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Standardization of Ragi (*Eleusine coracana*) - Nendran banana (*Musa paradisiaca*) based infant weaning food and its effect on nutritional composition

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Abstract

Complementary food denotes a soft and easily digestible nutritional option that is appropriate for infants between the ages of 6 to 24 months. The present study aims to formulate infant weaning food premix using Ragi (*Eleusine coracana*), Nendran banana (*Musa paradisiaca*) (10%, 15% and 20% ratio), almonds, cashew nuts and cardamom. The product was assessed for its sensory, nutritional quality and storage stability. Results suggested that the most acceptable product was T₃ sample with 20% of raw banana powder, with its well-balanced combination of colour, taste, aroma, and texture. Infant weaning food premix shows higher content of protein (10.8%), ash (3.0%), crude fiber (3.8%) and moisture (18.31%) in comparison to control and pH indicates the moderate acidity appropriate for infant digestion. While slight decrease was presence of phytochemicals in T₃ sample (sterols, terpenoids, flavonoids, quinones, glycosides, tannins, cardiac glycosides) in comparison to control. In addition, the glass jar packaging enabled it to offer greater microbiological protection up to 7 days in treatment (T₃) sample. Findings suggest that weaning food developed with Ragi and raw banana powder is considered good in terms of protein, fat, carbohydrate, moisture, dietary fiber, energy and phytochemicals. Thus, the present study encourages the adoption of health-focused complementary feeding practices, paving the way for improved dietary choices that promote optimal growth and development in infants. The present study promotes healthy and safe infant complementary food development by focusing on naturally available and affordable raw materials which can be effectively used to pave the way for improved dietary choices that promote optimal growth and development in infants.

Keywords: Complementary food, Nendran banana, nutritional analysis, Ragi-banana-premix, supplementary nutrition

Introduction

A nutritious diet during infancy is critical for proper growth and development, helps establish taste preferences, and can influence long-term health outcomes. Complementary food denotes a soft and easily digestible nutritional option that is appropriate for infants between the ages of 6 to 24 months, in addition to breast milk^[14]. The World Health Organization (WHO) recommends that infants be exclusively breastfed for a minimum of 6 months, after which nutritious complementary foods should be introduced to promote healthy and optimal feeding. The recommended dietary allowance (RDA) sets the necessary nutrient guidelines that are crucial for the growth and development of infants during their first year of life. As babies mature, they gain the skill to chew and eventually incorporate a diverse array of complementary foods into their diet, moving beyond just liquid sustenance like breast milk. Presenting a mix of cereals, pulses, nuts, fruits, and vegetables during weaning can offer infants a balanced diet rich in essential calories and nutrients. The Estimated Average Requirements (EAR) for Indian children, as outlined by the ICMR-NIN in 2020, specify the nutritional needs for different age groups. For infants aged 0-6 months, with a reference weight of 5.8 kg, the daily energy requirement is 530 Kcal and the protein requirement is 7.0 g. As children grow into the 6-12 months age group, which has a reference weight of 8.5 kg, their energy needs increase to 680 Kcal and protein needs to 9.0 g each day. Additionally, essential minerals and vitamins are identified for the older infants, including Iron (2.1mg), Zinc (2.8 mg), Vitamin B12 (1µg), and Vitamin A (170 µg) daily. For children aged 1-3 years, with a reference weight of 12.9 kg, the daily energy requirements escalate to 1110

Kcal and protein needs to 10.0 g. This age group also necessitates 400 mg of Calcium, 73 mg of Magnesium, 97 µg of Folate, and 24 mg of Vitamin C each day [6]. During the weaning process, introducing a variety of cereals, legumes, nuts, fruits, and vegetables may give babies a diet that is well-rounded and delivers adequate calories and minerals [10].

Fruits are one of the most significant sources of vitamins and minerals, making them an essential part of the human diet. *Musa* species, which include plantains and bananas, are among the most important fruit crops in the world. In 2021, a total of 125 million tonnes of *Musa* species were produced worldwide, according to the report by the Food and Agriculture Organization (FAO) [9]. Nendran (*Musa paradisiaca*), one of the numerous varieties of this fruit, is regarded as the most nutritious type due to its high carbohydrate and dietary value. Despite bananas being low in fat and protein, they are an abundant source of energy since they contain sugars and carbs. The Nendran bananas have a relatively high amount of manganese, potassium, dietary fiber, carbs, and vitamin B6. In addition to its nutritional value, bananas are abundant in phytochemicals with potential medical uses. Phytochemicals such as phenolics, flavonoids, anthocyanins, carotenoids, sterols and triterpenes, stearyl glycosides, diarylheptanoids, phytoalexins, neurotransmitters, indoles, and amino acids are found in several *Musa taxa* varieties [16]. As a complementary nourishment preference, Nendran bananas are usually chosen since they boost weight gain and satisfy the nutrients required for a baby's growth and development. Finger millet (*Eleusine coracana* L.), referred to as African millet, is popularly known as Ragi in India. It possesses remarkable nutritional benefits and functional characteristics, making it more advantageous than other widely consumed cereals [11]. In various regions of India and parts of eastern and central Africa, Ragi flour, made from finger millet, is a fundamental dietary item. It boasts a high concentration of iron, calcium, potassium, phosphorus, protein, fiber, and vitamins. The calcium content in Ragi exceeds that found in most grains, and its iodine levels are commendable for various food grains. Ragi is rich in vitamin A, B, and phosphorus, as well as offering top-quality protein and essential amino acids [7]. Therefore, Ragi serves as a nutritious food choice for growing children, individuals with diabetes, those with chronic illnesses, pregnant women, and the elderly or injured. Additionally, Ragi flour has the highest levels of antioxidants, calcium, and phytochemicals, ensuring it is quickly or easily absorbed [8]. Introducing almonds, cashew nuts and cardamom alongside Ragi and banana further enhances the nutritional benefits of the resultant product creating a richer complementary food.

In short, weaning food plays a vital role in the growth of infants' physical, cognitive, and immune systems. Bananas and Ragi are abundant in minerals such as calcium, sodium, potassium, iron, as well as vitamins (B₁, B₂, B₃, B₆, and C). Adding cashew nuts, almonds, and cardamom to Ragi and banana further improves the nutritional value of the resulting product, creating a more enriching complementary food. The aim of the study was to formulate and assess the

sensory quality, nutritional composition, and microbial properties of infant weaning food premix.

Materials and Methods

Raw material

Samples for the present study i.e., raw nendran banana were purchased from Kozhikode, Kerala, India. Finger millet, almond, cashewnuts, cardamom, jaggery were purchased from the local market. The preparation of the Infant weaning food premix was prepared in the Departmental Laboratory of Food Nutrition, Babasaheb Bhimrao Ambedkar University Lucknow, Uttar Pradesh, India.

Table 1: Formulation of Ragi-banana based complementary premix

Premix	Standard	T ₁	T ₂	T ₃
Raw banana Powder	-	10 g	15 g	20 g
Finger millet	70 g	70 g	70 g	70 g
Almond	15 g	15 g	15 g	15 g
Cashew nut	10 g	10 g	10 g	10 g
Cardamom	5 g	5 g	5 g	5 g

Preparation of standard Ragi-banana complementary mixture

The preparation of the standard Ragi complementary mixture involves combining 70% finger millet powder, 15% almond powder, and 10% cashew nut powder, along with 5% cardamom powder. The moisture content of the ingredients is reduced through roasting. Using a mixer, the ingredients are processed into a fine powder. These ingredients are formulated to create a base for the final product. Raw banana powder was added to this conventional combination at three different percentages (10%, 15%, and 20%) in order to increase its nutritional content. Kabeer *et al.*, (2023) [10] reported differing degrees of banana (40, 45, 50g/100 g) inclusion in complementary meals showing possibilities for improvement. Once the raw banana powder is measured according to the desired variation, it is carefully incorporated into the standard mixture. After thorough mixing, the prepared Ragi-banana-based complementary mixture is ready for packaging. It is packed into an airtight container to maintain its freshness and to protect it from moisture and external contaminants.

Sensory evaluation

The organoleptic evaluation was conducted using a highly specialized composite sensory table, designed to provide precise and comprehensive sensory analysis. Semi trained panel of 20 members, carefully selected for their expertise and extensively trained in sensory evaluation techniques, carried out the process. This evaluation focused on assessing the sensory attributes of the standard sample, T₁, T₂, and T₃, taking into account specific criteria such as color, taste, aroma, and texture. Each sample overall score out of 100 was determined by adding the score for each characteristic. This made it possible to compare the sensory qualities of the experimental formulations with the control sample. The findings emphasised variations in color, taste, aroma, texture and offered important information about each formulation's general acceptance.

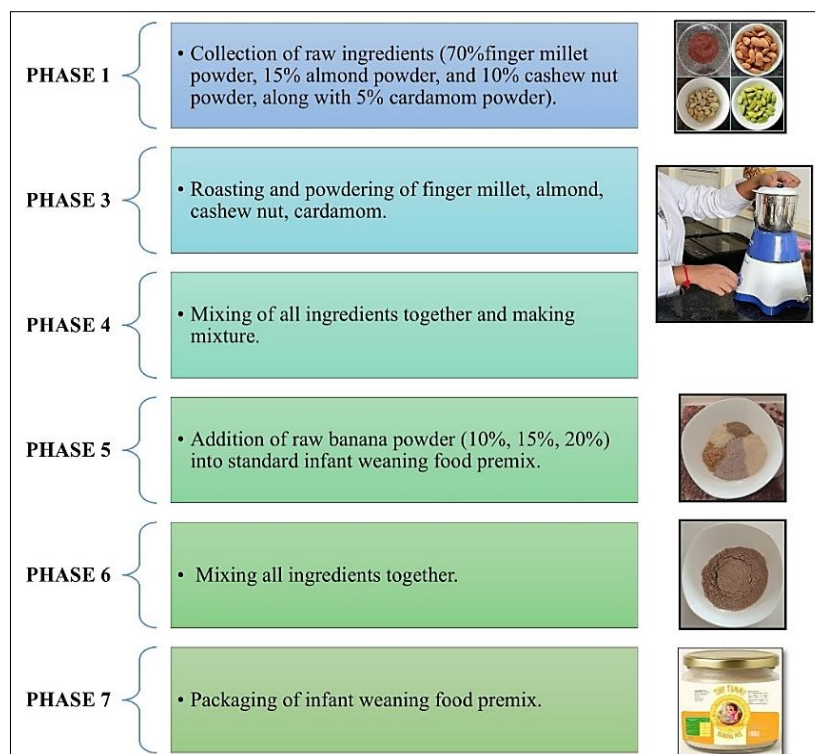


Fig 1: Preparation of Standard Ragi Complementary Premix

Proximate analysis

Proximate analysis was carried out on the developed complementary premix. The moisture content was assessed by drying samples at 105°C in a hot air oven until a stable weight was reached. Ash content was measured by incinerating the organic matter to quantify the remaining inorganic matter. The percentage of ash was computed based on the initial sample weight ^[1]. The protein content was assessed using the Kjeldahl method, which determines the nitrogen concentration of the sample. Protein amount was calculated by multiplying the nitrogen level by a conversion factor of 6.25. The crude fat content of the food sample was measured through Soxhlet extraction using a SOCS-PLUS apparatus with diethyl ether as the solvent. The fat percentage was derived from the weight difference of the beaker before and after extraction. The carbohydrate content was estimated using the difference method (SP 18 (P-6), 1981) by subtracting the collective sum of moisture, protein, fat, and ash contents from 100. Total energy content was calculated utilizing Atwater conversion factors: 4 kcal/g for carbohydrates and proteins, and 9 kcal/g for fat. Crude fiber was evaluated through the sequential acid and alkali hydrolysis (SAAH) method (AOAC). A 2 g sample that was free of fat and moisture was boiled with 0.128 M H₂SO₄, followed by 0.313 M NaOH, then filtered, dried, and ashed at 560 °C for 2 hours. The crude fiber percentage was calculated as $(W_1 - W_2) / W \times 100$. Each analysis was performed in triplicate, with values reported on a dry-weight basis.

Phytochemical analysis

Phytochemical analysis was done by using different methods to find out the presence of varieties of compounds such as flavonoids, alkaloids, tannins, sterols and saponins. Phytochemical analysis of the pectin extract was conducted using established methods. The presence of tannins was confirmed through the Ferric chloride (FeCl₃) test, which

resulted in a dark blue/green-black hue. Quinones were recognized with the concentrated sulfuric acid test, which produced a red coloration ^[4]. The presence of flavonoids was validated by the sodium hydroxide (NaOH) test, yielding a yellow color ^[1]. Saponins were identified through the froth test, demonstrating consistent froth formation. Glycosides were detected using the ammonia and chloroform test, which generated a pink color ^[4]. Sterols were confirmed through the chloroform and concentrated H₂SO₄ test, indicated by a reddish-brown ring. Alkaloids were identified using Mayer's reagent test, resulting in a green or white coloration ^[12].

pH and Total Soluble Solids (TSS)

Key physical characteristics, including pH and total soluble solids (TSS), of the chosen complementary premix were measured. The pH of the formulated product was evaluated with a pH meter, while the total soluble solids were assessed using a digital refractometer.

Shelf-life study

The shelf life of the product that was prepared was evaluated using the aerobic plate count method as outlined by AOAC. Buffered dilution water was created by dissolving KH₂PO₄ in distilled water, adjusting the pH to 7.2 with NaOH, autoclaving it, and then diluting as necessary. A volume of 1 mL from the test suspension was placed onto dry-film aerobic count plates, then the film was evenly spread to distribute the inoculum, and the gel was allowed to set for one minute. The plates were incubated at a temperature of 35 ± 1°C for 48 ± 3 hours, after which red-stained bacterial colonies were counted using either a colony counter or a magnifying glass. Counts of colonies ranging from 30 to 300 were recorded, and bacterial counts were determined by multiplying the average colony count by the reciprocal of the dilution factor.

Results and Discussion

Sensory evaluation

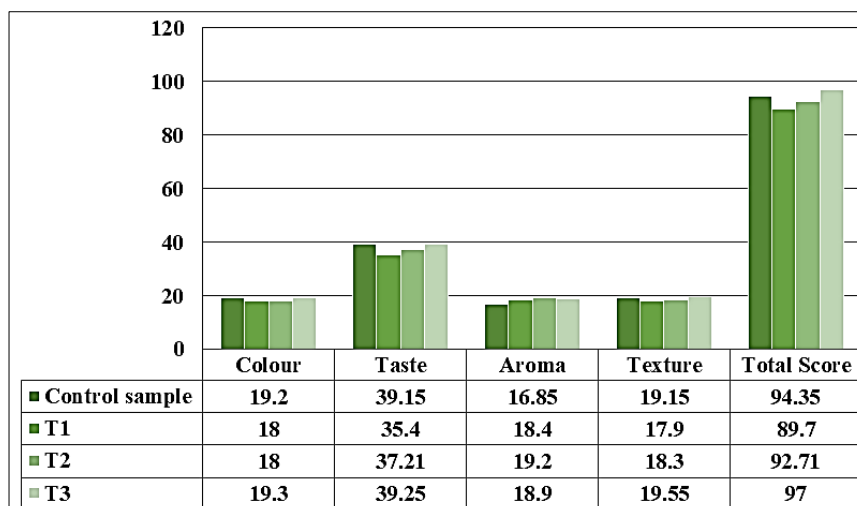


Fig 2: Sensory evaluation of control and treatment samples

The variations in sensory evaluation concerning the quality of Ragi-banana complementary premixes, where T_1 obtained the lowest total score of 89.7 out of 100 (Figure 2). T_1 recorded lower scores across all attributes when compared to both the standard premix and the other variants. Interestingly, T_2 achieved a notably higher score in aroma (19.2) in contrast to the other variants, leading to a total score of 92.71. However, T_3 stands out as the highest-scoring variant with a total score of 97, particularly excelling in Taste (39.25) and Texture (19.55). The results show T_3 provides the most favourable sensory experience among the assessed Ragi-banana complementary premixes, with its well-balanced combination of Colour, Taste, Aroma, and Texture. Thus, only the standard and T_3 sample were selected for further analysis in rest of the study.

Proximate analysis

The proximate analysis showed significant variations in the compositional characteristics of control sample and the T_3 sample. The moisture content was considerably greater in T_3 sample (18.31%) indicating a higher retention of water in the final formulation in comparison to the control sample. There was slight increase in ash (3%) and crude fiber (3.8%) content in comparison with control sample. There was a slight increase in protein (10.8%) and decrease in carbohydrate (57.49%), crude fat (10.8%) and energy (368.76 Kcal) in the T_3 sample. These findings indicate that the preparation process influenced the moisture, fat, carbohydrate, and energy levels, while slightly increasing the fiber and protein content.

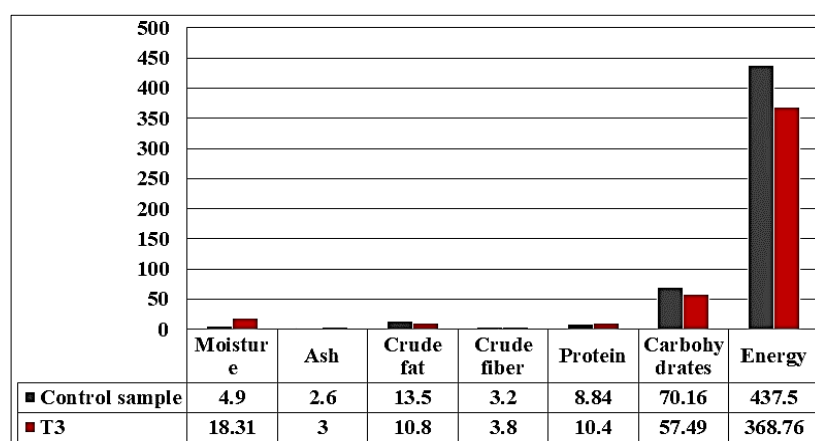


Fig 3: Proximate Analysis of control and Treatment (T_3) sample

Kabeer *et al.*, (2023)^[10] study also developed a Ragi-banana based complementary mixture with a different set of co-ingredients including whey protein, skimmed milk powder, and dates powder were 5 g/100 g, 10 g/100 g, and 10 g/100 g, respectively for this premix. The finding reported protein, fiber and fat content were 8.8 g/100 g, 2.39 g/100 g, and 7 g/100 g, respectively for this premix. These findings were inconsistent with the present study.

Phytochemical analysis

Table 2 shows similarities and differences when examining the components of the control sample and T_3 sample. Both formulations contain flavonoids, quinones, phenols, tannins, and glycosides without variation. However, the control sample includes sterols, while it was absent in T_3 sample. Furthermore, neither the control sample nor the T_3 sample contains saponin. These findings indicate that the control sample and the T_3 sample share certain elements, yet they also exhibit considerable differences.

Table 2: Phytochemicals constituents of control and treatment (T₃) sample

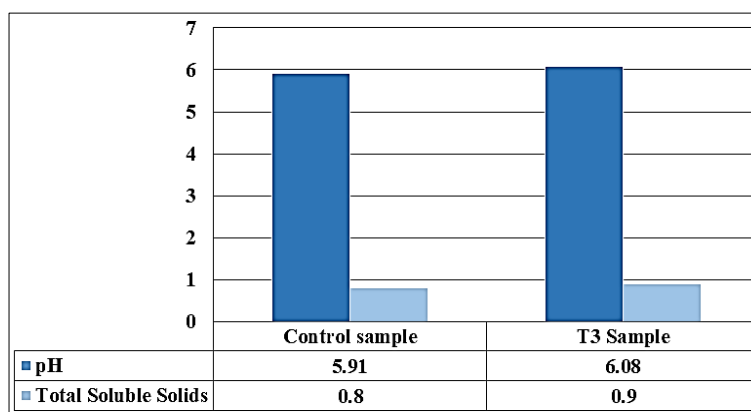
Constituents	Control Sample	T ₃ Sample
Sterols	+ve	-ve
Terpenoids	-ve	+ve
Flavonoids	+ve	+ve
Quinones	+ve	+ve
Glycosides	+ve	+ve
Tannins	+ve	+ve
Cardiac Glycosides	-ve	+ve
Saponins	-ve	-ve

* +ve- present; -ve- absent

pH levels and total soluble solids

The pH and total soluble solids levels of treatment (T₃) sample showed a slightly elevated value of pH of 6.08 and TSS of 0.9 °Brix, suggesting a small increase in alkalinity in comparison with control sample. These results imply that the preparation process made slight adjustments to both the acidity and the concentration of soluble solids, possibly highlighting changes in the chemical makeup or solute levels during product development. According to the study done by Kabeer *et al.*, in 2023^[10], the preliminary pH of the

formulated Ragi-banana weaning premixture was 6.19, which was remained acidic throughout the storage period. In present study also the pH of the Ragi-banana complementary premix shows a similar pH (6.08), which is slightly more acidic in nature. The slight variations are caused by differences in the formulation of ingredients and processing techniques. Since infants' digestive systems remain under development, mildly acidic nourishment is simpler for them to digest.

**Fig 4:** Physicochemical analysis of control and treatment (T₃) sample.

Shelf life study

Treatment sample (T₃) and control was assessed for microbial growth as part of the shelf-life study. The plates were incubated for a duration of 168 hours, and the Total Plate Count (TPC) technique was utilized to ascertain the number of Colony Forming Units (CFU). Throughout the entire incubation period, microbial growth was detected, resulting in a measurement of 5.1×10^2 CFU/ml in the treatment sample which was a slight increase in comparison to control sample (Table 3). Both the samples remained microbiologically safe and stable for up to 7 days under ambient storage conditions, with microbial counts well within acceptable limits as per regulatory standards of Food Adulteration Act (India).

Table 3: Shelf-life study of control and treatment (T₃) sample

Incubation Period	Control	APC (CFU/g)
Day 0	1×10^2	1.2×10^2
Day 3	2.2×10^2	2.5×10^2
Day 7	4.5×10^2	5.1×10^2

In a study by Jadhavar *et al.*, 2022, developed a Ragi based complementary mixture with a different set of co-ingredients including rice and green gram. This premix was packed in a low-density polyethylene pouche showed a gradual rise in microbial growth over time. It reported plate

counts were Standard plate counts were 8×10^2 , 10×10^2 , and 12×10^2 CFU/g on days 1, 60, and 120, respectively. The results showed modest microbial multiplication during storage, even these values were still considerably below the Prevention of Food Adulteration Act (India) permitted limit of 4×10^4 CFU/g. On the other hand, the Ragi-banana premix was maintained and packed in sealed glass containers, which reported considerably lower count of 5.1×10^2 CFU/ml and was constant over the duration of the study. The enhanced microbial safety is due to the better barrier properties of glass packaging, which is successfully prevented microbial entrance and moisture absorption, also the roasting procedure of ingredients, which decreased the initial microbial load and water activity which will help in preventing the growth of microorganisms.

Conclusion

This study explores the viability of Ragi-banana mixture as a safe and effective supplementary food alternative for infants. The T₃ sample created during this research exhibited concordance with the dietary need of infants for a healthy upbringing showcasing notable rise in protein, fibre and mineral content. The sensory characteristics of the product were identified to be widely acceptable among consumers, especially among infants. Importantly, the product adheres to the Recommended Dietary Allowances

(RDA) for all essential nutrients (properly fortified), underlining its adequacy in supporting infant growth and development. Despite the lack of adulterants of artificial preservatives, as commonly seen in currently available infant complementary foods, the microbial tests of the mixture exhibited a decent shelf-life period throughout which the mixture will maintain acceptable nutritive quality. This indicates to the fact that natural ingredients can be effectively utilised in nutrition to develop highly beneficial complexes of benignant nature. This can be made possible through careful formulation and strong quality control measures, as employed in this study. The developed formulation revealed both nutritional and functional enhancements over previously conducted research studies, including a higher content of protein, fat, and fibre, improved microbiological safety due to glass jar storage, and a pH compatible with prior findings. This product highlights the scope of future studies and developments in infant nutrition through effective use of naturally available and affordable raw ingredients.

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