. Mango, a popular tropical fruit rich in beta-carotene, adds both nutrients and flavour to the developed plant-based milk. These ingredients can be utilised to create nutrient dense, palatable beverage options. This plant-based milk substitute has promising applications in various sectors, including hospitals, particularly for infants with lactose intolerance or milk allergies.

Microbial enumeration of mango flavoured plant-based milk substitute

Microbial presence was not detected in the freshly prepared mango flavoured PMS. The developed mango-flavoured plant-based milk substitutes were sterilized at 121°C for 15-20 minutes and stored under refrigerated conditions for one week to find the extent of shelf life. Bacterial presence was not detected at the end of the storage period for the selected treatment (T6), but the presence of bacteria was found in the control (T1), though the levels remained within safe limits. The occurrence of bacterial colonies in the control could be attributed to its susceptibility as a medium rich in carbohydrates, proteins and fats, which supports microbial growth. The decreased pH in mango pulp incorporated plant-based milk makes it more microbial safe.

A similar finding was reported by Khodke *et al.* (2015) in their study on the storage of sterilized soymilk, which showed no bacterial, yeast, or fungal growth for 10 days under ambient and refrigerated conditions. Additionally, a study by Rubico *et al.* (1987) found that peanut-based beverages processed at 121°C and stored at 4°C for 20 days showed no microbial growth. These studies support the microbial stability of the developed mango flavoured plant-based milk substitute.

CONCLUSION

Rice milk, a cereal based alternative to animal milk, can have its nutritional value enhanced by adding groundnut and ragi milk. Compared to cow's milk, this plant-based milk has been shown to contain higher levels of macronutrients such as carbohydrates, protein and fat. Flavouring fruit-based plant milk enhances its palatability, making it more attractive to consumers, especially children. This makes it an excellent choice for hospital diets, especially for individuals with lactose intolerance or milk allergies, as it is naturally lactose-free. The developed product can also be a better choice for general consumption also. Additionally, from an environmental perspective, plant-based milk serves as a sustainable alternative to bovine milk production, addressing concerns related to environmental impact.

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