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Formulation, Nutritional Analysis and Sensory Evaluation of a Millet- and Legume-Based Health Mix for Elderly Nutrition: A Study

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ABSTRACT: Background: Population ageing in India is accompanied by a high burden of protein–energy undernutrition and micronutrient deficiency among older adults, compounded by poor dentition, reduced appetite and swallowing difficulty. Millets and legumes are inexpensive, locally available, climate-smart foods whose complementary amino acid profiles make them attractive as the basis of an energy- and nutrient-dense health mix suited to elderly nutrition in South India. Objective: To formulate four millet- and legume-based health-mix formulations, to characterise their proximate composition, mineral content and functional properties, and to compare their sensory acceptability among elderly panelists in order to identify the optimal formulation. Methods: Four formulations (F1–F4) combining finger millet, pearl millet, green gram, chickpea, soybean, skim milk powder, flaxseed, jaggery and cardamom were developed and analysed in four batches each by AOAC methods (protein, fat, ash, crude fibre, carbohydrate by difference, energy), with calcium and iron by atomic absorption spectrometry, and functional properties (bulk density, water absorption, reconstitution time, viscosity). Fifty elderly panelists (mean age 70.7 years, SD 6.5) rated each formulation on a 9-point hedonic scale, yielding 200 ratings. Data were summarised as mean ± SD and compared by one-way

ANOVA with eta-squared effect sizes ($p<0.05$). Results: Protein rose from 14.53 g/100 g (F1) to 19.80 g/100 g (F4); crude fibre, calcium (244–273 mg/100 g), iron (5.56–6.96 mg/100 g) and energy increased in parallel as legume and soybean content rose. Formulation F3 achieved the highest overall acceptability (8.08), taste (8.29) and ease of swallowing (8.20) and the highest willingness to consume regularly (84%). Differences across formulations were statistically significant with large effect sizes for overall acceptability ($F=32.98$, df 3,196, $p<0.001$, $\eta^2=0.335$), taste ($F=30.52$, $p<0.001$, $\eta^2=0.318$) and ease of swallowing ($F=31.53$, $p<0.001$, $\eta^2=0.326$). Conclusion: A balanced millet–legume health mix (F3) with moderate finger and pearl millet, higher green gram, chickpea and soybean and reduced jaggery delivered a nutrient-dense, protein- and calcium-rich, easy-to-swallow product with the strongest elderly acceptance, supporting its potential for elderly nutrition in South India.

1. INTRODUCTION

India is undergoing a rapid demographic transition. The population aged 60 years and older is projected to more than double over the coming decades, and South India in particular has among the highest proportions of older adults in the country. Ageing is accompanied by physiological changes — reduced lean body mass, declining appetite, altered taste and smell, impaired dentition, and difficulty in chewing and swallowing — that predispose older adults to inadequate dietary intake. Protein–energy undernutrition and deficiencies of calcium, iron and other micronutrients are widely reported among community-dwelling and institutionalised elderly people in India, contributing to sarcopenia, frailty, anaemia, impaired immunity and poorer quality of life [1-4]. Affordable, culturally acceptable and easy-to-consume foods that concentrate protein, energy and micronutrients in a small, swallowable serving are therefore an important public-health need.

Millets are small-seeded cereal grains that have been cultivated across South India for millennia. Finger millet (Eleusine coracana, known locally as ragi or kezhvaragu) and pearl millet (Pennisetum glaucum, kambu) are traditional staples that are remarkably drought-tolerant and climate-resilient, requiring low input and thriving on marginal land [5]. Beyond their agronomic virtues, millets are nutrient-dense: they supply complex carbohydrates with a low glycaemic index, dietary fibre, B-vitamins and minerals, and finger millet in particular is an exceptionally rich plant source of calcium [6]. A growing body of work has highlighted the role of millets in food security, sustainable diets and the prevention of non-communicable disease [7], and their processing into value-added foods such as porridges, snacks, biscuits and complementary foods is an active field [4,8]. The United Nations designation of 2023 as the International Year of Millets has further reinvigorated interest in these grains.

Millet protein, however, is limited in the essential amino acid lysine. Legumes — green gram (Vigna radiata), chickpea (Cicer arietinum) and soybean (Glycine max) — are lysine-rich but relatively limited in the sulphur amino acids that cereals supply. Combining millets with legumes therefore achieves protein complementation, raising the overall protein quality of the mixture beyond that of either component alone [9]. The addition of skim milk powder further improves protein quality and calcium density, flaxseed contributes fibre and unsaturated fatty acids, jaggery provides palatable energy and iron, and cardamom improves aroma and acceptability. Such millet–legume blends are the traditional basis of home-prepared "health mixes" (sathu maavu) widely consumed in South India, yet formulations optimised specifically for the sensory and nutritional needs of elderly consumers, and evaluated systematically with older panelists, remain uncommon.

For elderly consumers, sensory acceptability and, in particular, ease of swallowing are decisive determinants of whether a nutritionally sound product will actually be consumed. A mix that is too coarse, too thick, too sweet or unpalatable will be rejected regardless of its composition. Optimising formulation therefore requires balancing nutrient density against reconstitution behaviour, mouthfeel and hedonic appeal in the target population.

Against this background, the present study was undertaken to formulate four millet- and legume-based health-mix formulations differing in their millet-to-legume ratio, to characterise their proximate composition, calcium and iron content and functional properties, and to evaluate their sensory acceptability among elderly panelists [10-13]. The objective was to identify the formulation offering the best combination of nutrient density and sensory acceptability, and thereby the greatest potential as a practical health mix for elderly nutrition in South India.

2. MATERIALS AND METHODS

2.1 Study design and setting

This was a laboratory-based product-development study combined with a cross-sectional sensory evaluation. Product development and proximate, mineral and functional analyses were carried out at the Department of Food Science and Nutrition/Home Science, South India, over the study period [v no 7845]. The design comprised three components: (i) development of four millet–legume health-mix formulations; (ii) proximate, mineral and functional analysis of each formulation in analytical replicate batches; and (iii) sensory evaluation of the reconstituted products by a panel of elderly volunteers.

2.2 Development of formulations

Nine ingredients were used: finger millet, pearl millet, green gram, chickpea, soybean, skim milk powder, flaxseed, jaggery and cardamom. Grains and legumes were cleaned, dry-roasted to improve flavour, reduce anti-nutritional factors and extend shelf life, milled to a fine flour and sieved. Skim milk powder, powdered jaggery and ground cardamom were blended into the roasted flours in fixed proportions to produce four formulations (F1–F4) that differed principally in their millet-to-legume ratio (Table 1). Across F1 to F4 the combined pulse and soybean fraction was progressively increased and the finger-millet and jaggery fractions correspondingly reduced, so as to raise protein and mineral density while lowering added sugar. Each formulation was designed to be reconstituted with hot water or milk into a smooth, drinkable porridge or beverage.

2.3 Proximate and mineral analysis

Each formulation was analysed in four independent batches. Moisture, crude protein (Kjeldahl; nitrogen × 6.25), crude fat (Soxhlet), total ash and crude fibre were determined by standard AOAC methods. Available carbohydrate was estimated by difference, and energy value was calculated using Atwater factors. Calcium and iron were determined by atomic absorption spectrometry [AAS/standard methods] after acid digestion. All analyses were performed in duplicate and expressed per 100 g on a fresh-weight basis.

2.4 Functional properties

Bulk density, water absorption index, reconstitution time and apparent viscosity of the reconstituted mixes were measured by standard procedures to characterise the physical behaviour of each formulation relevant to preparation and swallowing.

2.5 Sensory evaluation

Sensory evaluation was conducted with 50 elderly volunteers aged 60 years or older (mean age 70.7 years, SD 6.5; 28 men and 22 women) who were able to consume the reconstituted beverage and provide informed ratings. Volunteers with known allergy to any ingredient, acute illness or severe swallowing impairment were excluded. Each panelist evaluated all four formulations, presented in coded, randomised order, giving a total of 200 ratings. Eight attributes — appearance, aroma, taste, texture, mouthfeel, ease of swallowing, aftertaste and overall acceptability — were rated on a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely). Panelists also indicated for each formulation whether they would be willing to consume it regularly (yes/no).

2.6 Statistical analysis

Continuous variables were summarised as mean ± standard deviation (SD). Differences in nutritional and sensory outcomes across the four formulations were assessed by one-way analysis of variance (ANOVA), with the eta-squared (η^2) statistic reported as a measure of effect size ($\eta^2 \approx 0.01$ small, 0.06 medium, 0.14 large). Willingness to consume regularly was summarised as the percentage of panelists responding "yes" for each formulation. A two-sided p-value <0.05 was considered statistically significant. Analyses were performed using standard statistical software.

3. RESULTS

3.1 Formulation composition

The compositions of the four formulations are shown in Table 1. Finger millet decreased from 30% in F1 to 20% in F4, while green gram rose from 15% to 20%, chickpea from 10% to 15% and soybean from 5% to 10%. Jaggery was progressively reduced from 9% in F1 to 4% in F4. Pearl millet, skim milk powder, flaxseed and cardamom were held relatively constant. F4 therefore represented the most legume-rich, least-sweetened formulation, and F3 an intermediate, balanced blend.

Table 1. Composition of the four millet–legume health-mix formulations (% by weight).

Ingredient	F1	F2	F3	F4
Finger millet	30	25	25	20
Pearl millet	20	20	15	20
Green gram	15	18	20	20
Chickpea	10	12	15	15
Soybean	5	5	8	10
Skim milk powder	8	8	8	7
Flaxseed	2	3	3	3
Jaggery	9	8	5	4
Cardamom	1	1	1	1
Total	**100**	**100**	**100**	**100**

3.2 Proximate, mineral and functional composition

Proximate and mineral composition (mean ± SD of four batches) is presented in Table 2. Protein content rose steadily with legume enrichment, from 14.53 ± 0.08 g/100 g in F1 to 16.46 ± 0.45 g/100 g in F2, 19.02 ± 0.63 g/100 g in F3 and 19.80 ± 0.31 g/100 g in F4. Crude fibre, fat, energy, calcium and iron followed the same upward gradient. Calcium increased from 244.4 mg/100 g in F1 to 273.1 mg/100 g in F4, and iron from 5.56 to 6.96 mg/100 g, reflecting the higher legume and soybean load. Available carbohydrate fell correspondingly, from 63.89 g/100 g in F1 to 54.92 g/100 g in F4, consistent with the reduced jaggery and higher protein content. Reconstitution time was shortest for F3 (43.7 s), indicating favourable ease of preparation. These trends are shown in Figure 2.

Table 2. Proximate, mineral and functional composition of the four formulations (mean ± SD, n = 4 batches).

Parameter (per 100 g)	F1	F2	F3	F4
Moisture (g)	5.56 ± 0.30	5.62 ± 0.20	5.48 ± 0.49	5.64 ± 0.33
Protein (g)	14.53 ± 0.08	16.46 ± 0.45	19.02 ± 0.63	19.80 ± 0.31
Fat (g)	5.76 ± 0.09	6.16 ± 0.21	7.22 ± 0.34	7.67 ± 0.31
Ash (g)	3.06 ± 0.23	3.08 ± 0.12	3.18 ± 0.15	3.14 ± 0.09
Crude fibre (g)	7.20 ± 0.20	7.68 ± 0.51	8.61 ± 0.22	8.82 ± 0.29
Carbohydrate (g)	63.89 ± 0.45	61.01 ± 1.19	56.48 ± 0.38	54.92 ± 0.89
Energy (kcal)	378.15 ± 1.72	382.40 ± 1.05	385.75 ± 3.94	389.52 ± 3.12
Calcium (mg)	244.40 ± 9.21	248.60 ± 6.64	265.90 ± 5.61	273.10 ± 6.59
Iron (mg)	5.56 ± 0.18	5.82 ± 0.38	6.65 ± 0.07	6.96 ± 0.22

Bulk density (g/mL)	0.59 ± 0.01	0.59 ± 0.02	0.57 ± 0.03	0.60 ± 0.02
Water absorption index	3.84 ± 0.12	3.96 ± 0.17	4.17 ± 0.12	3.88 ± 0.11
Reconstitution time (s)	53.42 ± 3.93	51.17 ± 2.12	43.67 ± 2.48	46.02 ± 2.23
Viscosity (cP)	816.45 ± 31.01	771.42 ± 25.69	726.83 ± 34.75	765.45 ± 13.66

3.3 Sensory evaluation

Mean sensory scores by attribute and formulation are given in Table 3 and displayed in Figure 1. Formulation F3 scored highest on almost every attribute, including appearance (8.04), aroma (8.00), taste (8.29), texture (8.10), mouthfeel (8.12) and ease of swallowing (8.20), and achieved the highest overall acceptability (8.08). F4 ranked second overall (7.68), followed by F2 (7.42) and F1 (7.08). The comparatively lower scores for F1 were consistent with its coarser, sweeter and less protein-rich profile, whereas the highly legume-rich F4, although nutritionally the densest, was rated slightly below F3 on taste and mouthfeel.

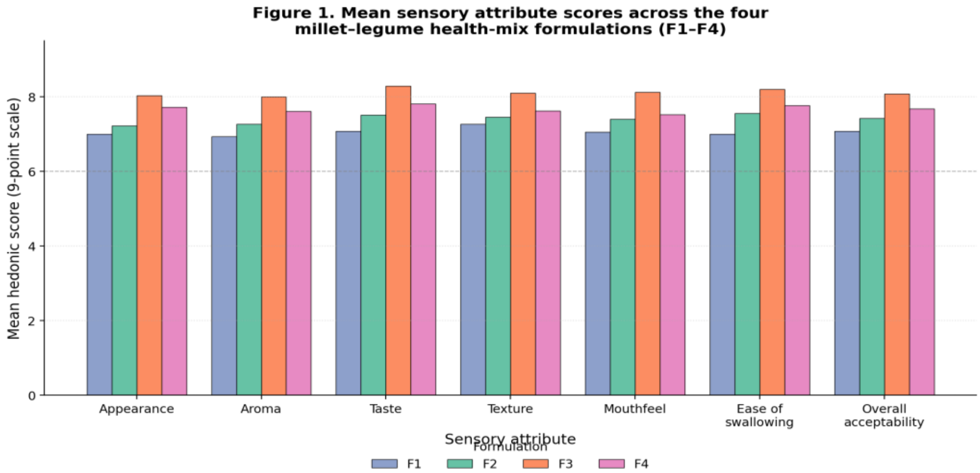

Figure 1. Mean sensory attribute scores across the four millet–legume health-mix formulations (F1–F4).

Table 3. Mean sensory scores (9-point hedonic scale) by attribute and formulation (n = 50 ratings per formulation; mean ± SD).

Attribute	F1	F2	F3	F4
Appearance	7.00 ± 0.68	7.23 ± 0.62	8.04 ± 0.65	7.72 ± 0.71
Aroma	6.94 ± 0.61	7.27 ± 0.72	8.00 ± 0.70	7.61 ± 0.71
Taste	7.08 ± 0.56	7.51 ± 0.70	8.29 ± 0.59	7.81 ± 0.73
Texture	7.27 ± 0.55	7.46 ± 0.73	8.10 ± 0.58	7.62 ± 0.70
Mouthfeel	7.06 ± 0.72	7.40 ± 0.71	8.12 ± 0.54	7.53 ± 0.74
Ease of swallowing	7.00 ± 0.67	7.56 ± 0.63	8.20 ± 0.54	7.77 ± 0.67
Aftertaste	6.91 ± 0.57	7.30 ± 0.68	7.96 ± 0.76	7.39 ± 0.71
Overall acceptability	7.08 ± 0.50	7.42 ± 0.53	8.08 ± 0.45	7.68 ± 0.59

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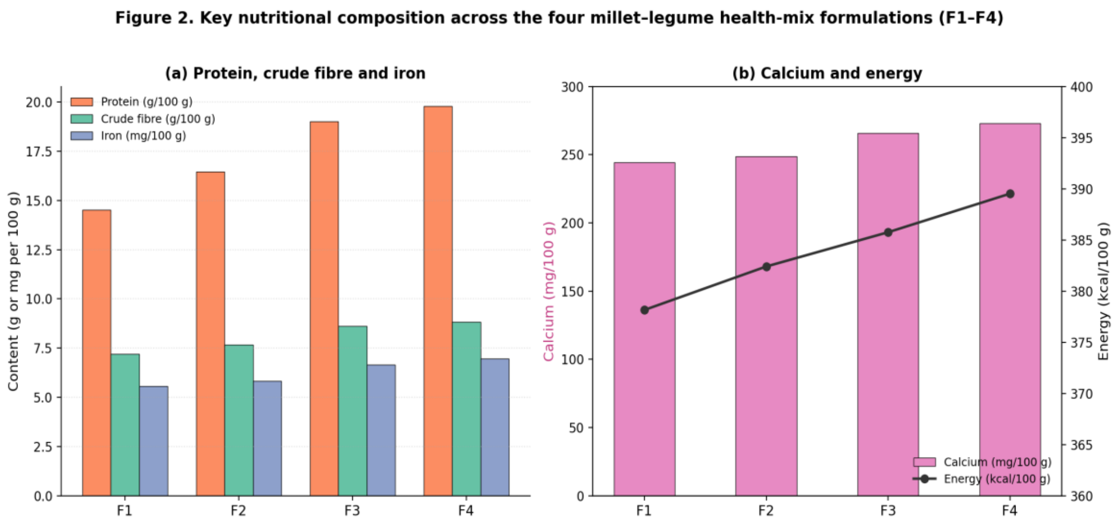

Figure 2. Key nutritional composition (protein, crude fibre, iron, calcium and energy) across the four millet–legume health-mix formulations (F1–F4).

3.4 Statistical comparison and willingness to consume

One-way ANOVA confirmed statistically significant differences across the four formulations for all three key hedonic outcomes, each with a large effect size (Table 4). Overall acceptability differed significantly ($F = 32.98$, df 3,196, $p<0.001$, $\eta^2 = 0.335$), as did taste ($F = 30.52$, $p<0.001$, $\eta^2 = 0.318$) and ease of swallowing ($F = 31.53$, $p<0.001$, $\eta^2 = 0.326$). The eta-squared values indicate that roughly a third of the variance in these ratings was attributable to formulation. Willingness to consume the product regularly tracked overall acceptability closely: only 42% of panelists would regularly consume F1 and 54% F2, rising sharply to 84% for F3 and 78% for F4. Formulation F3 was thus both the most liked and the most likely to be adopted in habitual use.

Table 4. One-way ANOVA results for key sensory outcomes and willingness to consume regularly.

Outcome	Test	F (df 3,196)	p-value	η^2 (effect size)
Overall acceptability	One-way ANOVA	32.98	<0.001	0.335 (large)
Taste	One-way ANOVA	30.52	<0.001	0.318 (large)
Ease of swallowing	One-way ANOVA	31.53	<0.001	0.326 (large)
Willingness to consume regularly (% "yes")	F1 = 42%	F2 = 54%	F3 = 84%	F4 = 78%

4. DISCUSSION

In this study, four millet- and legume-based health-mix formulations were developed and compared for their nutritional composition and sensory acceptability among elderly panelists. Increasing the legume and soybean content from F1 to F4 produced a clear, monotonic rise in protein (from 14.53 to 19.80 g/100 g), crude fibre, fat, energy, calcium and iron, at the expense of available carbohydrate. However, the most nutrient-dense formulation was not the most acceptable: formulation F3, an intermediate blend, achieved the highest overall acceptability (8.08), taste (8.29) and ease of swallowing (8.20), and the highest willingness to consume regularly (84%). The differences between formulations were statistically significant with large effect sizes, indicating that formulation choice materially shaped elderly acceptance [14-16].

Why did F3 emerge as optimal? F3 combined a substantial legume fraction — 20% green gram, 15% chickpea and 8% soybean — with moderate finger and pearl millet, giving high protein (19.02 g/100 g), calcium (265.9 mg/100 g) and iron (6.65 mg/100 g) while avoiding the very high soybean load of F4. Its lower jaggery content (5%) reduced excessive sweetness, an attribute several panelists disliked in the sweeter F1 and F2, while retaining enough to remain palatable. Functionally, F3 also had the shortest reconstitution time (43.7 s) and a favourable water absorption index and viscosity, producing a smooth beverage that was easy to prepare and swallow. F4, although marginally richer in protein and minerals, likely carried a more pronounced beany flavour and mouthfeel from its higher soybean content, which pulled its taste and mouthfeel scores below those of F3. F3 therefore represents the point at which nutrient density and sensory quality are jointly optimised — the balance that matters most for a food intended for daily use by older adults [17].

The concept of protein complementation is central to the nutritional rationale of these blends. Millet protein is limited in lysine, whereas legume proteins are lysine-rich but limited in sulphur amino acids; combining the two raises the biological value of the mixture, and the inclusion of skim milk powder further improves protein quality and calcium density. Finger millet is among the richest plant sources of calcium, and its prominence in all four formulations underpins their high calcium content — a nutrient of particular importance for older adults at risk of osteoporosis. The iron and fibre contributed by the legumes and flaxseed are similarly relevant to the anaemia and constipation frequently encountered in this age group. These findings are consistent with a broad literature documenting the nutritional richness of millets and their suitability for value-added, health-oriented food products [8,9,18]. Studies of finger-millet-based foods have reported favourable nutritional, sensory and glycaemic properties [19-22], and millet-based snacks, biscuits and complementary porridges have been shown to be acceptable across diverse populations [23]. Our results extend this evidence base specifically to an elderly-targeted, legume-complemented health mix.

Ease of swallowing deserves particular emphasis in the context of elderly nutrition. Age-related changes in dentition, salivation and oropharyngeal function make texture and swallowability decisive for actual consumption. In our data, ease of swallowing was not only rated highest for F3 but also differed significantly across formulations with a large effect size, underlining that this attribute is sensitive to formulation and should be an explicit design target for elderly foods. The close alignment between overall acceptability and willingness to consume regularly — 84% for F3 versus only 42% for F1 — demonstrates that hedonic ratings translated into stated behavioral intent, strengthening the case that a well-optimized mix could achieve real-world uptake.

These findings carry practical relevance for South India, where finger millet (ragi/kezhvaragu) and pearl millet (kambu) are traditional dietary staples and where home-prepared millet–legume "health mixes" are already culturally familiar. A standardized, nutrient-dense, easy-to-swallow formulation such as F3 could be produced at modest cost from locally grown, climate-resilient crops and integrated into geriatric nutrition programmers, old-age homes, and community and public-health nutrition schemes across South India. The use of indigenous millets also aligns with wider goals of sustainable, resilient and healthy food systems that have been emphasized for millets and other emergent crops [7,24,25]. Framing elderly nutrition around such traditional South Indian grains offers a culturally acceptable and environmentally sustainable route to improving protein-energy and micronutrient adequacy in an ageing population.

The study evaluated only immediate sensory acceptance and analytical composition; it did not assess protein digestibility-corrected amino acid score, in vitro or in vivo bioavailability of calcium and iron, glycemic response, shelf-life and microbial stability, or clinical outcomes such as changes in nutritional status, body composition or functional capacity following sustained consumption [26]. The sensory panel, though comprising 50 elderly volunteers, was drawn from a single setting and evaluated the products on a single occasion, so longer-term acceptability and sensory fatigue were not captured. Future work should validate the formulations experimentally, conduct in vivo digestibility and bioavailability studies, evaluate storage stability, and ideally undertake a clinical feeding trial in older adults to confirm nutritional benefit [27].

5. CONCLUSION

Four millet- and legume-based health-mix formulations were developed and compared for elderly nutrition. Increasing legume and soybean content progressively raised protein, fiber, calcium, iron and energy density, but the balanced intermediate formulation F3 — moderate finger and pearl millet with higher green gram, chickpea and soybean and reduced jaggery — achieved the highest overall acceptability, taste and ease of swallowing and the greatest willingness to consume regularly, with statistically significant, large-effect differences across formulations. F3 offers a nutrient-dense, protein- and calcium-rich, easy-to-swallow health mix well suited to the needs of older adults and grounded in the traditional millet-based food culture of South India. Subject to experimental validation and clinical testing, such a formulation could contribute meaningfully to addressing protein-energy and micronutrient inadequacy in India's growing elderly population.

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