RESEARCH PAPER

Development and Nutritional Evaluation of a Ready-to-Eat Banana Inflorescence Nutraceutical Soup Mix with Synergistic Micronutrient Fortification for Menstrual Health Support.

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ABSTRACT
Women's menstrual health requires adequate nutritional support to address physiological challenges including anaemia, fatigue, and hormonal imbalances. This study focused on developing a ready-to-eat functional soup composition incorporating banana inflorescence (Musa paradisiaca) enriched with essential micronutrients to support menstrual wellness. Four formulations were developed with varying ratios of banana inflorescence flakes, micronutrient premixes, and nutraceutical excipients. Formulation optimization was conducted through organoleptic evaluation, proximate analysis, mineral profiling, and shelf-life assessment. The optimized formulation contained banana inflorescence (22%), arrowroot starch (37%), and a traditional spice blend (20%), delivering 6-8 mg iron, 25-30 mg vitamin C, 80-100 mcg folate, 150-200 mg calcium, and 50-70 mg magnesium per serving. Proximate composition revealed energy (342 kcal/100g), protein (24.6 g/100g), carbohydrates (58.3 g/100g), dietary fibre (8.2 g/100g), and moisture (6.5 g/100g). The product demonstrated acceptable sensory attributes and remained microbiologically stable for 60 days when stored in glass containers at ambient temperature. This nutritionally fortified instant soup mix offers a convenient, plant-based dietary intervention to combat menstrual-related nutrient deficiencies and enhance women's reproductive wellness..
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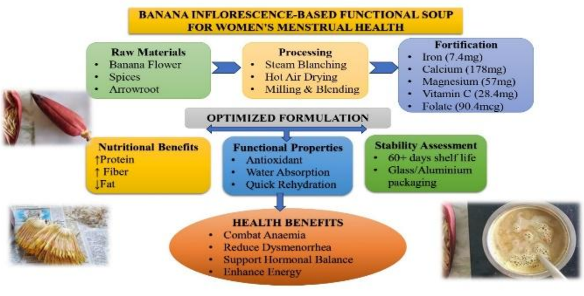
INTRODUCTION

Women's reproductive health encompasses complex physiological processes that demand adequate nutritional support throughout different life stages. Menstruation, a fundamental aspect of reproductive wellness, often presents challenges including iron-deficiency anemia, fatigue, dysmenorrhea, and hormonal fluctuations that significantly impact quality of life and daily productivity [1]. Global estimates suggest that approximately 30-40% of menstruating women experience iron deficiency, with higher prevalence in developing nations where dietary diversity remains limited [2].

The menstrual cycle involves substantial physiological demands, with average blood loss ranging from 30-80 mL per cycle, translating to approximately 15-30 mg iron depletion monthly [3]. This continuous nutrient drain, coupled with inadequate dietary intake, creates a persistent vulnerability to micronutrient deficiencies. Beyond iron, several other micronutrients including calcium, magnesium, folate, and B-complex vitamins play critical roles in regulating menstrual health, hormonal balance, and reproductive function [4].



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Contemporary nutritional science increasingly recognizes the therapeutic potential of functional foods products that provide health benefits beyond basic nutrition [5]. Traditional plant-based ingredients, particularly those with

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established ethnobotanical usage, offer promising avenues for developing accessible, culturally acceptable nutritional interventions. Banana inflorescence, commonly known as banana flower or banana blossom, represents one such underutilized botanical resource with remarkable nutritional properties.

Musa paradisiaca inflorescence has been traditionally consumed across South and Southeast Asian cuisines, valued for its purported medicinal properties in managing menstrual disorders, diabetes, and gastrointestinal conditions [6]. Phytochemical investigations reveal that banana inflorescence contains substantial amounts of dietary fibre (12-15%), protein (1.6-2.0%), minerals including iron (56-60 mg/100g fresh weight), calcium, phosphorus, and bioactive compounds such as flavonoids, tannins, and phenolic acids with demonstrated antioxidant and anti-inflammatory activities [7].

The convergence of traditional knowledge and modern nutritional science presents opportunities for developing evidence-based functional food products. Instant soup mixes represent an ideal delivery format, offering convenience, extended shelf-life, and potential for nutrient fortification while maintaining palatability [8]. However, existing functional soup formulations often focus on general nutrition rather than addressing specific physiological needs such as menstrual health support.

Previous research on nutritional interventions for women's health has explored various approaches. Studies have documented iron-rich herbal formulations demonstrating improved bioavailability through synergistic nutrient combinations [9]. Plant-based micronutrient formulations rich in iron and vitamin C have been developed to combat iron deficiency, providing sustainable nutritional support [10]. Micronutrient supplementation trials have shown significant improvements in menstrual regularity, reduced dysmenorrhea, and enhanced haemoglobin status among reproductive-age women [11]. However, pharmaceutical supplements often face challenges including poor compliance, gastrointestinal side effects, and limited accessibility in resource-constrained settings.

Food-based approaches offer distinct advantages including better nutrient absorption due to food matrix effects, simultaneous delivery of multiple bioactive compounds, and higher long-term adherence [12]. Despite these benefits, limited research exists on comprehensive functional food formulations specifically designed to address the multifaceted nutritional requirements of menstrual health. Most available products either focus on single-nutrient fortification or employ synthetic additives rather than whole-food ingredients.

The present investigation addresses this knowledge gap by developing a novel ready-to-eat soup composition leveraging the nutritional synergy of banana inflorescence, targeted micronutrient fortification, and traditional culinary ingredients. The study employs systematic formulation development, comprehensive nutritional characterization, sensory optimization, and stability evaluation to create a scientifically validated, culturally appropriate dietary solution for supporting women's menstrual wellness.

This research aims to: (1) optimize the formulation of banana inflorescence-based functional soup through systematic variation of ingredient ratios; (2) characterize the nutritional profile including proximate composition, mineral content, and bioactive compounds; (3) evaluate sensory acceptability and consumer preference; (4) assess product stability and determine optimal packaging conditions; and (5) compare nutritional value and cost-effectiveness against commercially available instant soup products.

2. MATERIALS AND METHODS

2.1 Selection and Procurement of Raw Materials

Fresh banana inflorescence (*Musa paradisiaca*) was procured from certified organic farms in the Western Ghats region, selecting specimens with intact outer bracts, firm texture, and absence of physical damage or discoloration. Micronutrient ingredients including ferrous BI glycinate (Albion Minerals®), calcium citrate malate, magnesium oxide, L-ascorbic acid (vitamin C), and folic acid (pharmaceutical grade) were obtained from authorized nutraceutical ingredient suppliers.

Arrowroot starch (*Maranta arundinacea*), selected as the primary texture-modifying agent due to its superior digestibility and neutral flavour profile, was sourced from regional processors. Traditional spice ingredients including cumin seeds (*Cuminum cyminum*), coriander seeds (*Coriandrum sativum*), turmeric rhizome (*Curcuma longa*), black pepper (*Piper nigrum*), dried ginger (*Zingiber officinale*), dehydrated garlic (*Allium sativum*), and dehydrated onion (*Allium cepa*) were procured from established spice merchants and verified for authenticity and quality parameters.

All ingredients were subjected to preliminary quality assessment including visual examination, moisture content determination, and microbiological screening to ensure compliance with food safety standards prior to formulation development.

2.2 Processing of Banana Inflorescence

Fresh banana inflorescence underwent systematic processing to develop shelf-stable flakes suitable for instant soup application. The inflorescence was manually cleaned by removing the outer purple-red bracts and discarding the hard basal portions. Individual florets were carefully separated and thoroughly washed in potable water (three consecutive washes) to remove residual latex and surface contaminants.

To prevent enzymatic browning, cleaned florets were immediately immersed in an anti-browning solution containing 0.15% lemon juice (providing citric acid and ascorbic acid) for 10 minutes at ambient temperature. This pretreatment effectively inhibited polyphenol oxidase activity while maintaining the natural colour and reducing astringency.

Steam blanching was performed in a stainless-steel blancher at 87-88°C for 2.5 minutes to achieve enzyme inactivation (peroxidase and polyphenol oxidase), reduce bitterness from tannins and saponins, and improve digestibility. Blanched florets were immediately cooled in chilled water (4-6°C) to arrest thermal processing and preserve heat-sensitive nutrients.

Drained florets were arranged in single layers on perforated trays and subjected to hot air drying in a cabinet dryer at 57-58°C with air velocity of 1.5-2.0 m/s. Drying continued until moisture content reached ≤7% (determined gravimetrically), typically requiring 6-8 hours. This moisture level was selected to ensure microbial stability while preventing excessive nutrient degradation.

Dried banana inflorescence was coarsely milled using a hammer mill equipped with a 2 mm screen to produce irregular flakes with particle size ranging from 1-3 mm. This flake form was preferred over fine powder to maintain visual identity in the final product and provide textural interest. Processed banana inflorescence flakes were packaged in high-density polyethylene bags with oxygen absorbers and stored at controlled conditions (temperature ≤25°C, relative humidity ≤45%) until formulation.

2.3 Preparation of Spice Blend and Functional Ingredients

Individual spice ingredients were cleaned, inspected for quality, and separately roasted at controlled temperatures (80-95°C depending on the spice) to develop flavour compounds and reduce moisture content. Roasted spices were cooled to ambient temperature and ground in a pulveriser to achieve particle size ≤200 mesh, ensuring uniform flavour distribution and rapid hydration characteristics.

A standardized spice blend was formulated to provide traditional Indian soup flavour profile while contributing bioactive compounds with anti-inflammatory and antioxidant properties (Table 1). The blend was carefully designed to deliver both organoleptic appeal and functional health benefits, with each component selected for its specific bioactive compounds and therapeutic properties documented in scientific literature [13-15].

Table 1: Spice blend composition and functional properties

Spice Component	Percentage (%)	Key Bioactive Compound	Health Benefit
Cumin (*Cuminum cyminum*)	28	Cumin aldehyde	Digestive, Anti-inflammatory
Coriander (*Coriandrum sativum*)	22	Linalool	Antioxidant
Turmeric (*Curcuma longa*)	15	Curcumin	Anti-inflammatory
Ginger (*Zingiber officinale*)	12	Gingerol	Pain relief
Garlic (*Allium sativum*)	10	Allicin	Antimicrobial
Black Pepper (*Piper nigrum*)	8	Piperine	Bioavailability enhancer
Onion (*Allium cepa*)	5	Quercetin	Antioxidant

The inclusion of cumin as the primary component (28%) provided characteristic aroma and flavour while contributing cumin aldehyde, which has been documented for its digestive and anti-inflammatory properties [13]. Coriander (22%) complemented the flavour profile while providing linalool, a monoterpene alcohol with potent antioxidant activity [14]. Turmeric (15%) served as both a natural colorant and the primary source of curcumin, a polyphenolic compound extensively studied for its anti-inflammatory effects relevant to dysmenorrhea management [15].

Ginger (12%) was incorporated specifically for its gingerol content, which has demonstrated analgesic properties and potential benefits in reducing menstrual pain [16]. Garlic (10%) provided allicin, contributing antimicrobial properties and supporting overall immune function [17]. Black pepper (8%) was included not only for flavour enhancement but critically for its piperine content, which significantly enhances the bioavailability of curcumin and other nutrients through inhibition of hepatic and intestinal glucuronidation [18]. Onion powder (5%) contributed quercetin, a flavonoid with antioxidant and anti-inflammatory properties [19].

This synergistic spice combination was designed to address multiple pathways relevant to menstrual health, including inflammation reduction, pain management, antioxidant protection, and enhanced nutrient absorption, while maintaining palatability and cultural acceptability.

Micronutrient premix was prepared by carefully blending pharmaceutical-grade minerals and vitamins with arrowroot starch as a carrier (1:10 ratio) to ensure homogeneous distribution in the final product. The premix was formulated to deliver target nutrient levels per 20g serving: iron 6-8 mg, vitamin C 25-30 mg, folate 80-100 mcg, calcium 150-200 mg, and magnesium 50-70 mg.

2.4 Formulation Development and Optimization

Four experimental formulations were developed with systematic variation in the proportion of banana inflorescence flakes while maintaining constant levels of starch, spice blend, and micronutrient premix (Table 2). The formulations were designed to evaluate the impact of banana inflorescence content on nutritional profile, sensory characteristics, and functional properties.

Table 2: Formulation composition of banana inflorescence-based instant soup mix

Ingredient (%)	Formulation A	Formulation B	Formulation C	Formulation D
Banana infloresc	22	18	14	26

ence flakes				
Arrowroot starch	37	37	37	37
Spice blend	20	20	20	20
Micronutrient premix	8	8	8	8
Sodium chloride	13	17	21	9

Blending was performed in a laboratory-scale V-blender at 25 rpm for 15 minutes to achieve uniform distribution. Ingredients were added sequentially: arrowroot starch first (providing base), followed by micronutrient premix (allowing adhesion to starch particles), banana inflorescence flakes (maintaining flake integrity), and finally spice blend (coating external surfaces for immediate aroma release during reconstitution).

Blending operations were conducted in a temperature-controlled environment (≤25°C, relative humidity ≤45%) to prevent moisture absorption and caking. Fine powder fractions were sieved through 80-100 mesh screens prior to final blending to ensure particle uniformity and prevent segregation during storage.

2.5 Sensory Evaluation

Sensory assessment was conducted using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) with a trained panel of 50 evaluators (25 males, 25 females, aged 22-45 years) representing the target consumer demographic. Panellists were briefed on evaluation procedures and provided informed consent.

Soup samples were prepared by reconstituting 20g instant soup mix in 200 mL boiling water with constant stirring for 2-3 minutes until complete hydration. Samples were served at 65-70°C in coded, opaque containers to prevent visual bias. Panellists evaluated appearance, colour, aroma, flavour, consistency, mouthfeel, aftertaste, and overall acceptability with 5-minute intervals between samples and palate cleansing with water.

Data were analysed using one-way ANOVA followed by Tukey's post-hoc test ($p<0.05$) to identify significant differences among formulations. The formulation receiving the highest overall acceptability score was selected for detailed characterization and stability studies.

2.6 Proximate Composition Analysis

Proximate analysis of the optimized formulation was performed following standard AOAC methods. Moisture content was determined by hot air oven method (105°C until constant weight). Crude protein was estimated by Kjeldahl nitrogen determination method (N × 6.25 conversion factor). Total fat content was analysed by Soxhlet extraction using petroleum ether. Crude fibre was determined by acid-alkali digestion method. Total ash was obtained by incineration at 550°C in a muffle furnace. Carbohydrate content was calculated by difference method. Energy value was computed using Atwater factors (4 kcal/g for protein and carbohydrate, 9 kcal/g for fat).

2.7 Mineral Analysis

Mineral content (iron, calcium, magnesium) was determined using atomic absorption spectrophotometry (AAS) following wet digestion with HNO_3-$HClO_4$ mixture. Folate content was analysed by microbiological assay using *Lactobacillus casei* as the test organism. Vitamin C was estimated by 2,6-dichlorophenolindophenol titration method immediately after sample preparation to minimize oxidative losses.

2.8 Physicochemical Characterization

Water absorption capacity (WAC) was determined by suspending 1g sample in 10 mL distilled water for 30 minutes at ambient temperature, followed by centrifugation (3000 rpm, 20 minutes) and measurement of absorbed water. Swelling capacity was evaluated by measuring volumetric expansion of sample in graduated cylinder after hydration. Solubility index was determined by centrifuging hydrated samples and measuring dissolved solids in supernatant.

Rehydration characteristics including time to complete dispersion and final consistency were assessed visually and by viscosity measurement using a Brookfield viscometer. pH of reconstituted soup was measured using a calibrated pH meter.

2.9 Antioxidant Activity Assessment

Total antioxidant capacity was evaluated using DPPH radical scavenging assay. Samples were extracted with methanol (1:10 w/v), and antioxidant activity was expressed as ascorbic acid equivalents (mg AAE/100g) based on standard calibration curve. Total phenolic content was determined by Folin-Ciocalteu method and expressed as gallic acid equivalents (mg GAE/100g).

2.10 Shelf-Life Evaluation

Accelerated shelf-life study was conducted by storing samples in four different packaging materials: (1) glass bottles with metal screw caps, (2) high-density polyethylene (HDPE) containers, (3) metalized polyester zip-lock pouches, and (4) Aluminum foil laminate sachets. Samples were stored at ambient conditions (25-30°C, 60-70% RH) for 90 days.

Sensory evaluation, moisture content, pH, peroxide value, microbial analysis (total plate count, yeast and Mold count), and visual observation were performed at 15-day intervals. Microbiological analysis was conducted following standard plate count method on nutrient agar for bacterial enumeration and potato dextrose agar for fungal enumeration.

2.11 Statistical Analysis

All experiments were performed in triplicate, and results were expressed as mean ± standard deviation. Statistical significance was evaluated using one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test. Differences were considered significant at $p<0.05$. Statistical analyses were performed using SPSS version 25.0 software.

3. RESULTS AND DISCUSSION

3.1 Formulation Optimization Through Sensory Evaluation

Sensory evaluation scores for the four experimental formulations revealed significant differences across various attributes (Table 3). Formulation A, containing the highest proportion of banana inflorescence (22%), received the highest overall acceptability score (7.8 ± 0.9), significantly superior to other variants ($p<0.05$).

Table 3: Sensory evaluation scores of different formulations (Mean ± SD, n=50)

Attribute	Formulation A	Formulation B	Formulation C	Formulation D
Appearance	7.6 ± 1.1[a]	7.2 ± 1.0[ab]	6.8 ± 1.2[b]	7.1 ± 1.3[ab]
Colour	7.7 ± 0.9[a]	7.3 ± 1.1[ab]	6.9 ± 1.0[b]	7.0 ± 1.2[b]
Aroma	7.5 ± 1.0[a]	7.4 ± 0.9[a]	7.2 ± 1.1[a]	7.3 ± 1.0[a]
Flavour	7.9 ± 0.8[a]	7.1 ± 1.0[b]	6.6 ± 1.3[c]	7.4 ± 0.9[ab]
Consistency	7.4 ± 1.1[a]	7.2 ± 1.0[a]	7.5 ± 0.9[a]	6.9 ± 1.2[b]
Mouthfeel	7.6 ± 1.0[a]	7.0 ± 1.1[b]	6.7 ± 1.2[b]	7.2 ± 1.0[ab]
Overall acceptability	7.8 ± 0.9[a]	7.1 ± 1.0[b]	6.5 ± 1.2[c]	7.2 ± 1.1[b]

Different superscript letters within rows indicate significant differences (p<0.05)

The superior performance of Formulation A was attributed to optimal balance between banana inflorescence content and sodium chloride level. The 22% banana inflorescence provided distinctive vegetable character and visual appeal through visible flake particles, while maintaining pleasant flavour without overwhelming bitterness. Similar observations were reported by Kumar and Vijayan [8], who found that optimal incorporation of functional ingredients significantly improved consumer acceptance in instant soup formulations. Panellists particularly appreciated the subtle earthy notes and slight nutty undertones characteristic of banana inflorescence.

Formulation D, despite higher banana inflorescence content (26%), received lower acceptability due to excessive astringency and slightly bitter aftertaste, likely resulting from higher tannin levels and insufficient salt balance. This finding aligns with previous research demonstrating that excessive phenolic compounds can negatively impact palatability despite their health benefits [20]. Formulations B and C, with lower banana inflorescence proportions, were perceived as lacking distinctive character and resembling conventional instant soups without notable functional food attributes.

Appearance and colour scores reflected consumer preference for products with visible whole food particles, reinforcing health perceptions [21]. The light beige colour with dispersed banana inflorescence flakes and spice particles created visual interest suggesting natural ingredients and minimal processing. The aromatic profile contributed by the spice blend (Table 1) received consistent high scores across all formulations, demonstrating that the cumin-coriander-turmeric combination successfully delivered culturally familiar and appealing sensory characteristics.

3.2 Proximate Composition

Comprehensive proximate analysis of the optimized formulation (Formulation A) revealed a well-balanced nutritional profile suitable for functional food applications targeting women's health (Table 4).

Table 4: Proximate composition of optimized banana inflorescence soup mix

Parameter	Content (per 100g)	% RDA per serving (20g)*
Energy	342.5 ± 3.2 kcal	3.4%
Protein	24.6 ± 1.1 g	10.9%
Total fat	2.8 ± 0.3 g	-
Carbohydrates	58.3 ± 1.8 g	4.5%
Dietary fibre	8.2 ± 0.6 g	10.9%
Moisture	6.5 ± 0.4 g	-
Total ash	5.1 ± 0.3 g	-

Based on RDA for adult women aged 19-50 years

The protein content (24.6 g/100g) was notably higher than conventional instant soup products (typically 8-12 g/100g), contributed primarily by banana inflorescence and micronutrient carriers [22]. This protein level provides approximately 4.9g per serving, contributing meaningfully to daily protein requirements particularly beneficial for menstruating women experiencing increased metabolic demands [23].

Low fat content (2.8 g/100g) aligns with contemporary dietary recommendations and prevents oxidative rancidity concerns during storage. The carbohydrate fraction (58.3 g/100g) predominantly comprised starch from arrowroot, providing energy substrate and desirable viscosity upon rehydration [24].

Particularly noteworthy was the substantial dietary fibre content (8.2 g/100g), delivering approximately 1.6g per serving. This fibre contribution, derived mainly from banana inflorescence, supports digestive health and may assist in managing menstrual-related gastrointestinal symptoms including constipation and bloating commonly reported during luteal phase [25]. Bernstein et al. [25] documented significant gastrointestinal symptom variations throughout the menstrual cycle, emphasizing the importance of dietary fibre in menstrual wellness.

The moisture content (6.5%) was well within acceptable limits for powdered products, ensuring microbiological stability and preventing caking during storage [26]. Total ash (5.1%) reflected the mineral-rich nature of the formulation, encompassing both naturally occurring minerals from banana inflorescence and fortified micronutrients.

3.3 Micronutrient Profile

Mineral analysis confirmed successful fortification achieving target nutrient levels critical for menstrual health support (Table 5).

Table 5: Micronutrient content and contribution to RDA

Micronutrient	Content per 100g	Content per serving (20g)	% RDA per serving*
Iron	37.2 ± 1.8 mg	7.4 mg	41.1%
Calcium	890 ± 24 mg	178 mg	17.8%
Magnesium	285 ± 12 mg	57 mg	15.7%
Vitamin C	142 ± 8 mg	28.4 mg	37.9%
Folate	452 ± 18 mcg	90.4 mcg	22.6%

Based on RDA for adult women aged 19-50 years

Iron content achieved 7.4 mg per serving, representing 41% of the recommended dietary allowance for menstruating women. The formulation utilized ferrous BI glycinate, a chelated iron form demonstrating superior bioavailability (approximately 25-30% absorption) compared to conventional ferrous sulphate (10-15% absorption) [27]. Cancelo-Hidalgo et al. [27] demonstrated that chelated iron forms significantly reduce gastrointestinal side effects while maximizing absorption efficiency. This choice minimizes gastrointestinal side effects commonly associated with iron supplementation while maximizing absorption efficiency.

Vitamin C inclusion (28.4 mg per serving) serves dual purposes: acting as a processing stabilizer for banana inflorescence and functioning as an absorption enhancer for non-heme iron. Research by Teucher et al. [28] demonstrates that vitamin C at 25-50 mg doses can increase iron absorption by 3-4-fold through reduction of ferric to ferrous iron and formation of soluble iron-ascorbate complexes.

Folate provision (90.4 mcg per serving) addresses critical needs during reproductive years, supporting erythropoiesis and DNA synthesis. Adequate folate status is particularly important for women of childbearing age to prevent neural tube defects in potential pregnancies and support normal cell division during rapid tissue turnover associated with menstruation [29]. Fekete et al. [29] established the crucial role of folate in pregnancy outcomes and reproductive health through systematic meta-analysis.

Calcium (178 mg per serving) and magnesium (57 mg per serving) were included at levels specifically targeting menstrual symptom management. Clinical studies by Ghanbari et al. [30] indicate that calcium supplementation (1000-1200 mg daily) significantly reduces premenstrual syndrome symptoms including mood changes, water retention, and pain. Magnesium plays complementary roles in muscle relaxation, neurotransmitter regulation, and prostaglandin metabolism, with supplementation studies by Parazzini et al. [31] showing reduced dysmenorrhea severity.

The synergistic nutrient combination in this formulation addresses multiple pathophysiological mechanisms underlying menstrual disorders: iron and folate combat anaemia, vitamin C enhances iron utilization, calcium modulates neuromuscular function, and magnesium regulates inflammatory mediators and smooth muscle contractility [32].

3.4 Physicochemical Properties

Physicochemical characterization provided insights into functional behavior during preparation and consumption (Table 6).

Table 6: Physicochemical properties of optimized formulation

Parameter	Value
Water absorption capacity	2.1 ± 0.2 g/g
Swelling capacity	1.8 ± 0.1 mL/g
Solubility index	32.6 ± 2.4%
Rehydration time	2.5 ± 0.3 min
Viscosity (reconstituted, 70°C)	185 ± 12 cP
pH (reconstituted)	6.2 ± 0.1

Water absorption capacity (2.1 g/g) indicated good hydration characteristics, allowing rapid reconstitution without excessive lumpiness. The swelling capacity (1.8 mL/g) contributed to desirable viscosity development and mouthfeel perception of body and thickness expected in soup products [33].

Solubility index (32.6%) represented the balance between suspended particles (banana inflorescence flakes, spice particles) providing texture and visual interest, and dissolved components (starch, minerals, soluble fibre) contributing to smooth consistency. Complete dissolution is undesirable in this product context as visible food particles reinforce natural ingredient perception [34].

Rehydration time (2.5 minutes) met consumer expectations for instant products, comparable to commercial soup mixes while incorporating minimally processed whole food ingredients. Kumar and Vijayan [8] reported similar rehydration times (2-3 minutes) for nutritious instant soup formulations. The relatively rapid hydration was facilitated by appropriate particle size distribution and high surface area of flaked banana inflorescence.

Viscosity (185 cP at 70°C) positioned the product within the preferred range for drinkable soups, sufficiently thick to convey satiation and substantiality while remaining easily consumable without spoon [35]. The pH value (6.2) represented slightly acidic conditions contributed by vitamin C fortification and natural organic acids in banana inflorescence, which may enhance iron solubility and absorption [36].

3.5 Antioxidant Capacity

Antioxidant analysis revealed significant bioactive potential beyond basic nutrition (Table 7).

Table 7: Antioxidant properties of optimized formulation

Parameter	Value

DPPH radical scavenging activity	68.4 ± 3.2% at 1 mg/mL
Total antioxidant capacity	612 ± 28 mg AAE/100g
Total phenolic content	485 ± 22 mg GAE/100g
Total flavonoid content	156 ± 14 mg QE/100g

The formulation demonstrated substantial antioxidant activity (68.4% DPPH scavenging) and total antioxidant capacity (612 mg ascorbic acid equivalents/100g). These properties derive from multiple sources: phenolic compounds in banana inflorescence (primarily flavonoids and hydroxycinnamic acids), curcumin from turmeric, piperine from black pepper, and ascorbic acid fortification [37].

The carefully formulated spice blend (Table 1) contributed significantly to the overall antioxidant profile. Curcumin from turmeric has been extensively documented for its free radical scavenging capacity [15], while quercetin from onion and linalool from coriander provide complementary antioxidant mechanisms [14,19]. The synergistic interaction of these bioactive compounds may provide enhanced antioxidant protection compared to individual components, as demonstrated in previous phytochemical interaction studies [38].

Piperine from black pepper plays a dual role in the formulation: contributing to the antioxidant pool while simultaneously enhancing the bioavailability of curcumin by up to 2000% through inhibition of hepatic and intestinal glucuronidation [18]. This bioavailability enhancement is particularly relevant for the anti-inflammatory benefits targeting menstrual discomfort.

Gingerol from ginger and cumin aldehyde from cumin provide additional phenolic compounds with documented anti-inflammatory effects [13,16]. These compounds may work synergistically to modulate prostaglandin synthesis and inflammatory mediator production, mechanisms directly relevant to dysmenorrhea pathophysiology [39].

Oxidative stress plays significant roles in menstrual disorders, with studies by Polat et al. [40] showing elevated lipid peroxidation and reduced antioxidant enzyme activity in women with dysmenorrhea and irregular cycles. The antioxidant-rich formulation may help counteract menstrual-associated oxidative damage while supporting overall cellular health.

The phenolic content (485 mg gallic acid equivalents/100g) and flavonoid content (156 mg quercetin equivalents/100g) reflect bioactive compound preservation during processing. Steam blanching, despite being a thermal treatment, can actually increase extractable phenolics by disrupting cellular structures and inactivating degradative enzymes, as demonstrated by Miglio et al. [41]. The roasting process applied to spices during preparation likely contributed to enhanced bioactive compound extractability through similar mechanisms of cellular structure disruption and moisture reduction.

The multi-source antioxidant profile of the formulation—combining banana inflorescence polyphenols, spice-derived bioactive (Table 1), and ascorbic acid fortification—provides comprehensive antioxidant protection through multiple mechanisms including direct free radical scavenging, metal chelation, and enzyme modulation. This comprehensive approach may offer superior benefits compared to single-source antioxidant interventions.

3.6 Shelf-Life Stability

Accelerated shelf-life evaluation across different packaging materials revealed critical insights for commercial viability (Table 8).

Table 8: Changes in quality parameters during storage (90 days, ambient conditions)

Parameter	Initial	Glass bottle	HDPE container	Metalized pouch	Aluminum laminate
Moisture (%)	6.5±0.4	7.2±0.3^{a}	8.6±0.5^{b}	7.8±0.4^{ab}	7.1±0.3^{a}
pH	6.2±0.1	6.1±0.1^{a}	6.0±0.2^{a}	6.1±0.1^{a}	6.1±0.1^{a}
Peroxide value (mEq/kg)	2.1±0.3	3.8±0.4^{a}	5.2±0.6^{b}	4.1±0.5^{a}	3.6±0.4^{a}
Total plate count (CFU/g)	<10^{2}	2.8×10^{3a}	1.2×10^{4b}	4.6×10^{3ab}	2.1×10^{3a}
Overall acceptability	7.8±0.9	7.4±0.8^{a}	6.2±1.1^{b}	7.0±0.9^{ab}	7.5±0.7^{a}

Different superscript letters within rows indicate significant differences (p<0.05)

Glass bottles and Aluminum laminate sachets demonstrated superior performance in maintaining product quality over 90 days. Moisture migration, the primary degradation mechanism in dry soup mixes, was minimal in these packaging systems (<15% increase from initial values). HDPE containers showed higher moisture gain (32% increase), likely due to higher water vapor permeability of polyethylene compared to glass or Aluminum barriers [42]. Peroxide value increases indicated minimal lipid oxidation across all packaging types, remaining well below concerning levels (<10 mEq/kg) throughout storage. The low-fat content of the formulation inherently reduced oxidative stability concerns. The inclusion of turmeric and other spices (Table 1) provided additional protection through natural antioxidants [15].

Microbiological stability remained excellent across all packaging systems, with total plate counts remaining within acceptable limits for dry food products (<10^{4} CFU/g) after 90 days. No yeast or Mold growth was detected in any samples, confirming that the moisture content (≤7%) successfully prevented fungal proliferation. The initial low microbial load reflected good manufacturing practices and the antimicrobial effects of drying. The antimicrobial properties contributed by garlic (allicin) in the spice blend

(Table 1) likely contributed to the enhanced microbiological stability observed [17].
Sensory acceptability declined most significantly in HDPE-packaged samples, correlating with higher moisture gain leading to texture degradation and reduced flavour intensity. Glass and Aluminum packaging maintained sensory scores above 7.0 (like moderately), indicating continued consumer acceptability through extended storage periods [43].
Based on these findings, glass bottles were selected as optimal packaging for the product, offering excellent barrier properties, zero flavour interaction, and consumer perception advantages associated with premium, health-focused products. Aluminum laminate sachets represent a viable alternative for single-serve applications where convenience and portability are prioritized.

3.7 Comparative Analysis with Commercial Products

Nutritional and economic comparison with leading commercial instant soup products revealed substantial advantages of the developed formulation (Table 9).

Table 9: Comparative evaluation with commercial instant soup mix

Parameter (per serving)	Developed formulation	Commercial product	Difference
Energy (kcal)	68.5	42.0	+63%
Protein (g)	4.9	1.2	+308%
Dietary fibre (g)	1.6	0.3	+433%
Iron (mg)	7.4	0.0	-
Calcium (mg)	178	0.0	-
Vitamin C (mg)	28.4	0.0	-
Cost per serving (USD)	0.12	0.18	-33%

The developed formulation delivered 308% more protein, 433% more dietary fibre, and substantial amounts of critical micronutrients entirely absent in the commercial comparator. The commercial product, typical of instant soup category, relied primarily on refined starch, flavour enhancers (including monosodium glutamate), and synthetic colorants, providing minimal nutritional value beyond calories [44].
Remarkably, the developed formulation achieved this superior nutritional profile at 33% lower cost per serving, attributed to: (1) utilization of underutilized banana inflorescence rather than expensive imported ingredients, (2) simple processing methods avoiding costly extraction or encapsulation technologies, and (3) locally sourced traditional spices (Table 1) replacing proprietary flavour systems [45].
This cost-effectiveness, combined with dense nutrition, positions the product advantageously for addressing women's health needs across socioeconomic strata, particularly in developing nations where both nutritional deficiencies and economic constraints are prevalent [46].

4. DISCUSSION

The successful development of this banana inflorescence-based functional soup demonstrates the viability of traditional plant resources for addressing contemporary nutritional challenges. The formulation strategy prioritized nutritional synergy over single-nutrient fortification, recognizing that menstrual health depends on multiple interacting physiological systems.
The selection of banana inflorescence as the primary functional ingredient was validated through both nutritional contribution and consumer acceptance. The inherent mineral richness of banana inflorescence, particularly iron, complemented the fortification strategy, allowing achievement of therapeutic iron levels while maintaining predominantly food-based composition [7]. The fibre contribution addressed often-overlooked aspects of menstrual wellness, with emerging research linking gut microbiome composition to hormonal balance and menstrual regularity [47].
Sensory optimization revealed that successful functional food development requires balancing health benefits with palatability. The iterative formulation process identified the threshold banana inflorescence concentration (22%) that maximized nutritional impact while maintaining flavour acceptability. Exceeding this level introduced excessive bitterness despite processing interventions, while lower levels failed to differentiate the product from conventional soups. This finding is consistent with the dose-response relationship between phenolic content and sensory perception documented in functional food research [20].
The carefully designed spice blend (Table 1) played a critical role beyond flavour enhancement. Each spice component was selected for dual functionality: organoleptic contribution and specific bioactive delivery. The 28% cumin content provided the characteristic soup flavour profile while contributing cumin aldehyde with documented digestive benefits [13]. Turmeric at 15% delivered curcumin at levels potentially therapeutic for inflammation management without imparting excessive bitterness or colour intensity that would reduce acceptability.
The strategic inclusion of black pepper at 8% was particularly important for maximizing the anti-inflammatory potential of the formulation. Piperine's well-documented enhancement of curcumin bioavailability [18] transforms turmeric from a poorly absorbed ingredient into a potentially therapeutic component. This exemplifies the synergistic approach underlying the formulation design combining ingredients that enhance each other's functionality.
Ginger's inclusion at 12% addresses the analgesic requirements specific to menstrual health applications. Clinical studies have demonstrated ginger's effectiveness in reducing dysmenorrhea severity, with mechanisms involving prostaglandin synthesis inhibition and cyclooxygenase pathway modulation [16]. The 12%

incorporation level was optimized to provide meaningful gingerol content while maintaining balanced flavour profile.

The quercetin contribution from onion powder (5%) and the linalool from coriander (22%) provide additional antioxidant mechanisms that complement curcumin's anti-inflammatory effects [14,19]. The allicin from garlic (10%) not only contributes antimicrobial properties but also supports cardiovascular health and immune function, benefits that extend beyond menstrual health to overall wellness [17].

The processing methodology for banana inflorescence proved critical for product quality. Steam blanching effectively reduced astringency and bitterness by gelatinizing tannins and inactivating enzymes, while preserving minerals and most vitamins [41]. The flaking approach, rather than fine powdering, maintained visual connection to whole food ingredients, enhancing consumer trust and perceived naturalness—increasingly important factors in functional food acceptance [21].

The comprehensive shelf-life evaluation addressed commercial viability concerns often neglected in academic formulation studies. The 90-day stability in appropriate packaging indicates compatibility with existing food distribution channels, eliminating cold chain requirements that would limit accessibility in resource-constrained settings. The antimicrobial properties contributed by garlic (allicin) and other spices in the blend (Table 1) likely contributed to the excellent microbiological stability observed across all packaging systems [17].

The economic analysis demonstrated that functional foods need not carry premium pricing to be viable. By leveraging locally abundant, underutilized crops (banana inflorescence), traditional spices available in regional markets (Table 1), and simple processing technologies, the formulation achieved cost-competitiveness with nutritionally inferior commercial products. This accessibility is crucial for population-level impact on women's health, as affordability barriers often limit functional food consumption to affluent demographics [46].

The formulation's micronutrient profile was specifically designed to address multiple pathways in menstrual disorder pathophysiology. Iron and folate combat anaemia-induced fatigue and support erythropoiesis elevated during menstruation [27,29]. Calcium and magnesium modulate neuromuscular excitability, potentially reducing cramping and muscle tension [30,31]. Vitamin C enhances iron absorption while contributing to collagen synthesis important for endometrial repair [28]. The polyphenolic compounds from banana inflorescence and the spice blend (curcumin, gingerol, quercetin, cumin aldehyde) as detailed in Table 1 provide anti-inflammatory effects potentially ameliorating prostaglandin-mediated pain and discomfort [13-16,19].

This multi-targeted approach reflects current understanding that menstrual disorders rarely result from single nutrient deficiencies but rather from complex interactions between nutritional status, inflammatory mediators, hormonal fluctuations, and oxidative stress [39,40]. Food-based interventions delivering multiple bioactive compounds through synergistic ingredient combinations may prove more effective than isolated nutrient supplements for such multifactorial conditions.

The synergistic effects between nutrients and bioactive compounds in the formulation deserve particular attention. The vitamin C-iron synergy enhances mineral bioavailability [28], while piperine-curcumin interaction dramatically improves anti-inflammatory compound absorption [18]. The calcium-magnesium balance supports neuromuscular function [32], and the diverse antioxidant profile from banana inflorescence, turmeric, coriander, onion, and vitamin C provides multi-mechanistic oxidative stress protection [37,38].

Limitations of this study include the relatively short shelf-life evaluation period and absence of clinical efficacy trials. Future research should extend stability assessment to 12-18 months under real-world distribution conditions and conduct randomized controlled trials measuring menstrual health outcomes (haemoglobin status, menstrual regularity, dysmenorrhea severity, premenstrual syndrome symptoms) in target populations consuming the product regularly. Additionally, bioavailability studies measuring actual absorption of iron, curcumin, and other bioactive compounds would strengthen the therapeutic claims.

The success of this formulation suggests broader applications for underutilized traditional plant resources in functional food development. Similar approaches could address other population-specific nutritional needs, such as bone health in aging populations or metabolic health in obesity prevention, while supporting agricultural diversification and traditional food culture preservation. The spice blend approach (Table 1) could be adapted for different therapeutic targets by modifying component ratios or incorporating additional functional spices.

5. CONCLUSION

This investigation successfully developed and characterized a novel banana inflorescence-based instant soup mix specifically formulated to support women's menstrual health. The optimized formulation containing 22% banana inflorescence flakes, fortified with synergistic micronutrients and a scientifically designed traditional spice blend (Table 1), demonstrated excellent nutritional profile, acceptable sensory attributes, and adequate shelf stability. The product delivers substantial amounts of iron, calcium, magnesium, vitamin C, and folate critical for menstrual wellness, while maintaining cost-competitiveness with commercial alternatives.

The research validates the potential of underutilized traditional plant resources for evidence-based functional food development, demonstrating that scientific rigor and traditional knowledge can be integrated to create practical nutritional interventions. The formulation offers a convenient, accessible, and culturally appropriate dietary approach to addressing menstrual-related nutritional deficiencies that affect millions of women globally.

The strategic spice blend design exemplifies how traditional culinary ingredients can be optimized for both palatability and therapeutic functionality, with each component (cumin, coriander, turmeric, ginger, garlic, black pepper, onion) contributing specific bioactive compounds that synergistically support menstrual health through anti-inflammatory, antioxidant, analgesic, and bioavailability-enhancing mechanisms.

Future directions should include clinical validation studies measuring actual menstrual health outcomes, scale-up to pilot production with techno-economic feasibility assessment, sensory evaluation with larger consumer populations across diverse demographics and cultural contexts, bioavailability studies measuring nutrient and phytochemical absorption, and investigation of complementary functional ingredients that could further enhance menstrual health support. Long-term stability studies under tropical and subtropical conditions would support commercialization in regions with highest menstrual health burden.

The successful methodology established in this research provides a framework for developing additional women's health-focused functional foods addressing lifecycle-specific nutritional requirements, including pregnancy, lactation, and menopause. The principles of synergistic ingredient combination, bioavailability optimization, cost-effective processing, and cultural acceptability demonstrated in this work can guide future functional food innovations targeting underserved health needs.

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PATENT DISCLOSURE AND CONFLICT OF INTEREST

The functional food formulation and preparation method described in this manuscript are covered by Indian Patent Application No. 202521125364, published by the Indian Patent Office, Government of India (Title: "Functional Food Composition for Women's Health Support"; Inventors: Dr. Divya S and Dr. Urmila Shirke). While the authors hold intellectual property rights to this invention, all research was conducted independently without commercial funding, and all experimental data and methodologies are disclosed transparently for peer review. The authors declare no financial conflicts or other competing interests.

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REFERENCE

1. Armour M, Parry K, Manohar N, Holmes K, Ferfolja T, Curry C, MacMillan F, Smith CA. The prevalence and academic impact of dysmenorrhea in 21,573 young women: a systematic review and meta-analysis. J Womens Health. 2019;28(8):1161-1171.
2. World Health Organization. The global prevalence of anaemia in 2011. Geneva: World Health Organization; 2015.
3. Hallberg L, Högdahl AM, Nilsson L, Rybo G. Menstrual blood loss—a population study. Acta Obstet Gynecol Scand. 1966;45(3):320-351.
4. Chocano-Bedoya PO, Manson JE, Hankinson SE, Willett WC, Johnson SR, Chasan-Taber L, Ronnenberg AG, Bigelow C, Bertone-Johnson ER. Dietary B vitamin intake and incident premenstrual syndrome. Am J Clin Nutr. 2011;93(5):1080-1086.
5. Martirosyan DM, Singh J. A new definition of functional food by FFC: what makes a new definition unique? Funct Foods Health Dis. 2015;5(6):209-223.
6. Sheng Z, Dai H, Wan S, Zhu X, Zha Y. Nutritional composition and potential health benefits of banana inflorescence: a review. Food Sci Nutr. 2021;9(4):2290-2303.
7. Bhaskar JJ, Shobha MS, Sambaiah K, Salimath PV. Beneficial effects of banana (Musa sp. var. elakki bale) flower and pseudostem on hyperglycemia and advanced glycation end-products (AGEs) in streptozotocin-induced diabetic rats. J Physiol Biochem. 2011;67(3):415-425.
8. Kumar AS, Vijayan K. Development of nutritious instant soup mix, its organoleptic and experimental evaluation with its popularization. Indian J Nutr. 2024;11(1):280-287.
9. Patil SM, Shirahatti PS, Kumari M, Ramu R, Prasad NR. Development of iron-rich dietary formulation from selected herbs and its optimization for higher iron content and bioavailability. Food Sci Nutr. 2022;10(8):2654-2665.
10. Sharma R, Kumar V, Thakur A. Plant-based micronutrient formulations for combating iron deficiency: development and evaluation. J Food Sci Technol. 2020;57(9):3421-3429.
11. Tabrizi R, Langari H, Zakeri M, Lankarani KB, Akbari M, Heydari ST, Kolahdooz F, Asemi Z. The effects of calcium supplementation on metabolic profiles and biomarkers of inflammation and oxidative stress in women with polycystic ovary syndrome: a systematic review and meta-analysis of randomized controlled trials. Horm Metab Res. 2020;52(01):1-8.
12. Scholz-Ahrens KE, Ade P, Marten B, Weber P, Timm W, Açil Y, Glüer CC, Schrezenmeir J. Prebiotics, probiotics, and synbiotics affect mineral absorption, bone mineral content, and bone structure. J Nutr. 2007;137(3):838S-846S.

13. Johri RK. Cuminum cyminum and Carum carvi: an update. Pharmacogn Rev. 2011;5(9):63-72.
14. Linalool N, Peana AT, D'Aquila PS, Panin F, Serra G, Pippia P, Moretti MD. Anti-inflammatory activity of linalool and linalyl acetate constituents of essential oils. Phytomedicine. 2002;9(8):721-726.
15. Anand P, Kunnumakkara AB, Newman RA, Aggarwal BB. Bioavailability of curcumin: problems and promises. Mol Pharm. 2007;4(6):807-818.
16. Rahnama P, Montazeri A, Huseini HF, Kianbakht S, Naseri M. Effect of Zingiber officinale R. rhizomes (ginger) on pain relief in primary dysmenorrhea: a placebo randomized trial. BMC Complement Altern Med. 2012;12:92.
17. Bayan L, Koulivand PH, Gorji A. Garlic: a review of potential therapeutic effects. Avicenna J Phytomed. 2014;4(1):1-14.
18. Shoba G, Joy D, Joseph T, Majeed M, Rajendran R, Srinivas PS. Influence of piperine on the pharmacokinetics of curcumin in animals and human volunteers. Planta Med. 1998;64(4):353-356.
19. Boots AW, Haenen GR, Bast A. Health effects of quercetin: from antioxidant to nutraceutical. Eur J Pharmacol. 2008;585(2-3):325-337.
20. Drewnowski A, Gomez-Carneros C. Bitter taste, phytonutrients, and the consumer: a review. Am J Clin Nutr. 2000;72(6):1424-1435.
21. Roman S, Sanchez-Siles LM, Siegrist M. The importance of food naturalness for consumers: results of a systematic review. Trends Food Sci Technol. 2017;67:44-57.
22. Farzana T, Mohajan S, Saha T, Hossain MN, Haque MZ. Formulation and nutritional evaluation of a healthy vegetable soup powder supplemented with soy flour, mushroom, and moringa leaf. Food Sci Nutr. 2017;5(4):911-920.
23. Barr SI, Rideout CA. Nutritional considerations for vegetarian athletes. Nutrition. 2004;20(7-8):696-703.
24. Singh N, Singh J, Kaur L, Sodhi NS, Gill BS. Morphological, thermal and rheological properties of starches from different botanical sources. Food Chem. 2003;81(2):219-231.
25. Bernstein MT, Graff LA, Avery L, Palatnick C, Parnerowski K, Targownik LE. Gastrointestinal symptoms before and during menses in healthy women. BMC Womens Health. 2014;14:14.
26. Rahman MS, Labuza TP. Water activity and food preservation. In: Rahman MS, editor. Handbook of food preservation. 2nd ed. Boca Raton: CRC Press; 2007. p. 447-476.
27. Cancelo-Hidalgo MJ, Castelo-Branco C, Palacios S, Haya-Palazuelos J, Ciria-Recasens M, Manasanch J, Pérez-Edo L. Tolerability of different oral iron supplements: a systematic review. Curr Med Res Opin. 2013;29(4):291-303.
28. Teucher B, Olivares M, Cori H. Enhancers of iron absorption: ascorbic acid and other organic acids. Int J Vitam Nutr Res. 2004;74(6):403-419.
29. Fekete K, Berti C, Trovato M, Lohner S, Dullemeijer C, Souverein OW, Cetin I, Decsi T. Effect of folate intake on health outcomes in pregnancy: a systematic review and meta-analysis on birth weight, placental weight and length of gestation. Nutr J. 2012;11:75.
30. Ghanbari Z, Haghollahi F, Shariat M, Foroshani AR, Ashrafi M. Effects of calcium supplement therapy in women with premenstrual syndrome. Taiwan J Obstet Gynecol. 2009;48(2):124-129.
31. Parazzini F, Di Martino M, Pellegrino P. Magnesium in the gynecological practice: a literature review. Magnes Res. 2017;30(1):1-7.
32. Vazquez-Lorente H, Herrera-Quintana L, Molina-Lopez J, Gamarra-Morales Y, Lopez-Gonzalez B, Minic I, Perez-Lopez P, Planells E. Response of vitamin D after magnesium intervention in a postmenopausal population from the Province of Granada, Spain. Nutrients. 2020;12(8):2283.
33. Anderson RA, Conway HF, Pfeifer VF, Griffin EL Jr. Gelatinization of corn grits by roll and extrusion cooking. Cereal Sci Today. 1969;14(1):4-12.
34. Akonor PT, Tortoe C, Buckman ES, Hagan L. Physicochemical and sensory properties of orange-fleshed sweet potato soup mix. Am J Food Technol. 2017;12(1):48-58.
35. Szczesniak AS. Texture is a sensory property. Food Qual Prefer. 2002;13(4):215-225.
36. Hurrell R, Egli I. Iron bioavailability and dietary reference values. Am J Clin Nutr. 2010;91(5):1461S-1467S.
37. Bhaskar JJ, Chilkunda ND. Banana (Musa sp. var. elakki bale) flower and pseudostem: dietary fiber and associated antioxidant capacity. J Agric Food Chem. 2012;60(1):427-432.
38. Liu RH. Potential synergy of phytochemicals in cancer prevention: mechanism of action. J Nutr. 2004;134(12):3479S-3485S.
39. Zahradnik HP, Hanjalic-Beck A, Groth K. Nonsteroidal anti-inflammatory drugs and hormonal contraceptives for pain relief from dysmenorrhea: a review. Contraception. 2010;81(3):185-196.
40. Polat A, Celik H, Gurates B, Aydın A, Yener I, Eroglu E. Prevalence of primary dysmenorrhea in young adult female university students. Arch Gynecol Obstet. 2009;279(4):527-532.

41. Miglio C, Chiavaro E, Visconti A, Fogliano V, Pellegrini N. Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. J Agric Food Chem. 2008;56(1):139-147.

42. Robertson GL. Food packaging: principles and practice. 3rd ed. Boca Raton: CRC Press; 2012.

43. Laguna L, Sarkar A, Bryant M, Beadling AR. Aging from a sensory and food texture perspective. Curr Opin Food Sci. 2015;3:82-89.

44. Wójtowicz A, Mościcki L. Influence of extrusion-cooking parameters on some quality aspects of precooked pasta-like products. J Food Eng. 2009;91(3):398-404.

45. Kennedy G, Nantel G, Shetty P. The scourge of "hidden hunger": global dimensions of micronutrient deficiencies. Food Nutr Agric. 2003;32:8-16.

46. Bailey RL, West KP Jr, Black RE. The epidemiology of global micronutrient deficiencies. Ann Nutr Metab. 2015;66(Suppl 2):22-33.

47. Baker JM, Al-Nakkash L, Herbst-Kralovetz MM. Estrogen-gut microbiome axis: physiological and clinical implications. Maturitas. 2017;103:45-53.