

Original Article

Development of Bioactive Candy Supplements Using Mixed Seeds and Dry Fruits for Emotional Resilience and Mental Clarity

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ABSTRACT

Background: Nutrient-dense seeds, nuts, and dried fruits provide protein, dietary fiber, unsaturated fatty acids, minerals, and phytochemicals that have attracted interest in functional-food development and broader dietary strategies relevant to brain health. However, incorporation of these ingredients into acceptable shelf-stable confectionery products requires physicochemical, antioxidant, microbiological, and sensory evaluation. **Objective:** To develop mixed-seed and dried-fruit bioactive candy formulations and characterize their nutritional composition, phenolic and flavonoid contents, antioxidant activity, microbial count, and sensory acceptability. **Methods:** Five 100-g formulations containing pumpkin, sunflower, flax and chia seeds, almonds, walnuts, dates, and figs were developed. Proximate composition, ash fractions, total phenolic content, total flavonoid content, DPPH radical-scavenging activity, total plate count, and sensory characteristics were evaluated. **Results:** Protein ranged from 13.87% to 14.86%, crude fiber from 5.88% to 6.78%, and carbohydrate from 60.58% to 63.98%. L5N had the highest total phenolic content (6.93 ± 0.51 mg GAE/g), L2N the highest flavonoid content (10.67 ± 0.58 mg QE/g), and L4N the highest DPPH inhibition ($56.98 \pm 0.41\%$). Total plate counts ranged from 5.1×10^2 to 7.0×10^2 CFU/g. The sensory evaluation identified L4N as the most favorably rated formulation, particularly for taste and texture. **Conclusion:** Mixed seeds and dried fruits were successfully incorporated into nutrient- and phytochemical-containing candy prototypes. The findings establish nutritional, antioxidant, microbiological, and sensory characteristics of the formulations but do not demonstrate improvement in emotional resilience, cognition, or mental health. **Keywords:** Bioactive Candy; Functional Food; Mixed Seeds; Dried Fruits; Polyphenols; Flavonoids; Antioxidant Activity; Sensory Evaluation.

INTRODUCTION

Mental health is an integral component of overall health and influences the ability to function, maintain relationships, work, learn, and cope with stress. Mental disorders contribute substantially to global disability and societal burden, increasing interest in potentially modifiable lifestyle factors that may complement established preventive and therapeutic strategies (1).

Nutrition is one such factor, although relationships between diet and mental health are complex and cannot be reduced to the effects of individual nutrients or food products. Dietary patterns rich in fruits, vegetables, nuts, seeds, whole grains, legumes, and unsaturated fats provide diverse nutrients and

bioactive compounds. Randomized-trial evidence and contemporary systematic reviews suggest that Mediterranean-style and other health-promoting dietary interventions may influence depressive symptoms in some populations, although effects vary according to intervention characteristics, population, adherence, and underlying clinical status (2,3). These findings concern whole dietary patterns and should not be extrapolated directly to individual snack or confectionery products.

Nuts are nutritionally dense foods containing proteins, unsaturated fatty acids, fiber, minerals, vitamins, and diverse phytochemicals. Reviews of nut consumption and cognition have identified potential relationships with cognitive performance, although the magnitude and consistency of observed effects vary according to population, nut type, dose, duration, and study design (4–6). Accordingly, incorporation of nuts into a functional-food prototype provides a nutritional rationale for product development but does not establish that the resulting product itself improves cognitive performance.

Seeds similarly provide nutritionally important lipids, proteins, fiber, minerals, and bioactive compounds. Flaxseed is particularly rich in alpha-linolenic acid, lignans, and dietary fiber, whereas chia contributes alpha-linolenic acid, protein, fiber, minerals, and phenolic constituents (7,8). Specialty seeds, including pumpkin and sunflower seeds, also contribute proteins, unsaturated lipids, minerals, tocopherols, and phytochemicals, although their composition varies with cultivar, processing, and analytical methodology (9). Pumpkin seed and pumpkin seed oil have been investigated as functional-food ingredients because of their lipid, micronutrient, and phytochemical profiles (10,11). More broadly, oilseed proteins have attracted increasing interest for food formulation because of their nutritional value and functional properties within food matrices (12).

Dried fruits provide concentrated carbohydrate, fiber, minerals, and phytochemical compounds. Dates are particularly useful in functional snack formulations because their naturally cohesive texture and sweetness can contribute both binding and palatability without reliance on conventional refined-sugar syrups. Date fruit has therefore been investigated extensively as a base ingredient for functional energy bars and related products, with formulation studies emphasizing its nutritional, technological, textural, and sensory properties (13).

The term functional food generally describes foods or ingredients intended to offer physiological or nutritional value beyond basic energy provision. Nevertheless, the presence of phytochemicals or measurable antioxidant capacity in a food matrix should be distinguished from demonstrated therapeutic efficacy. Fruits, seeds, nuts, and other plant-derived foods contain multiple compounds capable of producing antioxidant responses in laboratory assays, but analytical antioxidant activity does not by itself establish a clinical effect after consumption (14).

Food-product development must therefore balance nutritional composition with technological and sensory acceptability. Increasing the quantity of a nutritionally desirable ingredient can alter hardness, dryness, bitterness, oiliness, cohesiveness, aroma, sweetness, and overall mouthfeel. Studies of date-based functional bars and protein snack products consequently emphasize simultaneous optimization of nutritional composition and sensory characteristics rather than maximizing a single analytical parameter (13,15).

Ready-to-eat protein bars also illustrate the importance of stability during storage. Physicochemical properties and antioxidant activity can change over time, while formulation, packaging, moisture migration, lipid oxidation, and storage conditions may influence product quality (15). Such considerations are particularly relevant to formulations containing lipid-rich seeds and nuts.

Similar principles apply to fortified confectionery products. Functional gummy-candy research has demonstrated that physicochemical and sensory stability must be considered alongside the incorporation of bioactive ingredients, because a formulation that performs well analytically may not necessarily retain desirable texture, appearance, flavor, or acceptability during storage (16).

Phenolic-rich fruits, nuts, and seeds are additionally relevant because they contain compounds capable of reacting in commonly used in-vitro antioxidant assays. Total phenolic and flavonoid concentrations and free-radical-scavenging activity can be quantified analytically, but these measurements primarily characterize the food matrix and should not be interpreted as direct measures of neurological, psychological, or therapeutic efficacy (14).

A convenient confectionery format combining mixed seeds, nuts, dates, and figs could therefore provide a compact nutrient-dense snack while allowing systematic evaluation of compositional and sensory trade-offs. Such a prototype may justify subsequent investigation in target populations if its nutritional, antioxidant, microbiological, sensory, and storage properties are adequately characterized.

The present study developed five mixed-seed and dried-fruit candy formulations and evaluated their proximate composition, ash characteristics, phenolic and flavonoid contents, DPPH radical-scavenging activity, total microbial count, and sensory acceptability. Potential relevance to emotional resilience and mental clarity was considered a rationale for future clinical investigation rather than an efficacy outcome of the present food-development study.

MATERIALS AND METHODS

Study Design

An experimental developmental food-product study was conducted to formulate and characterize mixed-seed and dried-fruit candies. The development process included ingredient selection, roasting and grinding, formulation optimization, proximate and phytochemical analyses, antioxidant testing, microbiological assessment, and sensory evaluation.

Ingredient Selection and Preparation

The formulations contained pumpkin seeds, sunflower seeds, flaxseeds, chia seeds, almonds, walnuts, dates, and figs.

Seeds, nuts, and dried fruits were cleaned before processing. Seed and nut ingredients were roasted under controlled conditions to improve flavor and facilitate preparation, then cooled to room temperature and finely ground.

Dates and figs were blended to produce a cohesive fruit paste that functioned as the principal sweetening and binding component. Ground seeds and nuts were gradually incorporated into the fruit paste until a homogeneous mass was obtained. The mixture was shaped into bite-sized candies or spread before portioning. The products were dried and subsequently stored in airtight food-grade containers.

Formulation Plan

Five formulations were developed using different proportions of seed, nut, and dried-fruit components.

Table 1. Composition of the Five Bioactive Candy Formulations

Ingredient, g/100 g	L1N	L2N	L3N	L4N	L5N
Pumpkin seeds	15	10	20	10	10
Sunflower seeds	10	10	10	10	10
Flaxseeds	15	20	10	15	10
Chia seeds	15	15	15	15	15
Almonds	10	10	15	15	15
Dates	10	10	10	10	10
Figs	10	10	10	10	10
Walnuts	15	15	10	15	20
Total	100	100	100	100	100

Ash Analysis

Total ash was measured by incinerating approximately 2–4 g of dried powdered sample at 500–600°C until a carbon-free residue was obtained. Samples were cooled in a desiccator and reweighed to constant mass.

Acid-insoluble ash was assessed by boiling total ash with 25 mL of 2 N hydrochloric acid for five minutes, filtering through ashless filter paper, washing with hot water until neutral, and incinerating the residue.

Water-soluble ash was assessed by boiling total ash with 25 mL water, filtering, washing, drying, and incinerating the insoluble residue before determining the soluble fraction by difference.

Sulphated ash was determined after moistening the sample with concentrated sulfuric acid followed by heating and ignition at approximately 800±25°C.

Moisture and Total Solids

Approximately 2–5 g of each sample were dried at 105°C to constant mass. Moisture was calculated from the loss in sample weight.

Total solids were calculated as:

Total solids (%) = 100 – moisture (%).

The formulation-specific total-solids values were therefore derived directly from the corresponding mean moisture values using this equation.

Crude Fiber

Crude fiber was estimated by sequential acid and alkali digestion of defatted sample material, followed by drying, weighing, ashing, and calculation of the residual fiber fraction.

Protein

Protein was estimated using the Lowry method with bovine serum albumin as the calibration standard (17).

A stock BSA solution of 1 mg/mL was prepared and serially diluted. Samples or standards were reacted with freshly prepared alkaline copper reagent, incubated for 10 minutes, and subsequently reacted with diluted Folin-Ciocalteu reagent. Following a 30-minute dark incubation, absorbance was measured at 750 nm against a reagent blank.

The protein calibration equation was:

$$y = 0.0009x + 0.024; R^2 = 0.9756.$$

Carbohydrate

Total carbohydrate was calculated by difference. Formulation-specific mean carbohydrate values obtained during laboratory analysis were used for reporting.

Total Phenolic Content

Total phenolic content was determined using a Folin-Ciocalteu procedure with gallic acid as the calibration standard, consistent with established total-phenol methodology (18).

Sample and standard solutions were reacted with Folin-Ciocalteu reagent and 15% sodium carbonate and incubated at room temperature for approximately two hours. Absorbance was measured at 760 nm.

The gallic-acid calibration equation was:

$$y = 0.0054x + 0.0308; R^2 = 0.955.$$

Results were expressed as mg gallic acid equivalents per gram.

Total Flavonoid Content

Total flavonoids were quantified using a quercetin calibration curve.

The reported calibration equation was:

$$y = 0.0038x + 0.0066; R^2 = 0.9959.$$

Results were expressed as mg quercetin equivalents per gram.

DPPH Radical-Scavenging Activity

Antioxidant activity was evaluated using the DPPH free-radical method, an established in-vitro approach for estimating radical-scavenging activity (19).

One milliliter of sample solution was combined with methanol and 0.1 mM DPPH solution. Following approximately 30 minutes of reaction, absorbance was measured at 517 nm. Vitamin C served as a reference comparator. Measurements were performed in triplicate, and DPPH inhibition was expressed as a percentage.

Sensory Evaluation

A trained sensory panel evaluated the formulations using a 9-point hedonic scale, a widely established approach for measuring food preference and acceptability (20).

The evaluated domains included appearance, aroma, flavor/taste, texture, and overall acceptability. Feedback was also used during product optimization to modify formulations considered excessively dry, hard, or sweet.

Microbiological Evaluation

Total viable bacterial count was assessed using a standard plate-count approach.

Approximately 10 g of sample were homogenized in 90 mL sterile diluent to prepare a 10^{-1} dilution, followed by serial dilution. Aliquots were spread onto nutrient agar and incubated at 37°C for 24–48 hours. Countable plates were used to express microbial concentration as CFU/g.

Statistical Analysis

Data were processed using IBM SPSS Statistics version 21. Analytical measurements were summarized using means and standard deviations. Formulation comparisons were interpreted descriptively.

Ethical Approval

Ethical approval was obtained from the Institutional Review Board of Superior University, Lahore, Pakistan.

RESULTS

Proximate and Ash Characteristics

Protein content varied relatively little among the five formulations, ranging from $13.87 \pm 0.67\%$ in L3N to $14.86 \pm 0.38\%$ in L1N.

Carbohydrate ranged from $60.58 \pm 0.51\%$ in L2N to $63.98 \pm 0.45\%$ in L4N. Crude fiber ranged from $5.88 \pm 0.58\%$ to $6.78 \pm 0.59\%$, with L2N having the highest measured value.

Moisture ranged from $8.83 \pm 0.59\%$ in L4N to $10.76 \pm 0.49\%$ in L2N. Total solids, calculated as 100 minus moisture, were 90.22%, 89.24%, 90.91%, 91.17%, and 90.44% for L1N through L5N, respectively.

Total ash ranged from $2.54 \pm 0.23\%$ to $3.20 \pm 0.29\%$. L4N had the highest total-ash and sulphated-ash values.

Table 2. Proximate Composition and Ash Characteristics

Parameter	L1N	L2N	L3N	L4N	L5N
Total ash, %	2.54 ± 0.23	2.70 ± 0.21	2.99 ± 0.31	3.20 ± 0.29	2.98 ± 0.36
Acid-insoluble ash, %	0.51 ± 0.50	0.45 ± 0.49	0.76 ± 0.57	0.68 ± 0.34	0.58 ± 0.41
Water-soluble ash, %	1.53 ± 0.49	2.09 ± 0.51	1.31 ± 0.45	1.98 ± 0.55	1.66 ± 0.49
Sulphated ash, %	2.08 ± 0.38	2.51 ± 0.57	2.89 ± 0.57	3.87 ± 0.44	2.04 ± 0.58
Moisture, %	9.78 ± 0.65	10.76 ± 0.49	9.09 ± 0.58	8.83 ± 0.59	9.56 ± 0.57
Total solids, %	90.22	89.24	90.91	91.17	90.44
Crude fiber, %	5.88 ± 0.58	6.78 ± 0.59	6.03 ± 0.67	5.99 ± 0.48	6.33 ± 0.54
Protein, %	14.86 ± 0.38	14.42 ± 0.44	13.87 ± 0.67	14.76 ± 0.48	14.01 ± 0.49
Carbohydrate, %	60.77 ± 0.48	60.58 ± 0.51	62.76 ± 0.55	63.98 ± 0.45	60.87 ± 0.56

Phenolic, Flavonoid, and Antioxidant Characteristics

Total phenolic content ranged from 5.39 ± 0.59 to 6.93 ± 0.51 mg GAE/g. L5N had the highest phenolic concentration at 6.93 ± 0.51 mg GAE/g.

Total flavonoid content ranged from 8.67 ± 0.47 to 10.67 ± 0.58 mg QE/g, with the highest value observed in L2N.

DPPH inhibition ranged from $50.11 \pm 0.43\%$ to $56.98 \pm 0.41\%$ among the candy formulations. L4N had the highest DPPH inhibition, whereas the vitamin C comparator demonstrated $82.34 \pm 0.54\%$ inhibition.

Table 3. Total Phenolic Content, Total Flavonoids, and DPPH Activity

Parameter	L1N	L2N	L3N	L4N	L5N	Vitamin C Comparator
Total phenolics, mg GAE/g	6.43 ± 0.65	5.39 ± 0.59	6.15 ± 0.64	6.09 ± 0.59	6.93 ± 0.51	—
Total flavonoids, mg QE/g	8.89 ± 0.54	10.67 ± 0.58	9.78 ± 0.56	8.67 ± 0.47	9.45 ± 0.61	—
DPPH inhibition, %	50.11 ± 0.43	53.91 ± 0.49	51.78 ± 0.50	56.98 ± 0.41	54.89 ± 0.43	82.34 ± 0.54

Sensory Evaluation

The sensory evaluation identified L4N as the most favorably evaluated formulation overall, particularly for taste and texture.

L2N and L5N were also characterized by favorable aroma and appearance, whereas early L1N and L3N prototypes were comparatively dry or flaky. Because complete numerical hedonic scores were not available for analysis, the sensory findings are interpreted as formulation-development observations rather than formal comparative efficacy estimates.

Microbial Count

Total plate counts ranged from 5.1×10^2 to 7.0×10^2 CFU/g across the five candy formulations. L2N had the lowest count at 5.1×10^2 CFU/g, whereas L5N had the highest at 7.0×10^2 CFU/g.

Table 4. Total Plate Count

Sample	Total Plate Count, CFU/g
L1N	6.8×10^2
L2N	5.1×10^2
L3N	5.5×10^2
L4N	6.6×10^2
L5N	7.0×10^2
Vitamin C comparator	5.9×10^2

These counts represent recoverable aerobic microbial burden under the assay conditions and were used descriptively to compare the formulations.

DISCUSSION

The present study developed five candy formulations using mixed seeds, nuts, dates, and figs and demonstrated measurable differences in proximate composition, phenolic and flavonoid concentrations, DPPH radical-scavenging activity, microbial count, and sensory characteristics. Protein concentrations were broadly similar across formulations, whereas more marked formulation-specific differences were observed in crude fiber, carbohydrate, phytochemical measures, antioxidant activity, and sensory performance.

Protein concentrations ranged from approximately 13.9% to 14.9%, with L1N demonstrating the highest value. The relatively narrow range is consistent with the presence of substantial quantities of protein-containing seeds and nuts in all formulations. Oilseeds provide proteins with both nutritional and food-functional properties, while specialty seeds differ in amino-acid composition, processing behavior, lipid content, and associated bioactive constituents (9,12). Consequently, the measured protein concentration represents the contribution of the complete ingredient matrix rather than a single dominant seed or nut.

Previous functional snack research similarly demonstrates that seed- and nut-containing products can achieve appreciable protein and fiber concentrations while maintaining acceptable sensory characteristics. Formulation nevertheless involves trade-offs among nutrient density, moisture, texture, cohesiveness, oxidation, and palatability, and maximizing one compositional variable does not necessarily produce the most acceptable product (13,15).

Carbohydrate was highest in L4N at 63.98%. Because dates and figs were maintained at 10 g each across all five formulations, the difference cannot be attributed simply to a greater amount of dried fruit. Variation in the relative proportions of seeds and nuts, together with differences in their protein, lipid, fiber, and available-carbohydrate composition, can influence the overall proximate profile of mixed food matrices (9,12).

Crude fiber ranged from approximately 5.9% to 6.8%, with the highest value observed in L2N. Because the analytical procedure quantified crude fiber rather than total dietary fiber, these values should be interpreted specifically as crude-fiber measurements and not as complete estimates of all soluble and insoluble dietary-fiber fractions. Seeds and dried fruits nevertheless represent important sources of structural carbohydrates and fiber within mixed snack formulations (7–9,13).

Moisture concentrations were below approximately 11% in all formulations. Moisture is technologically relevant to food stability, but moisture percentage alone is not equivalent to water activity and cannot independently establish microbiological safety or shelf life. Water activity influences microbial growth, physicochemical stability, texture, and deterioration in low-moisture and lipid-rich foods and should therefore be assessed directly during formal shelf-life evaluation (21). Storage studies of ready-to-eat protein bars similarly demonstrate that formulation and storage conditions can alter physicochemical and antioxidant properties over time (15).

Total solids ranged from 89.24% to 91.17% when calculated directly as 100 minus the corresponding moisture percentage. This relationship demonstrates that the formulations had broadly similar solid fractions despite measurable differences in ingredient proportions and proximate composition.

The phytochemical analyses showed formulation-specific patterns. L5N had the highest total phenolic content, whereas L2N had the highest flavonoid concentration and L4N demonstrated the highest DPPH inhibition. Thus, the formulation with the greatest concentration of one measured phytochemical class did not necessarily exhibit the greatest radical-scavenging response.

This finding is scientifically plausible because DPPH activity reflects the combined radical-scavenging behavior of multiple extractable compounds rather than total phenolics alone. Seeds, nuts, dates, and figs contain chemically diverse phenolic compounds, tocopherols, pigments, fatty-acid-associated constituents, and other reducing substances that can contribute differently to in-vitro antioxidant assays (9,10,14,22). The Folin-Ciocalteu method also measures overall reducing capacity rather than identifying individual phenolic compounds (18), whereas DPPH directly evaluates radical-scavenging behavior under the defined assay conditions (19).

The observed DPPH values therefore demonstrate measurable in-vitro radical-scavenging activity of the formulation extracts but do not establish reduction of oxidative stress after human consumption.

Digestion, release from the food matrix, intestinal absorption, metabolism, circulating concentrations, tissue distribution, and interactions among compounds all separate laboratory antioxidant measurements from biological effects in humans (14,22).

The sensory findings favored L4N, which contained 10 g pumpkin seed, 10 g sunflower seed, 15 g flaxseed, 15 g chia seed, 15 g almonds, 15 g walnuts, and 10 g each of dates and figs. Because the quantities of dates and figs were held constant across the formulations, differences in sensory response were more likely related to changing seed and nut proportions and their effects on texture, oiliness, flavor, cohesiveness, and mouthfeel.

Such trade-offs are central to functional-food development. A formulation optimized solely for the highest protein, phenolic, flavonoid, or fiber concentration may not be the formulation preferred by consumers. Sensory acceptability must therefore be evaluated alongside analytical composition, particularly when nutrient-dense ingredients substantially modify taste and texture (13,15,16,20).

The microbiological findings also require appropriately limited interpretation. Total plate counts ranged from 5.1×10^2 to 7.0×10^2 CFU/g and were relatively similar across formulations. Total aerobic plate count provides information regarding recoverable aerobic microbial burden under defined culture conditions but does not by itself establish absence of specific pathogens, molds, or yeasts or demonstrate long-term shelf stability. Microbial assessment should therefore be combined with water-activity measurement, organism-specific testing, packaging assessment, and repeated measurements across the intended storage period (21).

The proposed relationship between these formulations and emotional resilience or mental clarity likewise requires careful distinction between nutritional rationale and demonstrated efficacy. Systematic reviews have examined associations between nut consumption and cognitive outcomes, while controlled human studies have begun to investigate physiological and cognitive responses to mixed-nut intake (4–6). For example, longer-term mixed-nut consumption has been evaluated in a randomized crossover trial examining brain vascular function and memory in older adults (23), and a separate controlled crossover trial has investigated brain insulin sensitivity after mixed-nut consumption in older adults with overweight or obesity (24). These studies provide a rationale for further human research but cannot be extrapolated directly to the present candy formulations.

Similarly, evidence that broader dietary interventions may improve depressive symptoms does not demonstrate that a single seed- and fruit-based food product improves mood, stress resilience, or cognition (2,3). The present study did not measure depression, anxiety, stress, resilience, memory, attention, executive function, mood, sleep, or quality of life. Accordingly, no clinical claim regarding emotional resilience or mental clarity can be established from the present food-characterization data.

The study instead represents an early food-development stage in a potential translational pathway. It establishes candidate formulations and identifies nutritional, phytochemical, antioxidant, microbial, and sensory characteristics that can guide subsequent formulation refinement. If psychological or cognitive benefits are ultimately proposed, future research should first establish complete nutritional composition, food safety, storage stability, and dose standardization before progressing to controlled human intervention studies with validated psychological or cognitive outcomes.

The sensory component also warrants further development. The final sensory-panel size and complete participant-level hedonic scores were not consistently available, limiting quantitative interpretation of consumer acceptance. A larger blinded sensory study with randomized sample presentation, clearly specified panel characteristics, standardized testing conditions, and complete domain-specific hedonic scores would provide stronger evidence regarding consumer preference and reproducibility (20).

The formulations contained dates and figs and should therefore not be characterized as sugar-free in the absence of direct sugar analysis. Future nutritional characterization should include glucose, fructose, sucrose, total sugars, crude fat, fatty-acid profile, amino-acid composition, total dietary fiber, minerals, vitamins, water activity, and energy density. These measurements would permit more complete nutritional labeling and facilitate comparison among formulations.

Overall, the study demonstrates successful laboratory development of mixed-seed and dried-fruit confectionery prototypes. Its principal contribution lies in food-science characterization and formulation optimization rather than demonstrated neuropsychological efficacy.

CONCLUSION

Five mixed-seed and dried-fruit candy formulations were successfully developed and characterized. L1N had the highest measured protein concentration, L2N the highest crude-fiber and flavonoid concentrations, L5N the highest total phenolic content, and L4N the highest carbohydrate concentration, DPPH radical-scavenging activity, and reported sensory preference.

Total plate counts ranged from 5.1×10^2 to 7.0×10^2 CFU/g across the formulations. The products therefore represent nutrient- and phytochemical-containing functional-food prototypes with measurable compositional and antioxidant characteristics.

The present findings do not establish clinical improvement in emotional resilience, mental clarity, mood, cognitive performance, or other mental-health outcomes. Further analytical, microbiological, storage, sensory, and controlled human-intervention research is required before psychological or therapeutic claims can be substantiated.

LIMITATIONS

The study did not evaluate psychological or cognitive outcomes in human participants.

Interpretation of sensory findings was limited by incomplete documentation of the final sensory-panel size and the absence of complete participant-level hedonic scores.

Crude-fat results were not available in the final analytical dataset, limiting independent reconstruction of the carbohydrate-by-difference calculation.

Total-solids values were derived mathematically from moisture measurements rather than measured independently.

Water activity was not measured. Microbiological evaluation was limited to total plate counts; validated yeast and mold enumeration and organism-specific pathogen results were not available for analysis.

Longitudinal microbial and physicochemical measurements over a defined shelf-life period were not conducted. Direct sugar, amino-acid, fatty-acid, mineral, vitamin, bioavailability, and energy-density analyses were not performed. No commercial comparator product was evaluated.

RECOMMENDATIONS

Future product-development studies should reproduce the formulations in independent batches and evaluate complete proximate composition, including crude fat.

Direct sugar profiling should be conducted before reduced-sugar or sugar-free terminology is considered. Water activity, yeast and mold counts, organism-specific pathogen screening, oxidative stability, packaging characteristics, and repeated storage measurements should be incorporated into formal shelf-life studies. Sensory assessment should be repeated using a larger blinded panel, randomized product presentation, standardized testing conditions, fixed participant numbers, and complete participant-level scores.

Bioaccessibility, simulated-digestion, and compositional studies may be undertaken before progressing to human efficacy research. If claims related to emotional resilience or mental clarity are subsequently investigated, a prospective controlled human study should use a standardized formulation and daily dose together with validated measures of mood, stress, resilience, attention, memory, executive function, and other prespecified outcomes.

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