JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

MANGO KERNEL, JACKFRUIT SEED AND WATERMELON SEED POWDERS AS EMERGING FUNCTIONAL INGREDIENTS FOR NUTRIENT-ENRICHED PANCAKE PREMIXES

Ms. SWATHI S[1], Ms. SOWMIYA G[2], Ms. SELVAKUMARI M[3], Ms. KANISHKA B[4]

[1]M.Sc Food and Nutrition, Department of Food Science and Nutrition,
[2]M.Sc Food and Nutrition, Department of Food Science and Nutrition,
[3]M.Sc Food and Nutrition, Department of Food Science and Nutrition,
[4]Assistant Professor, Department of Food Science and Nutrition.

Dr. N.G.P. Arts and Science College, Coimbatore, Tamil Nadu, India Email: shwathishwathi1102@gmail.com
Email: kanishka.b@drngpasc.ac.in

Abstract

The increasing demand for nutritious, convenient and sustainable foods has stimulated interest in the utilization of underexploited plant materials and food-processing by-products as functional food ingredients. Mango kernels, jackfruit seeds and watermelon seeds are nutrient-dense materials that are frequently discarded or underutilized despite their potential contribution to food formulation. Mango kernel contains carbohydrates, lipids, proteins, dietary fibre, minerals and diverse bioactive compounds, including phenolic compounds, tocopherols, phytosterols and carotenoids. Jackfruit seed is characterized by considerable amounts of starch, protein, dietary fibre and resistant starch, together with phenolic and other phytochemical constituents. Watermelon seed is particularly notable for its protein, lipid and mineral content and has demonstrated potential for improving the nutritional quality of cereal-based foods. Processing these materials into stable powders or flours can extend their shelf life, facilitate incorporation into food systems and support food-by-product valorization.

This review critically discusses the nutritional composition, bioactive constituents, processing requirements, functional properties and food applications of mango kernel, jackfruit seed and watermelon seed powders, with particular emphasis on their relevance to bakery and pancake-type products. Published evidence indicates that incorporation of seed-derived flours can increase selected nutritional components, including protein, fibre, minerals and phytochemicals; however, increasing substitution levels may adversely affect gluten development, batter or dough rheology, colour, texture, volume and sensory acceptability. Consequently, formulation optimization is essential. The complementary characteristics of mango kernel, jackfruit seed and watermelon seed powders provide a scientific rationale for investigating their combined incorporation into nutrient-enriched pancake premixes. However, limited research has specifically examined the combined use of these three seed powders in a standardized pancake premix. Future studies should investigate optimized inclusion ratios, antinutritional factors, digestibility, glycaemic response, storage stability, microbial safety, sensory acceptance and techno-functional interactions among the powders. Such research could support the development of convenient functional foods based on locally available and underutilized plant resources.

Keywords: mango kernel powder; jackfruit seed flour; watermelon seed flour; functional food; pancake premix; bakery products; food by-product valorization; composite flour; nutritional enrichment; sustainable food processing

I. INTRODUCTION

The modern food system is increasingly influenced by the need to provide foods that are convenient, palatable, nutritionally meaningful and environmentally sustainable. Consumer interest in foods containing dietary fibre, plant proteins, minerals and bioactive compounds has increased alongside awareness of the environmental consequences of food waste. At the same time, large quantities of agricultural and food-processing by-products are generated throughout the food supply chain. Fruit seeds and kernels constitute an important fraction of these materials and are frequently discarded despite containing potentially valuable nutrients and phytochemicals.

Food-by-product valorization has therefore become an important research area in food science and food processing. Recovery of valuable constituents from plant residues and their conversion into food ingredients can contribute to circular food systems, improve resource efficiency and generate value-added products. Mango kernel, jackfruit seed and watermelon seed are particularly relevant because each possesses a distinct nutritional and functional profile.

Mango (Mangifera indica L.) processing generates seeds containing a kernel that is rich in macronutrients and several classes of phytochemicals. A comprehensive review reported mango-kernel carbohydrate, fat, protein, crude-fibre and ash ranges of approximately 32.34–76.81%, 6–15.2%, 6.36–10.02%, 0.26–4.69% and 1.46–3.71%, respectively, on a dry-weight basis. Mango kernel also contains tocopherols, phytosterols, carotenoids, polyphenols and phenolic acids.

Jackfruit (Artocarpus heterophyllus Lam.) seeds are another underutilized plant resource. They are characterized by a substantial starch fraction together with protein, dietary fibre, minerals and phytochemicals. Reviews published in recent years have highlighted their potential as flour and starch sources for bakery, extrusion and other food applications.

Watermelon (Citrullus lanatus) seeds are similarly underutilized despite their nutritional value. Recent literature describes watermelon seeds as sources of fat, protein, carbohydrate, minerals and phytochemicals. A 2024 review reported approximately 40–50% fat, 18–30% protein and 10–18% carbohydrate, although the composition varies with cultivar and analytical conditions.

The conversion of these materials into powders or flours offers several technological advantages. Drying reduces moisture and improves storage stability, while milling facilitates uniform incorporation into composite flour systems. However, processing conditions can also alter phenolic compounds, antinutritional factors, colour, water absorption and other functional properties.

Pancakes are suitable carriers for functional flour incorporation because their formulation can accommodate partial substitution of conventional cereal flour. A pancake premix provides an additional advantage by enabling standardized blending of dry ingredients for convenient consumer preparation. Wheat flour provides the principal structural matrix, while functional seed powders may contribute protein, fibre, minerals, lipids and phytochemicals.

Although individual applications of mango kernel, jackfruit seed and watermelon seed flours have been investigated, limited attention has been directed toward their combined utilization in a single pancake-premix system. Therefore, this review critically examines the nutritional composition, bioactive components, processing, techno-functional characteristics and food applications of these three seed-derived powders and evaluates their potential as complementary ingredients for nutrient-enriched pancake premix development.

II. FUNCTIONAL FOODS AND FOOD-BY-PRODUCT VALORIZATION

Functional foods are foods that may provide physiological benefits beyond the supply of essential nutrients. From a food-product-development perspective, functionality can be associated with dietary fibre, resistant starch, proteins, essential fatty acids, minerals, vitamins and phytochemicals.

The recovery of food-processing by-products as functional ingredients provides an opportunity to integrate nutritional improvement with sustainable production. Instead of treating fruit seeds and kernels solely as waste, they can be processed into flours, starches, protein ingredients, oils or extracts.

Mango kernel, jackfruit seed and watermelon seed are particularly attractive because their nutritional characteristics are complementary. Mango kernel contributes carbohydrate, fat, protein, fibre and phytochemicals; jackfruit seed contributes substantial starch and resistant-starch potential together with protein and fibre; and watermelon seed contributes comparatively high protein and lipid fractions along with minerals and phytochemicals.

The combination therefore warrants investigation as a composite ingredient system. However, complementary composition should not automatically be interpreted as demonstrated nutritional synergy. The existence and magnitude of synergistic effects require experimental validation.

III. MANGO KERNEL POWDER

3.1 Nutritional Composition

Mango seed consists of an outer shell and an internal kernel. The kernel represents a potentially useful food resource because it contains carbohydrates, lipids, proteins, fibre and minerals.

Mwaurah et al. reported substantial variation in mango-kernel composition, with carbohydrate ranging from 32.34 to 76.81%, fat from 6 to 15.2%, protein from 6.36 to 10.02%, crude fibre from 0.26 to 4.69% and ash from 1.46 to 3.71% on a dry-weight basis. Such variability can arise from cultivar, maturity, geographical origin, environmental conditions and processing procedures.

The lipid fraction is of particular technological interest because mango kernel contains an appreciable amount of extractable fat. Mango kernel fat and butter have been investigated for food and other industrial applications.

3.2 Bioactive Constituents

Mango kernel contains diverse phytochemicals, including phenolic compounds, tocopherols, phytosterols, carotenoids and phenolic acids. Reported compounds include gallic, caffeic, coumaric, ellagic and ferulic acids, together with flavonoids and other polyphenolic constituents.

These compounds contribute to measured antioxidant activity in chemical assays. However, antioxidant capacity measured in vitro should not be directly equated with clinical health effects. Food applications should therefore describe these compounds as bioactive constituents or contributors to antioxidant potential unless physiological outcomes have been demonstrated.

3.3 Processing into Mango Kernel Flour

Processing is important because raw mango kernels can possess undesirable sensory characteristics and antinutritional compounds. Conventional processing may involve seed cleaning, kernel separation, slicing, soaking or blanching, drying, milling and sieving.

An earlier processing study described washing and drying of mango seeds followed by kernel separation, soaking, blanching, drying, grinding and sieving.

More recent research has demonstrated that pretreatment and drying method strongly influence the physicochemical, nutritional and bioactive properties of mango kernel flour. Nguyen et al. compared water soaking, hot-water soaking and salt soaking followed by blanching and evaluated convective, heat-pump and freeze drying. Water soaking performed favourably across the evaluated drying systems, while freeze drying showed superior retention of several nutritional and bioactive characteristics.

Therefore, standardized processing is essential for reproducible mango kernel powder intended for functional-food formulations.

3.4 Antinutritional Factors and Astringency

Mango kernels contain tannins and other compounds that can contribute to bitterness and astringency. The 2025 study by Nguyen et al. demonstrated that pretreatment influenced tannin content, phenolic retention and antioxidant activity.

Accordingly, soaking, blanching or other validated treatments may be necessary before incorporation into foods. Processing should be optimized to reduce undesirable components without causing excessive loss of desirable nutrients and bioactives.

3.5 Functional Properties and Bakery Applications

Mango kernel flour can influence water absorption, pasting behaviour, dough rheology and final product characteristics. Composite-flour studies indicate that incorporation of mango kernel flour can modify the functional behaviour of wheat-based systems.

These effects are particularly relevant to pancake batter because batter consistency, water absorption and viscosity directly influence spreading and final product texture.

Recent work has also explored fermentation as an alternative strategy for mango kernel valorization. Fungal fermentation using food-grade Aspergillus species was reported to reduce phytic acid and generate potentially useful functional characteristics, demonstrating that bioprocessing may provide another route for improving mango kernel flour.

IV. JACKFRUIT SEED POWDER

4.1 Nutritional Potential

Jackfruit seeds are an important underutilized component of the fruit. They contain substantial starch together with protein, fibre, minerals and phytochemicals. Reviews have consistently identified jackfruit seed as a promising source of food-grade starch and flour.

The starch fraction is particularly important because jackfruit seed starch can contribute bulk, viscosity and other functional properties to food systems.

4.2 Resistant Starch

Jackfruit seed contains starch fractions that may exhibit resistant-starch characteristics. Resistant starch is less susceptible to digestion in the small intestine and can contribute to the dietary-fibre fraction of a food.

However, resistant-starch content can change with processing conditions, including heating and cooling. Therefore, claims regarding glycaemic effects should be supported by analytical or physiological evidence from the specific processed product rather than inferred solely from the raw ingredient.

4.3 Bioactive Constituents

Jackfruit seeds contain phenolic acids, flavonoids and other phytochemicals. Recent reviews identify compounds including catechin, epicatechin, rutin, gallic acid and ferulic acid.

These constituents contribute to antioxidant activity and provide a basis for considering jackfruit seed flour as a functional rather than merely bulk ingredient.

4.4 Antinutritional Factors

Raw jackfruit seeds may contain antinutritional components such as tannins, phytates, saponins and protease inhibitors. Appropriate processing can reduce these compounds.

A 2024 study evaluating different treatments reported that blanching and boiling improved selected nutritional characteristics, while treatment conditions also influenced antioxidant properties.

Thus, processing should be regarded as an integral part of jackfruit seed flour production rather than a simple dehydration step.

4.5 Functional Properties

Jackfruit seed flour demonstrates considerable variation in water absorption, oil absorption, swelling and solubility depending on cultivar and processing conditions. A 2024 review summarized reported water-absorption values ranging widely among studies, illustrating the importance of raw-material and processing variability.

High water-binding capacity may be advantageous in some products but may also increase water requirements during pancake batter preparation.

4.6 Bakery Applications

Jackfruit seed flour has been evaluated in bread, cakes, biscuits, doughnuts and other bakery products. A 2024 review concluded that incorporation can improve nutritional and certain functional properties but that increasing substitution may adversely influence texture and colour, partly because jackfruit seed flour lacks gluten-forming proteins.

A 2022 study examining wheat replacement with jackfruit seed flour in doughnuts found that increasing substitution influenced dough rheology and texture characteristics, demonstrating the importance of substitution level.

These findings are directly relevant to pancake development because pancake batter also depends on the balance between flour functionality, hydration and structural development.

V. WATERMELON SEED POWDER

5.1 Nutritional Composition

Watermelon seeds are edible but are frequently discarded during processing and consumption. They contain substantial amounts of fat, protein and carbohydrate together with minerals and phytochemicals. A recent review reported approximate ranges of 40–50% fat, 18–30% protein and 10–18% carbohydrate.

Because composition varies according to cultivar, seed type, processing and analytical method, these ranges should be interpreted as representative rather than universal.

5.2 Protein Potential

Watermelon seed is particularly attractive as a protein-contributing ingredient. Recent experimental research reported approximately 32.08% protein in non-defatted watermelon seed flour and 34.71% in defatted flour, while a protein concentrate produced by alkaline extraction contained 82.52% protein.

This demonstrates the flexibility of watermelon seed as a source of either whole flour or more concentrated protein ingredients.

5.3 Bioactive Compounds

Watermelon seeds contain phenolic compounds, flavonoids and other phytochemicals. Their antioxidant potential has contributed to increasing interest in their utilization in functional foods.

However, as with mango kernel and jackfruit seed, chemical antioxidant activity should not be interpreted as direct evidence of therapeutic efficacy in humans.

5.4 Functional Characteristics

Watermelon seed flour can influence dough rheology, water absorption and baking properties. Jaroszewska et al. investigated wheat flour systems containing watermelon seed flour and evaluated chemical, mineral, phytochemical and farinographic characteristics.

Recent work on watermelon seed protein concentrate also demonstrated substantial water- and oil-absorption properties, indicating potential functionality in food systems.

5.5 Bakery Applications

Watermelon seed flour has demonstrated potential for nutritional enrichment of bakery products. In a 2023 study, incorporation of 5–15% watermelon seed flour into a low-carbohydrate, high-protein bread system modified nutritional and physical characteristics; the authors recommended 5% incorporation based on sensory assessment.

Earlier research using defatted watermelon seed flour in bread reported increases in protein and selected minerals, including phosphorus, potassium, iron and calcium, without significant differences in consumer acceptability across the tested fortification levels.

These findings support the use of watermelon seed flour as a nutritional enrichment ingredient in cereal-based products.

VI. COMPARATIVE NUTRITIONAL AND TECHNO-FUNCTIONAL POTENTIAL

Ingredient	**Principal nutritional characteristics**	**Important bioactive/functional attributes**	**Potential role in pancake premix**
Mango kernel powder	Carbohydrate, fat, protein, fibre, minerals	Phenolics, tocopherols, phytosterols, carotenoids	Bioactive and nutritional enrichment
Jackfruit seed powder	Starch, carbohydrate, protein, fibre	Resistant starch, phenolics, flavonoids	Bulk, starch functionality and fibre contribution
Watermelon seed powder	Protein, fat, minerals, carbohydrate	Phenolics, flavonoids, functional proteins	Protein and mineral enrichment
Wheat flour	Carbohydrate and gluten proteins	Gluten-forming proteins	Principal structural matrix
Baking powder	—	Chemical leavening system	Gas generation and product volume
Sweetener	Available carbohydrate	Depends on sweetener	Sweetness, colour and flavour
Salt	Sodium	—	Flavour enhancement

The comparison demonstrates that the three seed powders have complementary rather than identical roles. Mango kernel contributes a broad macronutrient and phytochemical profile; jackfruit seed is particularly relevant for starch and resistant-starch functionality; and watermelon seed provides a relatively strong protein and lipid contribution.

VII. PROCESSING REQUIREMENTS FOR SEED-DERIVED POWDERS

The quality of a composite pancake premix depends strongly on the quality and standardization of its component powders.

7.1 Raw Material Selection

Seeds and kernels should be obtained from sound, mature raw materials free from visible fungal growth, contamination, foreign matter and excessive deterioration.

7.2 Cleaning and Washing

Removal of adhering pulp and external contaminants is essential before further processing.

7.3 Pretreatment

Soaking, blanching, boiling or roasting may be employed depending on the seed material and intended functionality. Pretreatment can reduce undesirable compounds and modify hydration and sensory characteristics.

For mango kernel, recent evidence supports the importance of soaking and controlled drying for improving flour characteristics.

For jackfruit seed, blanching and boiling have demonstrated potential for modifying nutritional and antioxidant properties.

7.4 Drying

Drying reduces moisture and improves storage stability. However, excessive heat exposure can degrade heat-sensitive compounds.

Freeze drying preserved several mango-kernel nutritional and bioactive characteristics more effectively than the conventional methods investigated in a recent study.

7.5 Milling and Sieving

After drying, seeds or kernels are milled to produce flour or powder. Sieving provides a more uniform particle-size distribution.

Particle size is particularly important for pancake premix because it influences hydration rate, batter consistency and mouthfeel.

7.6 Packaging and Storage

Seed-derived powders should be protected against moisture, oxygen, light and contamination. Packaging with appropriate moisture and oxygen barriers may help maintain quality.

Storage studies should monitor moisture, water activity, rancidity, microbial quality, colour and sensory characteristics.

VIII. RELEVANCE TO PANCAKE PREMIX DEVELOPMENT

Pancake premix represents a practical food matrix for incorporating functional seed powders. Unlike a ready-to-eat product, a premix can be formulated as a standardized dry blend and prepared by the consumer with the addition of liquid ingredients.

Wheat flour provides gluten-forming proteins and contributes to batter structure. Partial replacement with non-wheat seed powders reduces the relative concentration of gluten proteins and can therefore influence batter structure.

The high water-binding capacity reported for some jackfruit seed flour samples suggests that incorporation may increase the water requirement of the premix.

Watermelon seed flour may contribute protein and lipids, while mango kernel powder contributes additional macronutrients and phytochemicals.

The formulation therefore requires optimization of:

- seed-powder inclusion level;
- wheat flour proportion;

- water absorption;
- batter viscosity;
- particle size;
- leavening level;
- sweetness;
- cooking temperature;
- cooking time;
- pancake thickness;
- colour;
- texture;
- flavour;
- overall acceptability.

A nutritionally improved product is unlikely to succeed commercially if the sensory and technological characteristics are unacceptable. Consequently, nutritional enrichment and consumer acceptance must be optimized simultaneously.

IX. POTENTIAL COMPLEMENTARY ROLE OF THE THREE SEED POWDERS

The combination of mango kernel, jackfruit seed and watermelon seed powders is scientifically attractive because of their differing nutritional profiles.

Jackfruit seed provides a starch-rich component and may contribute resistant starch and functional hydration properties. Watermelon seed provides relatively high protein and lipid fractions, while mango kernel provides carbohydrates, lipids, protein, fibre, minerals and diverse phytochemicals.

This creates a rationale for developing a composite formulation rather than relying on a single seed powder.

However, the literature currently provides substantially more evidence for individual ingredient applications than for the specific three-powder combination. Therefore, the combined formulation should be described as a promising research hypothesis rather than an established synergistic food system.

Future experimental work should determine whether the combination actually produces additive or synergistic effects in protein, fibre, antioxidant activity, mineral density, digestibility or other functional parameters.

X. TECHNO-FUNCTIONAL INTERACTIONS IN PANCAKE BATTER

The interaction between seed powders and wheat flour is central to pancake quality.

10.1 Water Absorption

Seed-derived powders contain proteins, starch and fibre that can bind water. Increasing their concentration may therefore alter the water requirement of the premix.

10.2 Batter Viscosity

Batter viscosity influences spreading behaviour during cooking. Excessively low viscosity can produce thin, poorly structured pancakes, whereas excessive viscosity may reduce spreading and produce dense products.

10.3 Gluten Dilution

Non-wheat powders dilute wheat gluten proteins. This may reduce structural development at higher inclusion levels. Evidence from jackfruit seed flour bakery studies demonstrates that increased substitution can negatively affect texture and colour.

10.4 Colour

Mango kernel and other seed powders may alter batter and pancake colour. Colour changes should be evaluated objectively using instrumental parameters such as L*, a* and b* where possible.

10.5 Texture

Texture is affected by flour composition, water availability, starch gelatinization, protein interactions and leavening. Therefore, texture optimization is particularly important when multiple unconventional flours are combined.

XI. NUTRITIONAL AND FUNCTIONAL EVALUATION

A publication-quality evaluation of a seed-enriched pancake premix should include both proximate and functional analyses.

Proximate composition

The major parameters should include:

- moisture;
- ash;
- protein;
- fat;
- dietary fibre;
- carbohydrate by difference;
- energy value.

Mineral evaluation

Depending on laboratory availability and research objectives, calcium, iron, magnesium, phosphorus, potassium and zinc may be assessed.

Functional and bioactive evaluation

Potential parameters include:

- total phenolic content;
- total flavonoid content;
- DPPH radical-scavenging activity;
- ABTS radical-scavenging activity;
- water absorption capacity;
- oil absorption capacity;
- swelling capacity;
- bulk density.

Product evaluation

For the prepared pancakes, researchers may evaluate:

- diameter;
- thickness;

- weight;
- volume;
- colour;
- texture;
- moisture;
- proximate composition;
- sensory acceptability.

The choice of analyses should be based on the research question and available validated methods rather than performing every possible test without a clear hypothesis.

XII. SENSORY EVALUATION AND CONSUMER ACCEPTABILITY

Sensory acceptance is a critical determinant of functional-food success. Increasing seed-powder concentration may improve selected nutritional parameters but can simultaneously produce darker colour, altered aroma, bitterness, astringency or changes in texture.

Previous studies illustrate the importance of optimizing substitution level. Jackfruit seed flour incorporation has been associated with changes in texture and colour at higher concentrations, while watermelon seed flour has shown acceptable sensory performance at selected incorporation levels in bakery systems.

A nine-point hedonic scale can be used to evaluate appearance, colour, aroma, taste, texture, mouthfeel and overall acceptability. A trained or appropriately selected semi-trained panel may additionally evaluate descriptive sensory characteristics.

For a pancake premix, sensory evaluation should preferably compare a control formulation with several optimized seed-powder formulations.

XIII. SAFETY, ANTINUTRITIONAL FACTORS AND STORAGE STABILITY

Nutritional value alone does not establish ingredient suitability. Food safety and storage stability must also be addressed.

Mango kernel may contain tannins and other compounds that influence astringency and nutritional availability. Jackfruit seeds may contain antinutritional factors including phytates, tannins and protease inhibitors. Processing can reduce some of these compounds, but the magnitude depends on treatment conditions.

Because seed powders contain nutrients and, in some cases, appreciable lipids, oxidation may become an important storage concern. Water activity and packaging conditions should therefore be controlled.

For a commercial pancake premix, future investigations should include:

- total viable count;
- yeast and mould count;
- selected foodborne pathogens where appropriate;
- moisture;
- water activity;
- peroxide value or other oxidation indicators;
- rancidity;
- shelf-life sensory characteristics.

These assessments are particularly important because the powders are derived from agricultural materials and may be exposed to environmental contamination during processing.

XIV. RESEARCH GAPS AND FUTURE PERSPECTIVES

The existing literature establishes substantial potential for each individual seed-derived ingredient, but several gaps remain.

14.1 Limited research on the combined formulation

Most studies investigate mango kernel, jackfruit seed or watermelon seed independently. Evidence specifically addressing their combined incorporation into a single pancake premix remains limited.

14.2 Lack of optimized inclusion ratios

The optimal ratio of the three powders cannot be inferred simply from their individual studies. Interactions among starch, protein, fibre and lipid fractions may alter batter behaviour.

14.3 Limited information on digestibility

Although jackfruit seed may contribute resistant starch and seed powders contain dietary fibre, the digestibility of the final composite pancake must be experimentally determined.

14.4 Glycaemic response

A product containing seed powders should not automatically be described as low-glycaemic. Glycaemic index or glycaemic response must be experimentally determined using appropriate validated protocols.

14.5 Antinutritional factors

Further work should quantify tannins, phytates and other relevant antinutritional factors before and after processing.

14.6 Storage stability

The stability of a composite seed-powder premix during storage remains an important area for investigation, particularly with respect to moisture migration, lipid oxidation and microbial quality.

14.7 Consumer acceptance

Long-term consumer acceptance and willingness to purchase products based on fruit-seed powders remain relatively underexplored.

14.8 Sustainability assessment

Future research should move beyond simple waste reduction claims and quantify environmental benefits through appropriate life-cycle or resource-efficiency assessments.

XV.PROPOSED CONCEPTUAL FRAMEWORK FOR FUNCTIONAL PANCAKE PREMIX

The literature supports the following conceptual pathway:

Underutilized fruit seeds/kernels

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Cleaning and pretreatment

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Drying

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Milling and sieving

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Mango kernel powder + jackfruit seed powder + watermelon seed powder

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Composite premix formulation

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Optimization of hydration and leavening

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Pancake preparation

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Physicochemical evaluation

↓

Nutritional and functional evaluation

↓

Sensory evaluation

↓

Storage and safety assessment

↓

Potential sustainable functional food product

This framework highlights that nutritional enrichment should be considered together with processing, technological performance, sensory quality and safety.

XVI. CONCLUSION

Mango kernel, jackfruit seed and watermelon seed represent promising underutilized plant resources for the development of sustainable and nutritionally enriched foods. Existing literature demonstrates that mango kernel contains substantial macronutrients and diverse phytochemicals; jackfruit seed provides starch, resistant-starch potential, protein, fibre and bioactive compounds; and watermelon seed provides substantial protein and lipid fractions together with minerals and phytochemicals.

Processing is a critical determinant of their suitability as food ingredients. Soaking, blanching, boiling, drying, fermentation and milling can influence nutritional composition, antinutritional factors, bioactive retention, water absorption, colour and other functional properties. Recent evidence demonstrates that appropriate processing can improve the usability of these materials while preserving selected desirable characteristics.

The incorporation of seed-derived flours into bakery products has demonstrated potential for nutritional enrichment, but higher substitution levels can adversely influence dough or batter rheology, colour, texture, expansion and sensory acceptance.

The complementary composition of mango kernel, jackfruit seed and watermelon seed provides a rational basis for investigating their combined incorporation into a functional pancake premix. Nevertheless, the combined three-ingredient system remains insufficiently investigated, and synergistic nutritional or functional effects cannot currently be assumed.

Future research should therefore focus on formulation optimization, nutritional composition, bioactive compounds, antinutritional factors, digestibility, glycaemic response, sensory acceptance, storage stability and microbial safety. Such investigations could contribute to the development of convenient, nutrient-enriched foods while supporting circular food systems and valorization of underutilized plant resources.

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