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Storage Stability and Quality Assessment of Red Banana (Musa acuminata) Complementary Powder Using Microbial, Antioxidant, and Organoleptic Parameters

Research Article

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Abstract

Complementary feeding plays a crucial role in meeting the nutritional requirements of infants after six months of age. The present study aimed to develop and evaluate a value-added Red Banana (Musa acuminata) complementary powder and assess its storage stability, antioxidant activity, microbiological quality, and organoleptic acceptability. The complementary powder was formulated using finger millet (16%), rice (24%), soybean (8%), pigeon pea (8%), green gram (8%), Bengal gram (8%), cashew nut (4%), almond (4%), and red banana powder (20%). The ingredients were processed, blended, and packaged in food-grade laminated polyethene pouches under hygienic conditions.

Storage studies were conducted under room temperature for 60 days, and samples were analysed at 0, 30, and 60 days for Total Colony Count (TCC), Fungal/Mould count, DPPH antioxidant activity, and sensory attributes. Organoleptic evaluation was carried out using a 9-point hedonic scale by a panel of 30–40 semi-trained and trained members.

Results indicated that the Total Colony Count increased marginally from 0.06×10^{-4} CFU/g at day 0 to 0.16×10^{-4} CFU/g at day 60, while Fungal/mould growth was not detected at 0 and 30 days and remained extremely low (0.02×10^{-4} CFU/g) at 60 days, demonstrating good microbial stability during storage. Antioxidant activity showed a slight decline from 47.62% to 45.03% DPPH inhibition during the storage period. Statistical analysis revealed that these changes were non-significant ($p > 0.05$). Organoleptic evaluation demonstrated good consumer acceptability, with overall acceptability scores ranging from 7.52 to 7.87 throughout storage. No significant differences were observed in appearance, colour, flavour, texture, taste, or overall acceptability during the study period.

The findings suggest that Red Dacca Banana Complementary Powder is a nutritionally enriched, microbiologically safe, antioxidant-rich, and consumer-acceptable complementary food with satisfactory storage stability for up to 60 days under room temperature.

Keywords: Red Dacca banana; *Musa acuminata*; complementary food; storage stability; antioxidant activity; organoleptic evaluation; infant nutrition.

Abbreviations

RBCP – Red Banana Complementary Powder; TCC – Total Colony Count; CFU/g – Colony Forming Units per Gram; DPPH – 2,2-Diphenyl-1-picrylhydrazyl; PDA – Potato Dextrose Agar; PCA – Plate Count Agar; SEM – Standard Error of Mean; CD – Critical Difference; CV – Coefficient of Variation; ANOVA – Analysis of Variance; NS – Non-Significant; GI – Geographical Indication; FAO – Food and Agriculture Organisation; WHO – World Health Organisation; UNICEF – United Nations Children's Fund; FSSAI – Food Safety and Standards Authority of India

Novelty of the Study

The novelty of this study lies in the development of a complementary powder incorporating GI-tagged Kamalapura Red

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Dacca Banana (*Musa acuminata*), which has not previously been reported in complementary food formulations. Unlike conventional complementary foods developed primarily from cereals and legumes, the present formulation utilizes Kamalapura Red Dacca Banana powder as a functional ingredient, thereby enhancing the nutritional and antioxidant profile of the product. Previous studies have reported that Red Dacca banana is rich in bioactive compounds, minerals, and antioxidant constituents (Amarasinghe et al., 2021; Tuárez-García et al., 2023; Avci et al., 2026). In the present study, Kamalapura Red Dacca Banana powder was characterized by high concentrations of potassium (1119.52 mg/100 g), magnesium (113.25 mg/100 g), zinc (7.22 mg/100 g), calcium (5.30 mg/100 g), manganese (1.25 mg/100 g), and iron (0.74 mg/100 g), together with significant antioxidant potential. These nutrients are essential for infant growth, bone mineralization, cognitive development, immune function, and overall physiological development. Therefore, the incorporation of this GI-tagged indigenous banana cultivar not only improves the nutritional and functional quality of the complementary powder but also promotes the value addition and utilization of a region-specific banana variety in infant nutrition.

Introduction

The complementary feeding period, which begins at six months of age, is a critical stage in infant growth and development. It is also the period during which malnutrition commonly begins in many children, contributing significantly to the high prevalence of undernutrition among children under five years of age worldwide. Poor infant feeding practices, inadequate nutrient intake, and the lack of suitable complementary foods are major factors responsible for childhood malnutrition, particularly in developing countries where poverty further aggravates the problem [1]. Infants aged 6–24 months are considered nutritionally vulnerable because of their high energy and nutrient requirements, which are often not adequately met by traditional complementary foods. This vulnerable period is further challenged by repeated infections, poor infant and young child feeding practices, and the consumption of complementary foods with low nutrient density [2]

Recognising the importance of appropriate complementary feeding, the Food and Agriculture Organisation (FAO), World Health Organisation (WHO), and United Nations Children's Fund (UNICEF) have emphasised the development and utilisation of complementary foods based on locally available ingredients. Such foods should possess high nutritional value to supplement breastfeeding, be acceptable to consumers, affordable, and easy to prepare at the household level [3.4,5]. The involvement of mothers in the formulation and acceptability evaluation of complementary foods has also been shown to improve nutrition knowledge and encourage positive dietary practices for young children [6].

Cereals, pulses, and nuts are commonly incorporated into complementary food formulations because they provide essential macronutrients and micronutrients required for infant growth. Finger millet (*Eleusine coracana*) is an excellent source of calcium and dietary fibre, while soybean (*Glycine max*) contributes high-quality protein and essential amino acids. Pulses such as pigeon pea, green gram, and Bengal gram enhance the protein, mineral, and bioactive compound content of complementary foods. Similarly, nuts such as cashew and almond improve the energy density and nutritional quality of infant food formulations [7].

Banana (*Musa acuminata*) is one of the most widely consumed fruits in tropical regions and is valued for its nutritional and functional properties. Among its cultivars, the GI-tagged Kamalapura Red Banana (Red Dacca) is particularly noteworthy due to its rich content of potassium, calcium, dietary fibre, carotenoids, vitamins, phenolic compounds, and natural antioxidants. These nutrients play an important role in supporting healthy growth, bone development, immune function, and overall well-being in infants and young children [8]. In addition, red banana possesses natural sweetness and desirable sensory characteristics that can enhance the acceptability of complementary foods. When combined with protein-rich ingredients such as cereals, pulses, and nuts, red banana can contribute to the development of a nutritionally balanced complementary food capable of meeting the dietary needs of growing children.

Processing red banana into powder form facilitates its incorporation into complementary food formulations, improves convenience, reduces preparation time for mothers, and enhances storage stability. However, the quality and safety of such products during storage must be carefully evaluated. Changes in microbial load, including total colony count (TCC) and Fungal/Mould growth, as well as reductions in antioxidant activity, may affect product quality and consumer acceptance over time. Therefore, assessment of storage stability under ordinary household conditions is essential to determine the shelf life and suitability of the product for regular use.

The present study was undertaken to develop a value-added red banana complementary powder using GI-tagged Kamalapura Red Banana along with nutrient-rich cereal, pulse, and nut ingredients. The study focused on evaluating the organoleptic properties of the developed complementary food, including appearance, colour, flavour, texture, taste, and overall acceptability, for children above six months to five years of age. In addition, the storage stability of the red banana complementary powder was assessed at room temperature under household conditions through microbiological analysis, including total colony count and Fungal/Mould count, as well as determination of DPPH antioxidant activity, to identify a storage period that maintains product quality, safety, nutritional value, and consumer acceptability.

Materials and Methods

Sample preparation and packaging

The complementary powder was formulated using finger millet (16%), rice (24%), soybean (8%), pigeon pea (8%), green gram (8%), Bengal gram (8%), cashew nut (4%), and almond (4%) (Table.1). The ingredients were cleaned thoroughly to remove extraneous matter and impurities. Finger millet, rice, soybean, pigeon pea, green gram,

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Table 1: Ingredients and quantity of red banana complementary powder .

Ingredient	Quantity (g) in 100 g Product	Percentage (%)
Finger millet	16	16
Rice	24	24
Soybean	8	8
Pigeon pea	8	8
Green gram	8	8
Bengal gram	8	8
Cashew nut	4	4
Almond	4	4
Red banana powder	20	20
Total	**100 g**	**100 %**

Table 2: The storage study and time interval of **Red Banana Complementary Powder**.

Code	Time Interval	Parameters of Analysis
RBCP–0	0 Day	TCC; Fungal/Mould Count; DPPH; Organoleptic evaluation
RBCP–30	30 Days	TCC; Fungal/Mould Count; DPPH; Organoleptic evaluation
RBCP–60	60 Days	TCC; Fungal/Mould Count; DPPH; Organoleptic evaluation

and Bengal gram were roasted separately to enhance flavour, improve digestibility, and reduce moisture content. Cashew nuts and almonds were lightly roasted to develop desirable sensory characteristics.

The roasted ingredients were ground individually into fine flour and sieved through a fine mesh sieve to obtain a uniform particle size. The flours were then blended according to the formulation to prepare the complementary powder (80 g). Red banana powder (20 g), prepared from ripe Red Dacca banana (Musa acuminata) fruits by washing, peeling, slicing, dehydration, and pulverisation, was incorporated into the complementary powder to obtain a final product weight of 100 g. The mixture was thoroughly homogenised to ensure uniform distribution of all ingredients.

Packaging

The prepared red banana complementary powder was packed in food-grade laminated polyethene pouches and heat-sealed to prevent moisture absorption and microbial contamination. The packaged samples were labelled and stored at room temperature for subsequent storage studies, microbial analysis, antioxidant evaluation, and organoleptic assessment. All processing and packaging operations were carried out under hygienic laboratory conditions to maintain product quality and safety throughout the study.

Storage Study of Red Banana Complementary Powder

The developed red banana complementary powder was packed in a polythene cover for storage studies. The packages were coded as RBCP-0, RBCP-30 and RBCP-60 (Table 2). The developed complementary powder was packaged in airtight, food-grade, laminated polyethene pouches and stored at ambient room temperature (27 ± 2°C).

The packaged samples were evaluated at regular intervals of 0, 30, and 60 days to assess their storage stability and quality characteristics. At each storage interval, the samples were analysed for microbiological quality, antioxidant activity, and sensory attributes. Microbiological analyses included Total Colony Count (TCC) and Fungal/Mould Count. Antioxidant activity was determined using the DPPH radical scavenging assay. Sensory quality was assessed through organoleptic evaluation based on appearance, colour, flavour, texture, taste, and overall acceptability (Figure 1).

The analysis of the storage study of Red Banana Complementary Powder was carried out at the Bio Chem Research and Testing Laboratory, Vijaypuri Colony, Tarnaka, Hyderabad – 500017, Telangana. The laboratory operates under the incubation support of KRISHIK-ABI (ICAR RKVY-RAFTAAR), University of Agricultural Sciences, Dharwad.

Total Colony Count (TCC)

Total Colony Count (TCC) was determined using the pour plate technique as described by FSSAI (2016). Serial dilutions of the sample were prepared in sterile diluent, and 1 mL aliquots were plated in duplicate using Plate Count Agar (PCA). The plates were incubated at 35 ± 2°C for 48 h, after which visible colonies were counted. Results were expressed as colony-forming units per gram (CFU/g) of sample. The method was employed to assess the microbiological quality and safety of the complementary powder during storage [9].

Fungal/Mould Count

Fungal and mould counts were estimated using acidified Potato Dextrose Agar (PDA) following the procedure outlined by FSSAI (2016). Appropriate dilutions of the sample were plated in duplicate and incubated at 25°C for 2–5 days. Developed fungal colonies were counted and expressed as CFU/g. The analysis was carried out to evaluate the microbial stability of the product during storage. Results were recorded at predetermined storage intervals [9].

DPPH Radical Scavenging Activity

The antioxidant activity of the samples was determined using the DPPH radical scavenging assay [10]. Sample extracts prepared in methanol were reacted with DPPH solution, and absorbance was measured at 515 nm. Antioxidant activity was expressed as the percentage inhibition of DPPH radicals. The assay was used to

Figure 1: Storage Study of Red Dacca Banana Complementary Powder (RBCP).

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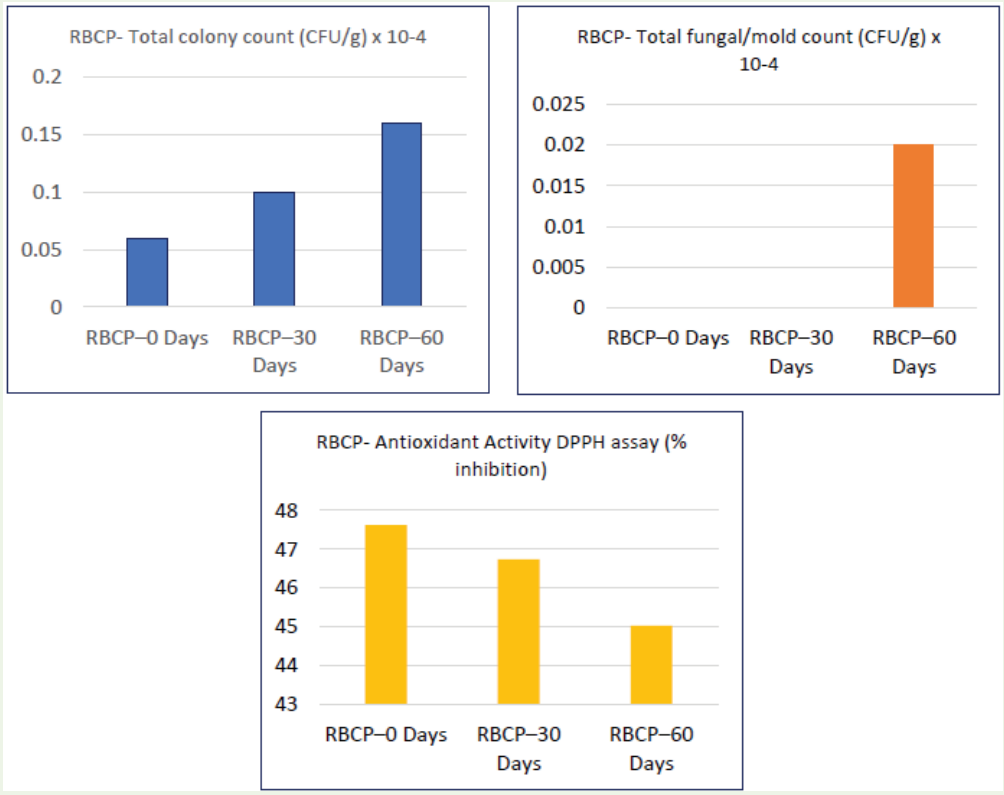

Figure 2: Analysis of Storage Study of Red Banana Complementary Powder (RBCP).

Table 3: Analysis of Storage Study of Red Dacca Banana Complementary Powder (RBCP).

Sl no	Parameters	RBCP–0 Days	RBCP–30 Days	RBCP–60 Days	mean	CD at 5%	Significance
1	Total colony count (CFU/g) x 10^{-4}	0.06	0.1	0.16	0.11	117.23	NS
2	Total Fungal/Mould count (CFU/g) x 10^{-4}	0	0	0.02	0.01	430.3	NS
3	Antioxidant Activity DPPH assay (% inhibition)	47.62	46.74	45.03	46.46	7.05	NS

*= Significant, NS=non-significant.

evaluate the free radical scavenging potential of the red banana complementary powder during storage. Higher percentage inhibition indicated greater antioxidant activity [10].

Organoleptic Evaluation

Organoleptic evaluation of the developed complementary powder was carried out using a 9-point hedonic scale by a panel of 35 members comprising trained and semi-trained participants, i.e. healthy adult volunteers including professors, lecturers, Ph.D. scholars, and postgraduate students from the Department of Food Processing and Nutrition, Karnataka State Akkamahadevi Women's University, Vijayapura. The samples were evaluated for appearance, colour, flavour, texture, taste, and overall acceptability. Sensory evaluation was conducted at different storage intervals to assess consumer acceptability and monitor changes in product quality throughout the storage period.

Statistical analysis

All experimental data were analysed using IBM SPSS Statistics for Windows, Version 20.0 [11]. Results are expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was performed to determine significant differences among storage intervals. Prior to ANOVA, the assumptions of normality and homogeneity of variances were assessed. Statistical significance was considered at $p < 0.05$, and results with $p > 0.05$ were regarded as non-significant [12]. Where appropriate, 95% confidence intervals (CI) were calculated and reported to indicate the precision of the estimated mean values.

Results and Discussion

The storage stability of Red Dacca Banana Complementary Powder (RBCP) was evaluated over a period of 60 days by assessing microbiological quality, antioxidant activity, and organoleptic

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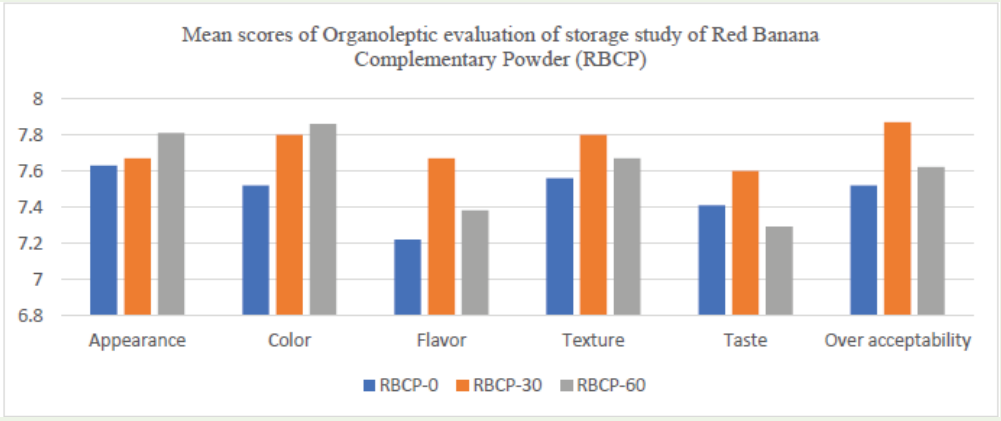

Figure 3: Mean scores of Organoleptic evaluations of storage study of Red Banana Complementary Powder (RBCP).

Table 4: Mean scores of Organoleptic evaluations of storage study of Red Dacca Banana Complementary Powder (RBCP).

Products Variations	Mean scores of Organoleptic evaluations of storage study of Red Dacca Banana Complementary Powder (RBCP)					
	Appearance	Colour	Flavour	Texture	Taste	Over acceptability
RBCP-0	7.63	7.52	7.22	7.56	7.41	7.52
RBCP-30	7.67	7.8	7.67	7.8	7.6	7.87
RBCP-60	7.81	7.86	7.38	7.67	7.29	7.62
SEM	0.71	1.36	1.77	0.90	1.21	1.36
CD at 5%	3.05	5.85	7.61	3.87	5.21	5.85
CV (%)	1.23	2.35	3.07	1.56	2.10	2.35
F value	0.247	0.904	0.706	0.284	0.349	0.894
P value	0.782	0.411	0.49	0.75	0.707	0.41
Remark	N	N	N	N	N	N

characteristics. As presented in Table 3, the total colony count increased marginally from 0.06×10^{-4} CFU/g at day 0 to 0.16×10^{-4} CFU/g at day 60, while the fungal/mould count remained negligible, with only 0.02×10^{-4} CFU/g detected at the end of storage. These values are substantially lower than the microbiological limits prescribed by the Food Safety and Standards Authority of India (FSSAI) and the Codex Alimentarius Commission for cereal-based complementary foods, which recommend a total plate count not exceeding 10^4–10^5 CFU/g and yeast and mould counts below 10^2 CFU/g, depending on the product category [17, 18]. Therefore, the developed complementary powder complied with acceptable microbiological safety standards throughout the storage period. The low microbial load may be attributed to the low moisture content of the formulation, hygienic processing practices, and storage in airtight food-grade laminated polyethylene pouches. Furthermore, the formulation was prepared without the incorporation of chemical preservatives or synthetic additives, demonstrating that appropriate processing and packaging were sufficient to maintain microbiological safety and product quality for at least 60 days. Similar findings have been reported for banana-based and cereal–legume complementary foods, where proper drying and suitable packaging effectively minimized microbial growth during storage [13, 14].

These findings are consistent with previous studies on banana-based complementary foods, which reported low microbial counts during storage when products were properly dried and packaged [14]. Similar observations have also been reported for cereal–legume complementary foods, where reduced moisture content and suitable packaging effectively limited microbial proliferation during storage [13, 15]. Although commercially produced complementary foods may achieve longer shelf life through the use of approved preservatives or advanced packaging technologies, the present study demonstrates satisfactory storage stability under natural preservation conditions.

The antioxidant activity determined by the DPPH assay showed only a slight reduction from 47.62% at day 0 to 45.03% at day 60, with the differences being statistically non-significant ($p > 0.05$) (Figure 2). The retention of antioxidant activity suggests that the bioactive compounds present in Red Dacca banana remained relatively stable during storage. The Red Dacca banana retains considerable antioxidant activity because of its phenolic compounds and flavonoids, although a slight decline may occur during storage or processing [14,16].

The organoleptic evaluation demonstrated that RBCP maintained good sensory quality throughout the storage period (Table 4; Figure 3). A slight increase in overall acceptability was observed at 30 days (7.87) compared with the initial score (7.52), followed by a marginal decrease at 60 days (7.62). However, all sensory attributes, including appearance, colour, flavour, texture, taste, and overall acceptability,

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showed no significant differences ($p > 0.05$) during storage. The stable sensory scores indicate that storage under ambient conditions did not adversely affect consumer acceptability. Similar findings have been reported for complementary foods prepared from cereal–legume blends and banana flour, where acceptable sensory quality was maintained during storage due to proper packaging and low moisture content [14,15].

Overall, the results demonstrate that the developed Red Dacca Banana Complementary Powder remained microbiologically safe, retained substantial antioxidant activity, and maintained acceptable sensory quality throughout 60 days of storage without the addition of chemical preservatives. These findings support the potential application of GI-tagged Kamalapura Red Dacca banana as a functional ingredient in naturally preserved complementary foods for infants. Nevertheless, further studies evaluating extended storage periods (90–180 days) under controlled environmental conditions and commercial packaging systems are recommended to establish the product's long-term shelf life.

Conclusion

The present study demonstrated that the developed Red Dacca Banana Complementary Powder (RBCP) possesses good storage stability, microbiological safety, antioxidant potential, and sensory acceptability during 60 days of storage under room temperature. The Total Colony Count and Fungal/Mould Count remained within acceptable limits throughout the storage period, indicating the effectiveness of the packaging and hygienic processing practices. Antioxidant activity, as determined by the DPPH assay, showed only a slight decline during storage, suggesting that the product retained a substantial proportion of its bioactive compounds.

Organoleptic evaluation revealed that the sensory attributes, including appearance, colour, flavour, texture, taste, and overall acceptability, were maintained throughout the storage period with no significant differences ($p > 0.05$). The product received favourable acceptance scores from the sensory panel, indicating its suitability as a value-added complementary food for infants.

Overall, the findings suggest that Red Dacca Banana Complementary Powder is a nutritionally enriched, microbiologically safe, and consumer-acceptable complementary food product with a storage stability of at least 60 days under room temperature. The incorporation of red banana powder enhanced the functional properties of the product while maintaining desirable sensory quality, making it a promising complementary food formulation for infant nutrition.

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