Formulation and evaluation of finger millet-based smoothie powder with aromatic spices

Oyami Perera[1], *Hisanithy* Parasuraman[1,*], *Anvarjon* Abrolov[2], *Rustamjon* Medatov[2], *Mohamed* Rifky[1,4], *Riyas* Ahamed[3], *Vejuka* Sivagopal[1] *and Fathima* Azeera[3]

[1]Eastern University, Sri Lanka, Chenkalady, Sri Lanka
[2]Fergana State Technical University, Fergana, Uzbekistan
[3]South Eastern University of Sri Lanka, Oluvil, Sri Lanka
[4]Naveen Jindal Young Global Research Fellowship, O.P. Jindal Global University, India

Abstract. Finger millet (*Eleusine coracana*) is one of the oldest and healthiest cereal grains. The aim of this research was to use milk powder and a few spices (cardamom and cinnamon) to improve the flavour and aroma of smoothie powder made from finger millet. Five different treatments (T1–T5) were made by changing the amounts (grams) of milk powder and finger millet flour (120: 0, 100: 20, 80: 40, 60: 60, 80: 40). All other ingredients were the same. A sensory analysis was conducted to know how good smoothie powders were in terms of mouth feel, appearance, taste and overall acceptability. According to the sensory analysis, Treatment 2 (T2) was the best. Physico-chemical tests showed that T2 had a pH of 6.45, a bulk density of 0.58 g/cm³, a water absorption capacity of 1.45 g/g, and a total soluble solid of 17.63°Brix. According to proximate analysis, T2 had 4.33% water, 23.01% protein, 17.50% fat, 0.54% fibre, and 5.55% ash. Microbial data that were within allowed limits showed that the product was safe.

1 Introduction

In the current years, due to the increasing awareness of the relationship between diet and health, interest in functional foods and nutraceutical products has grown worldwide. Millets, especially finger millet (*Eleusine* coracana*),* have attracted attention as climate-resilient, nutrient-rich crops with high potential for the development of value-added food products. Finger millet is a good source of dietary fibre, essential amino acids, minerals such as calcium and iron and bioactive components such as polyphenols and flavonoids which make it antioxidant, anti-diabetic and health promoting [1,2]. However, its use in modern processed foods is still limited and new products such as powdered instant beverages need to be developed.

People's lifestyle is changing and they are becoming more health conscious, this has increased the demand for instant drinks which are quick and nutrient rich. Cereal-based composite powders have gained popularity as healthy replacements of conventional dairy-

* Corresponding author: hisanithyp@esn.ac.lk

based products because of their health benefits [3]. Ready-to-mix drinks can be made healthier by adding nutrient-dense grains without making them any harder to use.

Finger millet (*Eleusine coracana*) is an important functional dietary ingredient due to its high calcium, fiber, and vitamin content [3]. Previous research has shown that millet-based formulations offer superior nutritional and functional qualities, such as increased water absorption capacity and improved rheological properties [4].

Moreover, it has been shown that the moderate addition of finger millet to beverage systems can improve the sensory appeal if properly adjusted [5]. Spices such as cardamom and cinnamon contribute flavour to food and have antioxidant and bioactive properties [6]. They may be added to cereal products to enhance the appeal to the consumer without detracting from their usefulness. However, few studies have investigated the physicochemical and sensory aspects of finger millet-based smoothie powders containing aromatic spices. As a result, the goal of this study was to create a finger millet-based smoothie powder with various degrees of milk powder and assess its nutritional, sensory, fragrance, and microbiological qualities.

Recent studies have explored finger millet-based beverages and powder formulations, reporting enhanced nutritional quality, antioxidant activity and sensory acceptability when blended with natural flavourings, legumes and milk powder [7,8]. Also, it has been shown that the addition of spices in millet-based products enhances their phenolic content and antioxidant potential, which further advocates their development as functional foods [9]. For instance, smoothie powders offer benefits such as longer shelf life, ease of preparation, and convenience that cater to the requirements of contemporary eating habits.

Thus, the formulation and evaluation of finger millet-based smoothie powder fortified with aromatic spices is a promising approach for the development of functional, practical and nutritionally enriched food product.

2 Materials and methods

2.1 Raw materials

Finger millet grains, milk powder, cinnamon, cardamom, sugar and salt were purchased from local markets in Godagama, Sri Lanka.

2.1.1 Preparation of raw materials

After cleaning, the finger millet grains were pan-roasted while being stirred all the time until they smelt different. The roasted grains were ground in a machine grinder and then sifted to make fine flour after they had cooled to room temperature. We cleaned the cinnamon and cardamom, ground them into small powders, and then sieved them to make sure they were all the same size.

2.2 Formulation of Smoothie Powder

Table 1. Formulations of Finger millet-based smoothie powder with aromatic spices.

Ingredients (g)	T_1 (Control)	T_2	T_3	T_4	T_5
Finger millet flour	0	20	40	60	80
Milk powder	120	100	80	60	40
Cardamom	4	4	4	4	4
Cinnamon	4	4	4	4	4
Sugar	20	20	20	20	20
Salt	2	2	2	2	2

Five formulations (T1–T5) were developed by changing the ratio of finger millet flour to milk powder while maintaining the same levels of cinnamon, cardamom, sugar, and salt in each treatment. The formulation data is shown in Table 1. Each ingredient was carefully weighed and mixed. A grinder was used to mix the mixture in order to obtain a uniform and homogenous powder.

2.3 Analysis of finger millet-based smoothie powder with aromatic spices

2.3.1 Sensory evaluation

50 mL of warm water (40–45 °C) was mixed with 25 g of smoothie powder to ensure sufficient solubility for the sensory assessment. The volume was adjusted to 100 mL and thoroughly mixed using potable water. After being refrigerated, the drinks were served at a constant temperature. Using a 7-point scale using hedonic scale (1 = detest very much; 7 = like very lot), thirty untrained panellists assessed colour, flavour, taste, texture, and overall acceptability. The 3-digit random numbers were deployed to code samples, which were then served in single-use cups.

2.3.2 Physicochemical, proximate and microbial analyses

Total soluble solids (TSS), bulk density, pH, water absorption capacity (WAC), and colour (L*, a*, b*) were all measured. AOAC protocols were used to measure the contents of moisture, protein, fat, fiber, and ash. Microbial quality was evaluated using the total plate count, yeast, and mold count.

2.4 Statistical analysis

Every measurement was done three times. One-way ANOVA was used to analyze the data at a significance level of $p = 0.05$. The Minitab software program was used for all statistical analyses.

3 Results and discussion

3.1 Sensory evaluation

The formulation containing 20 g finger millet flour (T2), which scored highly in terms of colour, flavour, taste, texture, and overall acceptability, demonstrated a higher level of

consumer preference. The sensory scores are shown in Figure 1. Significant differences ($p < 0.05$) existed between the treatments.

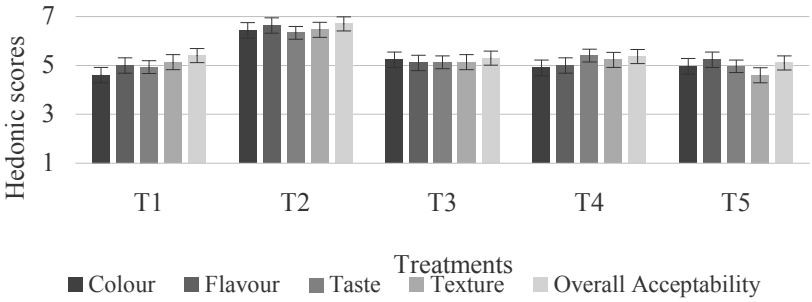

Fig. 1. Sensory scores of smoothie powder formulations.

Finger millet improved colour and flavour by adding a natural brown tone and a well-balanced cereal-milk profile. However, increasing finger millet above 20 g (T3-T5) resulted in lower sensory scores, possibly due to the richer cereal flavour and gritty texture. Similar trends have been seen in millet-based beverage formulations, where moderate inclusion increased acceptability while high levels negatively impacted texture and flavour [5,10]. Taking everything into account, the best balance between millet enrichment and sensory acceptance was achieved by adding 20 g of finger millet flour (T2).

3.2 Physicochemical analysis

The physicochemical properties of the smoothie powder formulations are presented in Tables 2 and 3. Significant differences ($p < 0.05$) were observed among treatments for all evaluated parameters.

Table 2. Physicochemical properties of finger millet-based smoothie powder with aromatic spices.

Treatment	Bulk density (g/cm^3)	Water Absorption Capacity (g/g)	Total Soluble Solids (°Brix)	p^H
T_1	0.45 ± 0.02^a	1.15 ± 0.05^e	19.76 ± 0.20^a	6.40 ± 0.05^e
T_2	0.58 ± 0.03^b	1.45 ± 0.02^d	17.63 ± 0.15^b	6.45 ± 0.02^d
T_3	0.62 ± 0.03^c	1.60 ± 0.03^c	16.50 ± 0.15^c	6.50 ± 0.02^c
T_4	0.65 ± 0.03^d	1.75 ± 0.03^b	15.80 ± 0.15^d	6.55 ± 0.02^b
T_5	0.68 ± 0.03^e	1.90 ± 0.03^a	15.20 ± 0.15^e	6.60 ± 0.02^a

Bulk density rose sharply from 0.45 to 0.68 g/cm³ as finger millet concentration increased. This is most likely due to finger millet's higher fiber and protein content, which reduces porosity and increases particle compactness. Comparable results have been reported for millet-based composite powders [4].

Water absorption capacity (WAC) increased significantly with higher finger millet inclusion (1.15-1.90 g/g). The increased WAC is due to the water-holding characteristics of millet starch and dietary fiber [11].

Total soluble solids (TSS) gradually declined from 19.76 to 15.20 °Brix with increased finger millet substitution due to the dilution of soluble solids from milk and the lower soluble sugar content in finger millet flour [11].

The pH values gradually increased from 6.40 (T1) to 6.60 (T5) with increasing finger millet. This increase could be due to the buffering effect and mineral content of finger millet flour, which have been reported to increase the pH of cereal-based milk blends [12].

Table 3. Colour parameters (L*, a*, b*) of finger millet-based smoothie powder with aromatic spices.

Treatment	Colour		
	L*	a*	b*
T_1	86.477 ± 0.005^a	1.853 ± 0.005^d	9.416 ± 0.005^a
T_2	82.973 ± 0.005^b	2.423 ± 0.005^c	8.816 ± 0.005^b
T_3	79.521 ± 0.005^c	3.050 ± 0.005^b	8.316 ± 0.005^c
T_4	75.842 ± 0.005^d	3.700 ± 0.005^b	7.816 ± 0.005^d
T_5	71.304 ± 0.005^e	4.250 ± 0.005^a	7.316 ± 0.005^e

The colour parameters showed a linear decrease in L* (lightness) and yellowness (b*) and a linear increase in redness (a*) with increasing finger millet concentration. This phenomenon is likely due to the natural colour and phenolic constituents of finger millet and is in line with other studies on millet-enriched products [13]. In summary, the bulk density, water absorption index, total soluble solids, pH and colour characteristics of the developed smoothie powder were significantly affected by finger millet.

3.3 Proximate analysis

Although a complete nutritional analysis (protein, fat, and fiber) was conducted for the control (T1) and the formulation (T2) that was selected to be the most appealing, based on sensory analysis, the approximate composition was calculated for moisture and ash content for all formulations. There was a slight trend of increasing moisture content (4.28-4.48%) with increasing finger millet levels (Table 4). The higher moisture content of the millet-enriched smoothie powder might be due to the water retention properties of finger millet starch and fibre [4].

Nonetheless, every result remained below 5%, indicating that the generated powder had excellent storage stability. According to Table 4, the ash concentration progressively decreased from 5.92% (T1) to 4.44% (T5), suggesting that milk powder provided more minerals than finger millet flour. Similar patterns have been seen in cereal-milk composite formulations, where the overall ash level was decreased by substituting dairy solids [13].

Table 4. Moisture and ash content of finger millet-based smoothie powder with aromatic spices

Treatment	Moisture content, (%)	Ash content, (%)
T_1	4.28 ± 0.00^e	5.92 ± 0.00^a
T_2	4.33 ± 0.00^d	5.55 ± 0.00^b
T_3	4.38 ± 0.00^c	5.18 ± 0.00^c
T_4	4.43 ± 0.00^b	4.81 ± 0.00^d
T_5	4.48 ± 0.00^a	4.44 ± 0.00^e

T1 had a slightly higher protein value (23.71%) than T2 (23.01%) because milk powder has more protein than finger millet flour. Similar reductions in protein content have been observed in composite formulations following the partial substitution of cereal flours for dairy solids [14]. In the same way, when low-lipid finger millet flour was used instead of milk fat, the fat content went from 20.82% (T1) to 17.50% (T2), which is what previous studies on cereal-milk blends found [14].

The fibre content of T2 (0.54%) was much higher than that of T1 (0.19%), which shows that adding finger millet made the food healthier. Finger millet is known for its high fibre content and usefulness in mixed food systems [4].

Table 5. Protein, fat, and fiber content of finger millet-based smoothie powder with aromatic spices.

Treatment	Protein content, %	Fat content, %	Fiber content, %
T_1	23.71 ± 0.02^a	20.82 ± 0.02^a	0.19 ± 0.00^b
T_2	23.01 ± 0.04^b	17.50 ± 0.00^b	0.54 ± 0.04^a

3.4 Microbial analysis

Table 6 shows how good the smoothie powders are for bacteria. T1 had the highest Total Plate Count (TPC), while T5 had the lowest. The values ranged from (0.50-1.70) × 10^2 CFU/g. The microbial load slowly went down as finger millet was added. The roasting method used to make finger millet flour, which kills vegetative microorganisms, may be why the TPC values are lower across all treatments. Also, cardamom and cinnamon have been shown to kill bacteria, so adding them may help lower the number of germs [15].

All treatments had yeast and mould counts that were too low to be seen (<1.0 × 10^2 CFU/g), which could be because the powders had very little moisture (<5%). Low moisture levels stop fungi from growing in powdered food systems. In general, all of the formulations had good processing and sanitary quality and were within the acceptable microbiological limits for powdered foods.

Table 6. Microbial quality of finger millet-based smoothie powder with aromatic spices.

Treatment	Total Plate Count (CFU/g)	Yeast and Mold Count (CFU/g)
T_1	$1.70 \pm 0.10 \times 10^2$	$<1.0 \times 10^2$
T_2	$1.20 \pm 0.10 \times 10^2$	$<1.0 \times 10^2$
T_3	$0.90 \pm 0.10 \times 10^2$	$<1.0 \times 10^2$
T_4	$0.70 \pm 0.10 \times 10^2$	$<1.0 \times 10^2$
T_5	$0.50 \pm 0.10 \times 10^2$	$<1.0 \times 10^2$

4 Conclusion

The present study revealed the feasibility of utilising underexploited cereal grains in value-added instant beverage products by successfully formulating and assessing a finger millet-based smoothie powder augmented with aromatic spices (cardamom and cinnamon). The partial substitution of milk powder with finger millet flour significantly influenced the sensory, physicochemical, nutritional, and microbiological characteristics of the resultant formulations. The treatment that worked best for sensory acceptability while keeping the desired functional properties, low moisture content, and microbiological safety was T2 (substituting 20 g of finger millet). Adding finger millet was very important because it increased the amount of dietary fibre and improved the nutritional quality without significantly lowering the protein levels or the stability of the product. These results show that finger millet could be a useful, sustainable ingredient for making creative food products that are easy to find. The smoothie powder made with climate-resilient crops in modern convenience meals is a promising way to use cereal in new ways, make it healthier, and support sustainable food system initiatives.

References

1. S. Mitharwal, S. Kumar, K. Chauhan, Nutritional, polyphenolic composition and in vitro digestibility of finger millet (Eleusine coracana L.) with its potential food applications: a review, Food Biosci. **44**, 101382 (2021). https://doi.org/10.1016/j.fbio.2021.101382
2. P. Kokisi, F. Nchu, L. Kambizi, C. Bvenura, Finger millet and soybean as functional ingredients in next-generation fermented foods: a review of nutritional, technological, and health-promoting perspectives, Front. Nutr. **13**, 1718090 (2026). https://doi.org/10.3389/fnut.2026.1718090
3. M.P. Zamancwane, O.P. Bamidele, S.A. Oyeyinka, J. Wilkin, O.A. Adebo, Enhancement of nutritional and functional properties in finger millet (Eleusine coracana) and cricket (Acheta domesticus) flours through traditional and novel processing methods, Int. J. Food Sci. Technol. **60**, 1 (2025). https://doi.org/10.1093/ijfood/vvaf056
4. S.E. Ramashia, E.T. Gwata, S. Meddows-Taylor, T.A. Anyasi, A.I.O. Jideani, Some physical and functional properties of finger millet (Eleusine coracana) obtained in sub-Saharan Africa, Food Res. Int. **104**, 110 (2018). https://doi.org/10.1016/j.foodres.2017.09.065
5. D. Agrahar-Murugkar, P. Bajpai-Dixit, N. Kotwaliwale, Rheological, nutritional, functional and sensory properties of millets and sprouted legume based beverages, J. Food Sci. Technol. **57**, 5 (2020). https://doi.org/10.1007/s13197-019-04200-y
6. N.E.T. Castillo, G.D. Teresa-Martínez, M. Alonzo-Macías, C. Téllez-Pérez, J. Rodríguez-Rodríguez, J.E. Sosa-Hernández, R. Parra-Saldívar, E.M. Melchor-Martínez, A. Cardador-Martínez, Antioxidant Activity and GC-MS Profile of Cardamom (Elettaria cardamomum) essential oil obtained by a combined extraction method-instant controlled pressure drop technology coupled with sonication, Molecules **28,** 3 (2023). https://doi.org/10.3390/molecules28031093
7. R. Kalsi, J. Bhasin, G. Goksen, P. Kashyap, Exploration of nutritional, pharmacological, and the processing trends for valorization of finger millet (Eleusine coracana): A review, Food Sci. Nutr. **11,** 11 (2023). https://doi.org/10.1002/fsn3.3659
8. N. Malleshi, S. Kannan, S.N. Malleshi, A. Manickavasagan, Finger Millet (Eleusine coracana) Malt: A Comprehensive Review of Its preparation, and Functional Properties, Nutritional Benefits, and Novel Food Product Formulations, Food Rev. Int. **42,** 3 (2026). https://doi.org/10.1080/87559129.2025.2515167
9. A. Chandrasekara, I. Senanayake, D. Kumari, F. Shahidi, Effect of processing on the antioxidant activities of porridges and Pittu prepared from finger millets (Eleusine coracana). Food Prod. Nutr. **18,** 4 (2022)
10. S. Shobana, R.P. Selvi, V. Kavitha, N. Gayathri, G. Geetha, R. Gayathri, P. Vijayalakshmi, K.K.G. Balasubramaniam, V. Ruchi, V. Sudha, R.M. Anjana, R. Unnikrishnan, N.G. Malleshi, C.J. Henry, K. Krishnaswamy, V. Mohan, Development and evaluation of nutritional, sensory and glycemic properties of finger millet ('Eleusine coracana'L.) based food products, Asia Pac. J. Clin. Nutr. **27**, 1 (2018). https://doi.org/10.6133/apjcn.032017.18
11. K.T. Murungweni, S.E. Ramashia, M.E. Mashau, Effect of malting on physicochemical, antioxidant, and microstructural properties of finger millet (Eleusine coracana) flours, Food Sci. Nutr. **12,** 1 (2023). https://doi.org/10.1002/fsn3.3790

12. J.O. Owheruo, B.O.T. Ifesan, A.O. Kolawole, Physicochemical properties of malted finger millet (Eleusine coracana) and pearl millet (Pennisetum glaucum), Food Sci. Nutr. **7,** 2 (2018). https://doi.org/10.1002/fsn3.816
13. J.E. Aisoni, M. Yusha'u, O.O. Orole, Greener, Fermented millet products across the globe: a bibliometric and systematic narrative review of potential health impact, J. Biol. Sci. **8**, 2 (2018). https://doi.org/10.15580/GJBS.2018.2.032018048
14. I. Mohammed Ali, S.F. Forsido, C.G. Kuyu, Discov, Nutritional quality and functional properties of finger millet, sweet potato, and soybean composite flour as affected by blending ratios, Food **4**, 1 (2024). https://doi.org/10.1007/s44187-024-00212-6
15. P. Ranasinghe, S. Pigera, G.A. Premakumara, P. Galappaththy, G.R. Constantine, P. Katulanda, Medicinal properties of 'true'cinnamon (Cinnamomum zeylanicum): a systematic review, BMC Complement. Altern. Med. **13,** 1 (2013). https://doi.org/10.1186/1472-6882-13-275