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Research Article

Optimization and Formulation of Lactose-Free Milk Using Finger and Pearl Millet

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ABSTRACT

Milk alternatives from non-dairy or plant-based sources help people with lactose intolerance and lactose indigestion. Formulations for alternate milk were optimized based on the sensory and nutritional properties. Optimized milk was proportioned by preparing different combinations of finger millet and pearl millet in ratios of T_1 (60:40), T_2 (70:30) and T_3 (80:20), while cow's milk was T_0 (control milk). The current investigation was carried out to optimize and develop a plant-based milk alternative using millets. The millet milk (Lactose-free milk) blends were analyzed for the organoleptic parameters, and further proximate analysis was done for the selected variation. Among the variations, the panellists most accepted T_2 (70% Finger millet + 30% Pearl millet). Nutrient analysis except for calcium, the other energy content, carbohydrate, fat, and mineral content all were higher in the lactose-free milk than in cow milk, and the protein content was the same. Based on the nutrient and sensory scores, millet milk is a non-dairy or Lactose-free milk alternative.

Keywords: *Finger millet, Pearl millet, Lactose-free milk, sensory score, blends.*

INTRODUCTION

Millets are commonly used for beverages that the population relishes for age-old decades, as they have a uniqueness for appetite, satiety and a healthy nutritional profile (Patil et al., 2010). In the present decade, the consumption of milk in day-to-day life has become a concern, as it is having many health issues like allergies to milk, lactose indigestion and lactose intolerance and also having effects on metabolic disorders due to high-fat content (Swagerty et al., 2002). Milk formulated from the plant-based is the best alternative for milk. Alternative milk formed from plant-based products is low in saturated fats, triglycerides, cholesterol and, importantly, the absence of Lactose. They contain essential fatty acids, proteins and minerals (Bode et al., 2008).

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Hence, plant-based products are taken as nutraceuticals and functional foods that contain antioxidants, fibre, vitamins and minerals. Millets, the minor cereals, are easy to acquire, and by using traditional methods, we can produce healthy, palatable, good flavour alternative milk (Kneepkens et al., 2009).

Finger millet has abundant stores of dietary fibre, phytates, and minerals. Also, the bran of the millet is a reservoir of numerous health benefits (Chandrasekara, 2010). They contain flavonoids with antioxidants and have the properties of anti-allergy, anti-inflammation, anti-cancer properties and gastro-protective properties (Sreeramulu, 2009). Finger millet consists of many phenolic compounds like vanillic acid and quercetin, which helps inhibit cataract in the eye lens. Clinical trials have shown that finger millet has good digestive attributes and has improved the bioavailability of minerals (Makokha et al., 2002).

Therefore, paediatricians in southern India mostly prefer and suggest finger millet products for infants above 6 months due to their good protein digestibility and micronutrient composition (Kannan, 2010). The functional grain is assimilated into different types of foods. The flour can be mixed with milk, boiling water and curds (Rai et al., 2008). Due to its high nutritional value, this is one of the ingredients used for product development.

Pearl millet was taken as the second millet to develop lactose-free milk. Malnutrition and, most commonly, protein-energy malnutrition is the dreadful cause of around 50% of childhood mortality in many developed countries (Grigsby, 2002). One of the growth defects, stunting was a major indication among 15% of infants below 12 months (SALDRU, 1994).

These malnutrition conditions result due to infections like diarrhoea, vomiting or insufficient dietary consumption due to intolerances (Pelletier, 1993). Thaoge et al. (2003) stated that the addition of small amounts of pearl millet could be a very good source of energy and has the good protein of 11.8%, fat of 4.8%, which are the essential nutrients during infancy and also gluten-free (FAO, 1995). The two millets were selected as the main ingredients for developing lactose-free milk (LFM), which were available locally and rich in energy, carbohydrates, calcium, protein and minerals like magnesium. The milk alternatives of millets are the liquids derived from the permeate of millets by soaking, sprouting and micronized to 5-20 µm by homogenization, which is similar in appearance and consistency (Das et al., 2012). The two millets have nutrients like carbohydrates, protein and calcium and give a creamy white liquid appearance and little similar consistency. Therefore, taking into the sensory attributes, both millets can be blended to develop milk. The current study optimized and formulated millet milk (Lactose-free).

MATERIALS AND METHODS

The current research was focused on the preparation and optimization of millet milk. The methodology adopted for the present study is illustrated below.

2.1. Locale of the study

The study was conducted at the food science laboratory in the Department of Home Science, Sri Venkateswara University, Tirupati of Andhra Pradesh.

2.2. Procurement of raw materials

Millets, finger millet and pearl millet were purchased from local markets in good quality conditions in Tirupati, Andhra Pradesh. Before the preparation of the millet milk, the purchased millets were cleaned thoroughly for any physical contaminants like dust particles, small stones and twigs.

2.3. Preparation of millet milk

Initially, to know the yield of milk, millets were processed separately. Finger millet milk was made by soaking finger millet for 12h in water overnight. The water is drained, and the finger millet is tied in a wet muslin cloth for sprouting for 24 hours. The sprouted finger millet was dry-roasted for 2-3 minutes and then pulverized in the blender with water for optimization at room temperature. The finger

millet mix was then filtered using the muslin cloth, and the milk was filtered. The same procedure was followed for the pearl millet milk preparation.

2.4. Optimization of millet milk

The amount of finger millet and water used for the extraction of finger millet milk was optimized based on the preliminary trials where finger millet and water were used in different ratios (1:1, 1:2, 1:3). The most suitable one, based on the sensory and nutritional profile was selected. The most acceptable ratio was 1:1, as it had the highest nutritional value among all three combinations. The millet flavour revealed in the sensory analysis was permissible, presuming that it would be later overcome by blending with pearl millet milk during optimization trials. The same procedure was followed for pearl millet milk.

Table-1: Finger millet and water combination in different treatments (100ml)

Trial	Finger millet	Water	Millet Milk
T1	100g	100ml	100ml
T2	100g	200ml	200ml
T3	100g	300ml	300ml

2.5. Finger – Pearl millet milk (Lactose-free milk)

Different finger millet and pearl millet blends were prepared by mixing finger millet and pearl millet in different proportions, as given in Table 1.

Table 1: Combination of finger millet and pearl millet in different proportions

Treatments	Finger millet	Pearl millet
V_0^*	-	-
V_1	60%	40%
V_2	70%	30%
V_3	80%	20%

*Cow's milk was taken as control (T_0)

2.6. Sensory Analysis of Millet Milk (Lactose-free)

The acceptability of the different millet milk (LF) formulations was evaluated through organoleptic evaluation using the nine-point hedonic scale. The sensory evaluation of millet milk was carried out in triplicates by a panel of 20 semi-trained judges. Prior instructions were given to the panel members, and they were requested to fill out the scorecard as per the guidelines instructed. The best accepted sample was selected for further proximate analysis.

2.7. Nutrient Analysis

The standardized sample was analyzed for proximate analysis as per the standard methods described in AOAC, 2000. Protein content was analyzed by the micro Kjeldahl method described in AOAC, 2005. Fat content was estimated by methods described in AOAC, 2005. AOAC, 1990 determined mineral content (calcium and iron).

2.8. Statistical analysis

The data from triplicate observations were analyzed statically, the mean and standard deviation were calculated in Microsoft Excel, ANOVA test, and t-test was done using SPSS version 26.

RESULTS

The minor millets, which are frequently used for their food security and abundant nutrients present, were taken to formulate millet milk. For optimization and formulation of millet milk, three ratios of finger millet: pearl millet were evaluated, that is, 60:40, 70:30 and 80:20. The different combinations obtained thereof were considered using the nutrient composition from the Nutritive value of Indian foods, C. Gopalan (1999).

Table 2: Nutrient composition of raw ingredients of finger millet:pearl millet (100g)

Finger millet: pearl millet (100g)			
Nutrients	**Variations**		
	V1 (60:40)	**V2 (70:30)**	**V3 (80:20)**
Energy (kcal)	331.65	328.92	326.2
Carbohydrate (g)	64.8	65.3	65.82
Protein (g)	8.68	8.3	7.92
Fat (g)	3.32	2.97	2.63
Iron (mg)	5.34	5.16	4.98
Calcium (mg)	229.34	263.01	296.67

The nutrient composition of ingredients was taken from the nutritive value of Indian foods, C. Gopalan

Protein, carbohydrate, fat content, energy, calcium and iron nutrient composition were calculated based on the (Gopalan, 1999). The protein content of the variations was 8.68g, 8.3g and 7.92g. carbohydrate content was 64.8g, 65.3g and 65.82g, and the fat content was 3.32g, 2.97g and 2.63g; the energy content of the combined millets was 331.65kcal, 328.92kcal and 326.2kcal respectively. The mineral content of iron was 5.34mg, 5.16mg and 4.98mg, whereas calcium was 229.34mg, 263.01mg and 296.67mg, respectively, for the variations of finger millet: pearl millet 60:40, 70:30 and 80:20 as shown in the below table-2. The optimization of millet milk was done by varying the ratio of finger millet to pearl millet (60:40, 70:30, 80:20), leading to different combinations. The evaluation of the adequacy of different formulations of millet milk was carried out on the basis of nutritional attributes and sensory profile.

2.4. Sensory evaluation for optimization of finger millet milk

Table 3 shows the sensory scores of finger millet milk, given by 20 panel members, who were given the optimized finger millet milk for evaluation of organoleptic characteristics, viz. aroma, colour, flavour, mouthfeel, taste and overall acceptability. The mean scores of sensory evaluations showed that in the three formulated optimizations with different water quantities. In that treatment, (T1) in which the water content was equal to the finger millet, i.e., finger millet: water was 100:100, had significantly better aroma (8.8), colour (8.1), flavour (8.2), mouthfeel (8.8), taste (8.7) and overall acceptability (8.7), when compared with other two treatments. It was revealed from the scores that the overall acceptability of the finger millet milk of 100:100 treatment was best acceptable among the panellists. The pearl millet milk was also optimized with 100:100 treatment.

Table 3: Optimization of finger millet with water (Finger millet: water)

Sensory Attributes	**T1 (100:100)**	**T2 (100:200)**	**T3 (100:100)**	**f-value**	**p-value**
Aroma	8.8±0.41	6.6±1.56	5.4±0.51	60.0393	0.00001*
Colour	8.1±0.81	6.4±1.19	5.4±0.51	47.7885	0.00001*
Flavor	8.2±0.85	6.3±1.30	5.3±0.73	45.1123	0.00001*
Mouthfeel	8.8±0.41	6.3±0.87	6.9±0.78	71.4105	0.00001*
Taste	8.7±0.44	6.5±1.46	5.3±0.47	71.7392	0.00001*
Overall acceptability	8.7±0.47	6.3±1.46	5.1±0.74	67.2215	0.00001*

*Statistically significant at 1% level

2.5. Sensory evaluation for Finger Pearl Millet milk (Lactose Free Milk)

The data in Table 4 and Figure 1 show the sensory score of millet milk developed, given by 20 panel members, who were given the formulated millet milk for evaluation of organoleptic characteristics, viz. aroma, colour, flavour, mouthfeel, taste and overall acceptability.

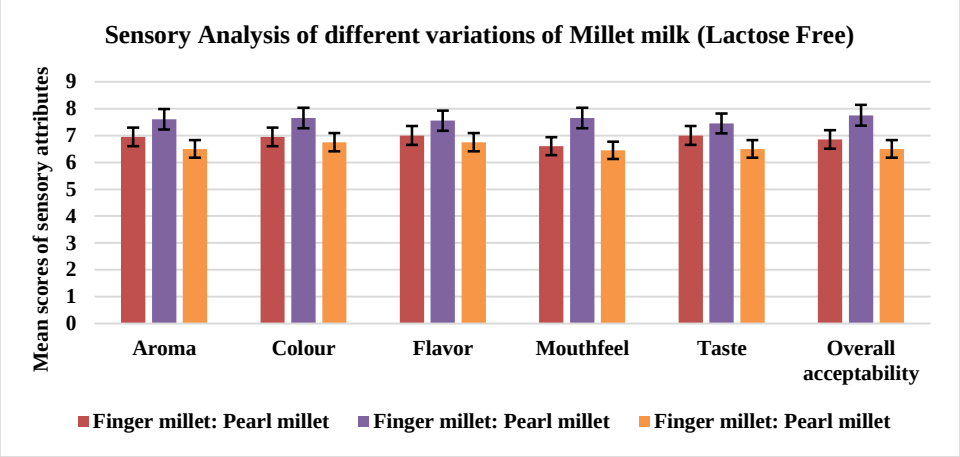

Fig 1: Graph representing the sensory analysis of millet milk

The mean scores of sensory evaluations showed that in the three formulated variations, variation V2 (70:30) had significantly better aroma (7.6), colour (7.6), flavour (7.5), mouthfeel (7.6), taste (6.4) and overall acceptability (7.7) when all the variations were compared with the cow's milk.

Table 4: Sensory Analysis by ANOVA of different variations of millet milk

Parameters	Finger millet: Pearl millet			f-value	p-value
	V1 (60:40)	V2 (70:30)	V3 (80:20)		
Aroma	6.95±0.615	7.6±0.812	6.5±0.688	14.1	0.00001*
Colour	6.95±0.510	7.65±0.745	6.75±0.443	13.22	0.00001*
Flavor	7±0.00	7.55±0.680	6.75±0.443	15.03	0.00001*
Mouthfeel	6.6±0.590	7.65±1.080	6.45±0.511	14.2	0.0001*
Taste	7±0.642	7.45±0.990	6.5±0.510	8.05	0.0008*
Overall acceptability	6.85±0.367	7.75±0.962	6.5±0.513	18.05	0.00001*

*Statistically significant at 1% level

It was revealed from the overall acceptability scores and, as shown in Figure 2 that the millet milk of V2 (70:30) is acceptable among the panellists. Hence, V2 was finalized and selected for further analysis.

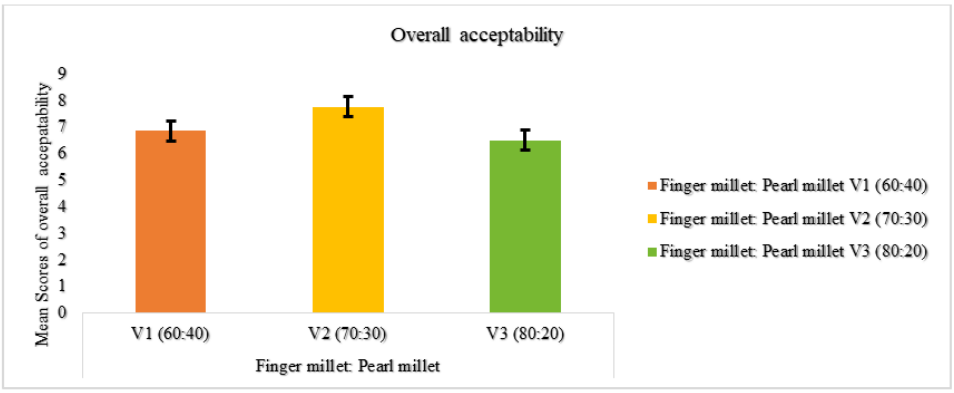

Fig 2: Graph representing the overall acceptability of millet milk by the panel members

2.6. Lactose determination

Lactose is a sugar molecule, a disaccharide found in the milk for about 4-5%. Lactase enzyme is required to properly digest Lactose, and the enzyme's insufficiency will lead to lactose intolerance. Benedict's test estimated the Lactose (Nande et al., 2008). No changes or precipitate formation was seen, confirming the absence of Lactose.

2.7. Nutrient Analysis

The energy value was the highest in the millet milk (87.12 kcal) compared to the cow's milk (67 kcal). Mbithi-Mwikya et al. 2000 stated that traditional technologies like soaking, sprouting, and shade drying processes help reduce the antinutritional factors and increase the millet's energy.

The protein content of the millet milk (3.2g) was similar to cow milk. Finger millet and pearl millet are relatively good in protein content when compared to the other millets. The high concentration of essential amino acids was threonine to the least valine. The finger millet contains 44% of the amino acids of total amino acids. Tryptophan is a deficient amino acid in many cereals, but it is present in the finger millet.

The fat content of millet milk (0.4g) when compared to cow's milk (4.1g). The fat content in the fermented and germinated/sprouted millets is relatively low when compared to the ungerminated millets and, therefore, helps in increasing the shelf life of any developed products from millets, as the risk of rancidity is very low.

The carbohydrate content of the millet milk (17.7g) when compared to the cow's milk (4.4g). The carbohydrate content in millets is around 63%- 70%, which the finger millet has good carbohydrate content due to the starches, pentosans, xylose, and simple sugars like fructose, glucose, maltose, raffinose, maltotriose and some higher oligosaccharides (Wankhede, 1979).

The iron content of millet milk (1mg) when compared to the cow's milk (0.2mg). The millets are rich in mineral content, and finger millet has a high content of iron. Except for calcium, all the other nutrients in the millet milk have high content compared to the cow's milk, and the protein content is the same as the cow's milk.

Table 4: Proximate analysis of Developed millet milk of variation 70:30 finger millet: pearl millet

Nutrients	Millet milk	Cow's milk	t-test	p-value
Carbohydrate (g)	17.7	4.4	210.29	0.0001*
Protein (g)	3.2	3.2	0.00	0.9^{ns}
Fat (g)	0.4	4.1	58.5	0.0001*
Energy (kcal)	87.12	67	318.12	0.0001*
Calcium (mg)	80	120	632.45	0.0001*
Iron (mg)	1	0.2	12.64	0.0001*
The nutrients were analyzed using the AOAC, 19th edition standards. **ns-Non significant** ***Extremely significant at 1% level**				

The graph below predicts that all the nutrients in millet milk have extremely significant levels at 1% level when compared to the cow's milk, and there was no significant difference between protein values in both millet milk and cow's milk.

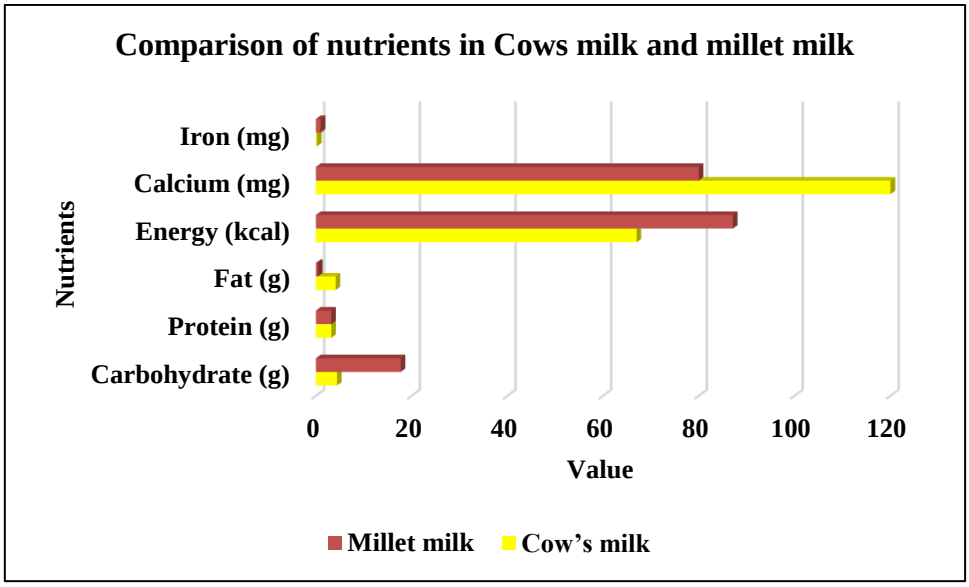

Fig 3: Graph representing the nutrients in both the cow's milk and the millet milk

CONCLUSION

Based on the analysis of cow's milk and millet milk used in this study, it can be concluded that millet-based milk prepared by the combination of finger millet and pearl millet can be a good alternative to cow milk due to the absence of Lactose and with good nutritional and sensory profile. Since it is a study based on lactose-free alternatives for milk, further alterations and modifications with respect to adding sweeteners, emulsifiers, or any other additives could be carried out to further commercialize the product.

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Author Contribution

All the authors made substantial contributions to the following: (1) Conception and Design of the study, (2) acquisition of the data, (3) interpretation of the data, (4) drafting the article or revising it critically for important content, and (5) final draft for the submission.

Author declaration: None

Conflicts of Interest: None

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