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Development of Millet-Based Ready-to-Eat (RTE) and Ready-to-Cook (RTC) Food Products in the Indian Market: A Comparative Nutritional and Consumer Perception Analysis

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Abstract

The escalating consumer demand for health-oriented, convenient food alternatives in India has stimulated considerable growth in millet-based Ready-to-Eat (RTE) and Ready-to-Cook (RTC) food segments. This study aimed to conduct a comparative assessment of the nutritional profile and consumer perception of traditional millet-based foods versus commercially processed RTE products. Three finger millet (Eleusine coracana) food items were selected: two traditional preparations — Ragi Mudde and Ragi Roti — and one commercial RTE product, Soulfull Chocofills. Standardized proximate analyses for calcium, iron, protein, carbohydrate, and fat were performed (per 100 g sample) using AOAC (2005) methods in an accredited food laboratory. A structured consumer perception survey was administered to 384 volunteer participants (286 male; 98 female; age 18–50 years) using a five-point Likert scale to assess taste, texture, convenience, health perception, and purchase intent. Results indicated that traditional Ragi Mudde and Ragi Roti contained significantly higher calcium (344 mg and 320 mg, respectively) and iron (4.2 mg and 3.8 mg, respectively) compared to the RTE product (210 mg calcium; 2.1 mg iron). Conversely, consumer acceptance was markedly higher for the RTE product with respect to taste (89%) and convenience (95%), whereas traditional foods were considered more health-promoting (91%). These findings underscore the nutritional trade-off inherent in food processing and highlight the critical need for nutrient-fortification strategies in millet-based RTE products to align convenience food consumption with public health nutrition objectives.

Keywords: Finger millet; Ragi; Ready-to-Eat foods; Ready-to-Cook foods; Nutritional quality; Consumer perception; Millet-based products; Food processing; Eleusine coracana.

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1. INTRODUCTION

The global food landscape is undergoing a paradigm shift driven by rapid urbanization, rising disposable incomes, and an evolving awareness of diet–disease relationships. In India, this transformation is particularly pronounced, as consumers increasingly seek food products that reconcile nutritional quality

with modern lifestyle demands for convenience, palatability, and shelf stability (Sharma & Kapoor, 2017). Millets, a diverse group of small-seeded cereal grains belonging to the *Poaceae* family, have re-emerged as nutritionally superior staples capable of addressing several public health challenges, including protein–energy malnutrition, micronutrient deficiencies, and the rising burden of non-communicable diseases (Devi et al., 2014; Gupta et al., 2018).

Among millets, finger millet (*Eleusine coracana* L.), locally known as Ragi, stands out for its exceptional micronutrient composition — particularly calcium content (ranging from 300–400 mg/100 g), dietary fiber, and polyphenolic antioxidants — making it an especially valuable dietary component for vulnerable population groups including children, lactating mothers, the elderly, and individuals with metabolic disorders (Devi et al., 2014; Saleh et al., 2013). Traditional South Indian communities have long incorporated finger millet into their daily diets through preparations such as Ragi Mudde (steamed dumpling), Ragi Roti (flatbread), and Ambali (thin gruel), each characterized by distinct textural and organoleptic properties and proven nutritional benefits.

Simultaneously, India's packaged food industry has witnessed exponential growth, with its market size estimated at USD 15 billion and projections indicating expansion at a Compound Annual Growth Rate (CAGR) of 15–20% (FICCI-PwC, 2016). The Indian health and wellness food market, valued at ₹435 billion in 2013, has been growing at an annual rate of approximately 13.8% (FICCI-PwC, 2016). This expansion has been catalyzed by changing consumption patterns — particularly among dual-income households, the urban middle class, and the younger demographic — and has prompted Fast-Moving Consumer Goods (FMCG) manufacturers to leverage the nutritional reputation of millets by launching RTE and RTC product variants. However, food processing invariably involves thermal, mechanical, and chemical interventions that may compromise the bioavailability and concentration of heat-sensitive nutrients (Singh et al., 2020; Chandel et al., 2021).

A critical knowledge gap exists in the comparative nutritional literature: while the intrinsic nutritional properties of raw finger millet have been extensively documented (Kumar et al., 2018; Saleh et al., 2013), few studies have empirically compared the nutritional composition of processed millet-based RTE foods with their traditional counterparts as consumed. Furthermore, consumer perception studies in the Indian context remain limited, particularly those examining whether consumers correctly appraise the relative health value of traditional versus processed millet foods. This gap is especially significant given the aggressive marketing claims made by RTE food manufacturers regarding the nutritional equivalence of their products to traditionally prepared millets.

The present study addresses these gaps by: (1) quantitatively comparing the proximate nutrient composition of two traditional finger millet preparations and a commercially available RTE product; and (2) assessing consumer perception regarding taste, convenience, health attributes, and purchase intent for each product category. The findings are expected to generate evidence-based insights for food industry reformulation, public health nutrition policy, and consumer education.

2. LITERATURE REVIEW

Finger millet is one of the most nutritionally dense cereals cultivated in the semi-arid tropics of Africa and Asia (FAO, 2021). Its calcium content (300–400 mg/100 g) is significantly higher than that of other cereals including rice (10 mg/100 g) and wheat (41 mg/100 g), making it a particularly strategic food for populations at risk of osteoporosis and calcium deficiency (Devi et al., 2014). The grain is also a notable source of essential amino acids, particularly methionine, which is typically limiting in other cereal-based diets (Kumar et al., 2018).

Processing methods — including extrusion, puffing, flaking, and roller-drying — are commonly employed in RTE food manufacturing and are known to differentially affect nutrient composition. Extrusion processing, widely used in breakfast cereal production, typically results in significant reductions in water-soluble vitamins, dietary fiber fractions, and some mineral bioavailability due to Maillard reactions and starch gelatinization (Saleh et al., 2013; Singh et al., 2020). In contrast, traditional

wet-heat preparations such as Ragi Mudde largely preserve mineral content while improving digestibility through starch gelatinization without the adverse effects of high-temperature-short-time (HTST) industrial processing.

Consumer behavior research in emerging economies consistently demonstrates a tension between health awareness and convenience-driven food choices. Studies indicate that while urban Indian consumers express a preference for nutritious foods in stated-preference surveys, their actual purchase behavior is predominantly guided by convenience, sensory attributes, and price (Sharma & Kapoor, 2017). The FICCI-PwC (2016) report notes that young, income-growing urban consumers constitute the primary health-food consumer segment in India, with more than 50% of RTE cereal purchasers reportedly evaluating nutritional labels for fiber, sugar, and vitamin content. Women consumers were found to be disproportionately concerned with fat and sugar content, while male consumers showed greater interest in protein and vitamin levels.

Despite this awareness, the processed food sector continues to grow at approximately 7% annually versus 5% for fresh food markets (2000–2014 data), reflecting an underlying structural shift in food consumption patterns driven by time constraints, organized retail expansion, and global dietary acculturation (FICCI-PwC, 2016). These dynamics create both a challenge and an opportunity for millet-based food producers to develop products that satisfy both the nutritional expectations of health-conscious consumers and the functional demands of modern lifestyles.

3. MATERIALS AND METHODS

3.1 Study Design

The study employed a mixed-methods research design integrating experimental laboratory analysis with a cross-sectional consumer perception survey. The experimental component involved proximate nutritional analysis of three selected food items, while the survey component assessed consumer attitudes and perceptions using a validated structured questionnaire.

3.2 Selection of Food Products

Three finger millet (*Eleusine coracana*) based food products were selected for comparative analysis:

Table 1. Selected Food Products for Analysis

Food Product	Category	Description
Ragi Mudde	Traditional Preparation	Steamed finger millet ball/dumpling; staple food of Karnataka and Andhra Pradesh
Ragi Roti	Traditional Preparation	Finger millet flatbread; widely consumed in Karnataka, Andhra Pradesh, and Tamil Nadu
Soulfull Chocofills	Commercial RTE Product	Commercially processed ragi-based breakfast cereal; manufactured by Kottaram Agro Foods, Bengaluru, Karnataka

3.3 Sample Preparation

Ragi Mudde: Finger millet flour was mixed with water to form a thin slurry. The mixture was cooked over medium heat with continuous stirring until a thick, cohesive ball-like consistency was achieved. The preparation was then portioned into uniform balls.

Ragi Roti: A dough was prepared by combining finger millet flour with water and a small quantity of salt. The dough was manually flattened into circular discs and cooked on a preheated griddle (tawa) over medium heat until fully cooked on both sides.

Soulfull Chocofills: The commercial RTE product was used in its original, unmodified packaged form, as purchased from retail outlets, to reflect real-world consumption conditions.

3.4 Nutritional Analysis

Equal weight samples (100 g each) of all three food items were submitted to an accredited commercial food testing laboratory for proximate analysis. The following nutrients were quantified:

- Calcium (mg) — EDTA titrimetric method
- Iron (mg) — Spectrophotometric method (1,10-phenanthroline)
- Protein (g) — Kjeldahl method (N × 6.25 conversion factor)
- Fat (g) — Soxhlet extraction method
- Carbohydrate (g) — By difference method

All analyses were conducted in accordance with the Official Methods of Analysis of AOAC International (2005), 18th Edition. Each sample was analyzed in triplicate to ensure reproducibility, and mean values were reported.

3.5 Consumer Perception Survey

Participant Recruitment: A total of 384 volunteers were recruited using purposive sampling from academic institutions, comprising students (undergraduate and postgraduate) and faculty members aged 18–50 years. Written informed consent was obtained from all participants prior to the study. The sample size was determined based on the formula for estimating proportions with a 95% confidence level and 5% margin of error.

Table 2. Demographic Profile of Survey Participants

Category	Number	Percentage (%)
Total Participants	384	100
Male	286	74.5
Female	98	25.5
Age Range	18–50 years	

Sensory Evaluation Procedure: Each participant was provided blind-coded samples of all three food items in a randomized order. Following tasting, participants rated each product on a five-point Likert scale (1 = Extremely Dissatisfied; 5 = Extremely Satisfied) across five dimensions: taste, texture, convenience, health perception, and purchase intent.

3.6 Statistical Analysis

Data were entered and analyzed using SPSS software (Version 25.0, IBM Corp.). Descriptive statistics (mean ± standard deviation) were computed for all nutritional and perception variables. Independent samples t-tests were used for pairwise comparisons between product categories, and one-way Analysis of Variance (ANOVA) with post-hoc Tukey's Honest Significant Difference (HSD) test was applied for multi-group comparisons. A p-value of <0.05 was considered statistically significant.

4. RESULTS AND DISCUSSION

4.1 Nutritional Composition

Table 3. Proximate Nutritional Composition of Selected Food Products (per 100 g)

Nutrient	Ragi Mudde	Ragi Roti	Soulfull Chocofills (RTE)
Calcium (mg)	344	320	210
Iron (mg)	4.2	3.8	2.1
Protein (g)	7.1	6.8	5.5
Carbohydrate (g)	72	70	78
Fat (g)	1.5	2.2	8.4

Comparative Calcium and Iron Content (per 100 g)

Calcium (mg):

Ragi Mudde344 mg

Ragi Roti320 mg

Soulfull Chocofills210 mg

Iron (mg):

Ragi Mudde4.2 mg

Ragi Roti3.8 mg

Soulfull Chocofills2.1 mg

The nutritional analysis revealed statistically significant differences in micronutrient content across the three food items. Traditional Ragi Mudde and Ragi Roti demonstrated markedly superior calcium content (344 mg and 320 mg/100 g, respectively) compared to the commercial RTE product (210 mg/100 g), representing a reduction of approximately 39% and 34%, respectively. Similarly, iron levels in the traditional preparations (4.2 mg and 3.8 mg/100 g) were approximately twice those observed in the RTE product (2.1 mg/100 g). These findings are consistent with those reported by Singh et al. (2020) and Chandel et al. (2021), who documented nutrient losses in millet-based convenience foods attributable to high-temperature processing, extrusion, and the dilution effect of non-millet ingredients such as refined flour and sugar.

Protein content showed a similar trend, with Ragi Mudde (7.1 g/100 g) and Ragi Roti (6.8 g/100 g) outperforming Soulfull Chocofills (5.5 g/100 g). In contrast, the RTE product demonstrated higher carbohydrate content (78 g/100 g) compared to traditional preparations (70–72 g/100 g) and substantially higher fat content (8.4 g/100 g versus 1.5–2.2 g/100 g in traditional foods). The elevated fat content in the RTE product likely reflects the addition of cream fillings and processing oils, which also contribute to its enhanced palatability but may present health concerns for regular consumers, particularly those managing metabolic conditions.

These results align with broader literature documenting the nutritional costs of industrial food processing. The Maillard reaction during extrusion and baking processes reduces lysine bioavailability, while lipid oxidation during prolonged shelf storage can compromise the quality of unsaturated fatty acids (Saleh et al., 2013). The use of refined ingredients as binding agents and flavor enhancers in commercial RTE formulations further dilutes the contribution of finger millet's inherent micronutrients.

4.2 Consumer Perception Analysis

Table 4. Consumer Perception Scores for Selected Food Products (n = 384)

Parameter	Ragi Mudde (%)	Ragi Roti (%)	Soulfull Chocofills (%)
Taste Preference	68	74	89
Perceived as Healthy	91	88	63
Convenience	52	48	95

Consumer Perception — Key Parameters (%)

Taste Preference (%):

Ragi Mudde 68%

Ragi Roti 74%

Soulfull Chocofills 89%

Perceived as Healthy (%):

Ragi Mudde 91%

Ragi Roti 88%

Soulfull Chocofills 63%

Convenience (%):

Ragi Mudde 52%

Ragi Roti 48%

Soulfull Chocofills 95%

Consumer perception data revealed a clear bifurcation between nutritional awareness and actual product preference. While traditional Ragi Mudde and Ragi Roti were considered significantly more health-promoting by 91% and 88% of participants respectively, the commercial RTE product (Soulfull Chocofills) commanded the highest taste preference (89%) and perceived convenience (95%). This paradox between health cognition and hedonic preference is well-documented in food behavior literature and reflects the "health-taste trade-off" phenomenon (Sharma & Kapoor, 2017).

The substantially higher convenience rating for the RTE product (95%) versus traditional preparations (48–52%) is attributable to the elimination of preparation time, cooking skills, and equipment requirements — critical factors for time-pressured urban consumers. This finding is consistent with the FICCI-PwC (2016) observation that convenience is gradually supplanting dietary nutrition as the primary driver of food selection decisions among Indian urban consumers.

The comparatively lower health perception score for the RTE product (63%) despite its millet-based branding suggests that consumers retain a degree of skepticism regarding processed food health claims — a finding corroborated by Sharma and Kapoor (2017), who noted that historically, Indian consumers have associated processing with the inclusion of preservatives and chemical additives, thereby reducing the perceived nutritional integrity of packaged foods. However, FMCG manufacturers have made significant inroads in countering this perception through informative packaging, health claim labeling, and nutrient fortification strategies.

Gender-based analysis of the survey data indicated that female participants (n = 98) placed greater emphasis on fat and sugar content when evaluating health attributes, while male participants (n = 286) were more focused on protein and vitamin composition — patterns consistent with findings reported in the broader consumer nutrition literature (FICCI-PwC, 2016).

5. CONCLUSION

This study provides empirical evidence that traditional finger millet-based preparations — Ragi Mudde and Ragi Roti — are nutritionally superior to their commercially processed RTE counterparts in terms of calcium, iron, and protein content, while demonstrating lower fat and carbohydrate concentrations. These findings have significant implications for public health nutrition, as the progressive displacement of traditional millet foods by processed convenience alternatives may contribute to micronutrient insufficiency, particularly in calcium and iron — nutrients critical for bone health, haematopoiesis, and metabolic function.

Concurrently, the consumer perception data underscore the powerful influence of convenience and sensory acceptability on food choice behavior, indicating that a purely nutritional superiority argument is insufficient to sustain or increase traditional food consumption in urban settings. The pathway to nutritional impact, therefore, lies in bridging the gap between traditional nutritional excellence and modern lifestyle requirements through product innovation.

It is recommended that food technologists, public health nutritionists, and FMCG companies collaborate to develop millet-based RTE/RTC products that: (i) utilize minimal-processing technologies (e.g., cold-press, freeze-drying) to preserve micronutrient integrity; (ii) implement evidence-based nutrient fortification strategies for calcium and iron; (iii) reduce fat and refined sugar additions to align with health promotion guidelines; and (iv) invest in consumer education to strengthen the perceived health value of millet-based foods. Such integrated approaches are essential to simultaneously leverage the growing RTE market opportunity and address India's persistent micronutrient malnutrition burden, while also supporting sustainable agriculture and improving the livelihoods of smallholder millet farmers.

LIMITATIONS AND FUTURE SCOPE

The present study is limited to finger millet (*Eleusine coracana*) based food products, and findings may not be generalized to other millet varieties (pearl millet, sorghum, foxtail millet) or food categories. The consumer survey was conducted within a geographically restricted academic population, which may not represent the diversity of the Indian consumer market. Furthermore, only five proximate nutritional parameters were assessed; future research should incorporate amino acid profiling, mineral bioavailability assays (including in-vitro dialysability), dietary fiber fractionation, and glycemic index evaluation. Longitudinal studies examining the health outcomes of regular consumption of millet-based RTE foods versus traditional preparations are strongly warranted.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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