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<https://doi.org/10.5109/7395653>

出版情報 : Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.1129-1138, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences

バージョン :

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**Valorization of Agricultural By-Products as Functional Ingredients in Instant Premix Powder:
A Review of Formulations, Processing Methods, Applications, and Quality Evaluation**

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Abstract: *The valorization of agricultural by-products has been a key focus for many food engineers and scientists in recent years, aiming to promote a circular bioeconomy and reduce environmental problems for greater sustainability. Agricultural by-products rich in bioactive, nutritional, and functional compounds have attracted interest in repurposing as supplements in the formulation of value-added and fortified food products. With increasing urbanization and limited time for food preparation, especially among working individuals, the demand for ready-to-cook premix powders with nutritious formulations has increased. One promising approach in the development of instant premix foods is the incorporation of agricultural by-products as nutritional substitutes for raw materials such as wheat flour. Hence, this review highlights the key considerations in the valorization of agricultural by-products as functional ingredients in instant premix formulations, with emphasis on formulation strategies, processing methods, and the evaluation of techno-functional properties. This critical review aims to provide foundational knowledge for food processors and researchers with a strong interest in circular economy practices and innovative food product development.*

Keywords: Premix Powder; Functional Foods; Techno-functional Properties; Quality Evaluation; Valorization.

1. INTRODUCTION

Fruit and vegetable wastes represent a significant portion of global food waste, contributing around 0.5 billion tons out of the 1.3 billion tons discarded annually. These losses are particularly pronounced at the agricultural stage in developing nations but also occur notably during food processing. However, these wastes are rich in phytochemicals, vitamins and minerals, and dietary fibers that are good for human health [1, 2, 3]. Hence, repurposing food waste and by-products is a primary strategy for addressing environmental issues while supporting both economic growth and societal well-being [4]. One promising approach in the valorization of agricultural by-products is the utilization of their valuable bioactive and nutritional compounds as supplements in the formulation of ready-to-use powders and other innovative food products for fortification and other functionally designed foods (Fig. 1). Food fortification is widely regarded as the most effective method for combating micronutrient deficiencies, as it offers a cost-efficient long-term solution and can achieve results comparable to those of dietary diversification [5]. Fortified and nutrient-rich premix formulations, typically in powder form, are considered convenient products that enhance daily nutrition and simplify food preparation and cooking [6].

In food fortification, selecting a coating material that enhances the functional delivery such as by improving the micronutrient's bioavailability, is crucial. Hence, the use of agricultural by-products as coating agents and supplements for fortified new food products has increased interest in recent years [7]. Although it is a long-term solution, the food-based approach is regarded as the most sustainable method for tackling malnutrition [8]. Fortification serves multiple purposes: it helps prevent widespread nutrient deficiencies, restores nutrients lost during food processing, balances the overall nutrient profile of the diet, and caters to consumers seeking dietary enhancement. As such, it can be an effective public health strategy to boost nutrient intake across populations [9, 6]. Moreover, industrial food fortification involves incorporating essential nutrients into foods during processing to enhance their nutritional value. This approach is effective in addressing and preventing micronutrient deficiencies, as the sensory characteristics of fortified foods are typically like those of their non-fortified counterparts [10]. The efficacy of fortified foods largely depends on the stability of the micronutrients, which can degrade when exposed to moisture, oxygen, or interactions with other components in the food matrix.

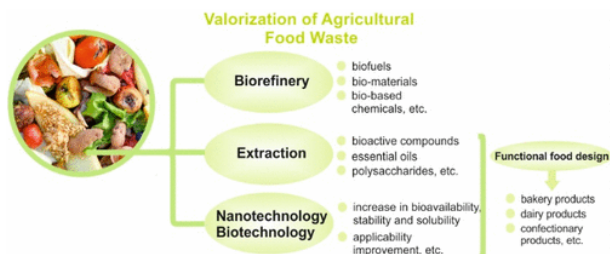


Fig. 1. Common valorization routes of agricultural by-products with end-use for functional food formulation such as supplement to bakery and confectionary products [4].

With increasing urbanization, modern lifestyles, and limited time for food preparation, the demand for fast, ready-to-eat, and ready-to-serve foods has surged, as consumers prioritize convenience and time-saving meals [11, 6]. However, this shift often leads to unbalanced diets and related health issues, driving a growing demand for protein- and nutrient-rich ready-to-eat or ready-to-cook products. This growing demand has encouraged food manufacturers to develop nutritious premixes that can be consumed directly or transformed into various forms such as energy balls, bars, flatbreads, cakes, extruded snacks, or soup powders [12]. Kiin-Kabari and Akusu [13] emphasized that time is a valuable resource particularly for working individuals. Therefore, convenience should be a key consideration in food ingredient formulation. Promoting awareness of the advantages of premixes can help ease the burden of cooking, minimize postharvest losses, and ensure that agricultural products remain accessible and affordable to consumers, even during the off-season.

A premix is a product consisting of a blend of two or more ingredients, formulated for immediate use [14]. In the context of food fortification, premixes typically refer to mixtures of food additives or food-based materials that can be dissolved in water and are often used as carriers. The main goal of developing premixes from agricultural by-products is to provide an alternative means of valorizing these nutritionally rich food processing wastes by transforming them into nutrient-dense, easy-to-prepare, and shelf-stable ingredients with suitable technological properties [15]. Premix instant powders serve as convenient and time-saving options for preparing ready-to-cook food and ready-to-use beverages, while also offering a potential method for preserving perishable fruits and vegetables. Aside from that, premix instant powders are highly preferred by most consumers nowadays due to their ease of making and longer shelf stability [3]. Modern food technologies have facilitated the development of ready-to-use premixes from agricultural by-products, such as powder premix with incorporation of banana [14], apple pomace [15], mango [16], strawberry and pineapple [17], potato [6], surimi [18], *Moringa oleifera* leaf [19], dates [20] and among others.

However, to the best of our knowledge, no comprehensive review is currently available in the literature that highlights the insights and critical aspects of developing ready-to-use premix powder from agricultural by-products, particularly regarding formulation considerations, specific applications, processing procedures, and quality evaluation parameters relevant to marketability. Therefore, this review

primarily aims to highlight the key considerations in the valorization of agricultural by-products as functional ingredients in instant premix formulations, with emphasis on formulation strategies, processing methods, and the evaluation of techno-functional properties. Moreover, this brief review will provide foundational knowledge for food processors and researchers with a strong interest in circular economy principles and innovative food product development. Lastly, this brief review on valorization of agricultural by-products through their incorporation into functional food formulations particularly in instant premix powders aligns closely with several United Nations Sustainable Development Goals (SDGs) such as SDG 2 (Zero hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate action) while supporting sustainable resource utilization and food security.

2. CONSIDERATIONS & TECHNIQUES IN PREMIX POWDER FORMULATIONS

Table 1 presents the summary of nutritional, functional, and proximate composition that must be considered in utilizing agricultural by-products as supplementary materials for the development of instant premix powders. Table 1 also listed all the common considerations in the powdering methods as well as the common ingredients applied in the premix formula. In this case, before formulating and utilizing any agricultural by-product as ingredient for premix formulation, a pre-characterization and identification of some of the nutritional profile of the powder is highly important for the basic understanding of the food material to be developed [10]. Aside from the nutritional and proximate compounds, phytochemicals such as polyphenols, flavonoids, carotenoids, nitrogen-containing compounds, and other functional compounds contribute significantly to the health benefits that can be harnessed in the development of premix powders [21]. A wide range of intrinsic nutrients and bioactive ingredients found in fruits, vegetables, and their by-products, such as proteins, dietary fibers, antioxidants, and minerals, are increasingly being used together as optimized supplements in the formulation of instant premix powders [22, 23]. Another major consideration in premix powder formulation is the choice of powdering technique. In many processing scenarios, powder form is essential for operations such as mixing and dissolution [24]. The particle size, distribution, shape, surface characteristics, and density of the powders are highly variable and depend on both the properties of the raw materials and the processing conditions during their formation [25, 26]. In most cases, the choice of what specific drying techniques to use for premix formulation falls for either of the following reasons: nature of the raw material, desired particle size, nutritional and functional preservation, cost and energy efficiency. Consequently, several parameters must be carefully considered when drying and powdering agricultural by-products. Time, temperature, speed, and carrier agents all play pivotal importance in determining the final quality of the powdered materials. Therefore, the selected powdering technique plays a critical role in achieving the production of a nutritionally optimized premix powder.

Table 1. Summary of considerations in the premix powder formulations.

Considerations	Parameters	References
Fundamental Properties	<ul style="list-style-type: none"> • Proximate: Moisture, Protein, Ash, Fat, Fiber, Carbohydrates. • Physical: Powder size, shape, porosity, bulk density, angle of repose, color. • Microstructure: Morphology and surface structure. 	
Functional and Shelf-Life Properties	<ul style="list-style-type: none"> • Techno-functional: Viscosity, Water solubility index (WSI), water absorption capacity (WAC), oil absorption capacity (OAC) and swelling power. • Shelf-life: Oxidative stability, peroxide value, free fatty acids, total plate count, and yeast and mold count. 	
Nutritional Properties	<ul style="list-style-type: none"> • Vitamins: Vitamin A, C, D and E. • Minerals: Calcium, Iron, Potassium, Magnesium, Phosphorus, Zinc, Manganese, and Copper. • Phytonutrients: Phenolics, Antioxidants, Carotenoids, Flavonoids, Methylxanthines. 	[3], [6], [11], [13], [14], [15], [16], [17], [20], [22], [23], [27], [31], [32], [33], [34], [35], [38], [39], [45]
Powdering Techniques	<ul style="list-style-type: none"> • Drying followed by milling: Sun, oven, freeze, spray, vacuum, and drum. • Direct Milling: Hammer, ball, jet, pin, and cryogenic. • Processing Variables: Time, Temperature, Pressure, Speed, Agents, and Volume. 	
Commonly used Ingredients	<ul style="list-style-type: none"> • Primary: Refined wheat flour, sugar powder, baking powder, sodium bicarbonate powder, and milk powder. • Supplementary/Enricher: Powder from agricultural by-products as substitute to flour, salt powder (if needed), and other flavoring powder. 	

The information provided is summarized/synthesized from the various references listed. It is suggested to read the specific reference for further information on the different considerations and parameters used.

Moreover, with the growing interest in gluten-free food products, since most items made from refined flour and starch contain gluten and are often not enriched or fortified, many researchers have explored the potential of valorized powders from agricultural by-products as partial substitutes for flour, offering unique health-enhancing properties [27]. With this development, careful consideration must be given to the use of valorized powders from agricultural by-products,

especially in formulating premixes, beyond just their nutritional, proximate, and techno-functional properties. With the growing use of powders in the food industry, understanding the properties of different powders has become increasingly important for ensuring quality control and optimizing processing conditions [26]. Consequently, powder production has become a significant area of research, as many newly developed food products cannot be easily converted into powder form, such as premixes, due to their inherent composition and tendency to exhibit sticky behavior. Hence, aside from the raw ingredients, it is crucial for food engineers and processors to consider the physicochemical and techno-functional properties of the by-product powder before incorporating it as a substitute or supplementary agent in premix formulations.

3. RECENT APPLICATIONS & QUALITY EVALUATION OF INSTANT PREMIX POWDER

The goal of formulating premix powders for various food applications is to provide a nutrient-dense and ready-to-use formula while simultaneously minimizing food waste resulting from postharvest operations. Consequently, in designing premixes, as shown in Fig. 2, it also aims to develop products with balanced formulations that are user-friendly and have extended shelf lives. This technological advancement offers several benefits, including cost reduction, enhanced quality and product standardization, labor optimization, simplified sanitation processes, and reduced space requirements for raw material storage [28, 29]. Selecting appropriate ingredients for developing a value-added premix is essential for optimizing reconstitution properties. Therefore, formulating instant mixed powders with enhanced nutritional value and optimal physical characteristics remains a challenging task [19]. Nevertheless, to provide sustainable solutions to emerging issues, particularly food waste, numerous research efforts have been undertaken to valorize by-products of various fruits and vegetables by converting them into ready-to-use functional premix powders and thereby evaluated their physicochemical and techno-functional qualities, as summarized in Table 2. A critical discussion on the successful implementation of the reported literature is provided in this paper, grouped into three categories: root and tuber crops; grains, beans, and seeded products; and fruits and vegetables.

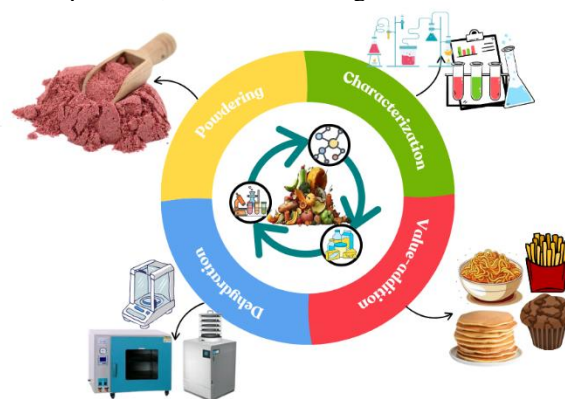


Fig. 2. Value-addition process of foods using premix powder from agricultural wastes and their by-products.

3.1 Premix of Root and Tuber Crops and their by-products

Root and tuber crops are among the most highly sought-after commodities worldwide due to their richness in carbohydrates and other starch-related characteristics. However, they have also gained increasing interest in valorization because of the large volume of waste generated annually [30]. From this point of view, the valorization of root crops as ingredients in premix formulations is discussed. For instance, Singh et al. [3] investigated the potential of potato by-products (mash and peels) to enhance the textural and functional quality of waffles by formulating an instant premix powder (Table 2). The selected premix formulation was packed in laminate bags (100 g each) and stored in plastic containers at ambient temperature (25–38 °C/RH 35–85%) for a period of 6 months. In this context, the shelf life of the prepared product was assessed by evaluating changes in various physicochemical, phytochemical, microbiological, and sensory attributes during storage (Table 2). The results showed that, compared to the control, the moisture, ash, protein, fat, and crude fiber contents increased significantly ($p < 0.05$) with the increasing concentration of potato waste in the waffle premix formulations. Similar observations were made in the techno-functional properties, where a significant ($p < 0.05$) increase in all phytochemical constituents of the waffle premix was observed with the addition of potato waste, compared to the control. In terms of texture, the incorporation of waste powders in the waffle premix significantly ($p < 0.05$) reduced hardness while increasing springiness, an attribute preferred in waffles. These findings are consistent with those of an earlier study by Waseem et al. [31], which also used potatoes as the primary commodity. In that study, composite premixes of straight grade flour (SGF) and potato powder were developed (Table 2). The premixes were intended for chapati dough preparation, where potable water was added to the premix to form 50 g of dough. The dough was rested for 30 minutes, then rolled into thin sheets with a diameter of 12 cm and a thickness of 2 mm. The results indicated that supplementation of SGF with processed potato powder significantly ($p < 0.05$) improved the ash (from 0.48 to 0.63 g/100 g), dietary fiber (from 2.15 to 2.61 g/100 g), and protein (from 8.33 to 9.91 g/100 g) contents of the composite chapatis.

In a recent study, Kaul et al. [6] formulated four types of *parantha* dough premixes (P1, P2, P3, and P4) using different proportions of potato flour and wheat flour (Table 2). *Parantha* is an unleavened, flat, hot plate-baked product made from whole wheat flour and water, with additional ingredients such as salt and spices added to taste. Techno-functional and organoleptic evaluation of the prepared *paranthas* revealed that all the ready mixes were well accepted, with P3 being rated the best. The iron and zinc contents of the preferred potato *parantha* ready-mix were estimated at 9.63 mg/100 g and 6.84 mg/100 g, respectively, and the product was also found to be a rich source of antioxidants and phenolic compounds. Since the study also involved storage of the premix powder, moisture content was considered a critical factor for determining product stability. The results showed an increase in moisture content from 9.12% to 11.95% over a period of five months. It can be inferred that, for premix powders, moisture content and other

shelf-life properties must be carefully considered, especially since these powdered products are intended for long-term storage.

3.2 Premix of Grains, Beans and Seeds and their by-products

Due to the high volume of waste generated from highly valued commodities like wheat, rice, corn, and sorghum, many researchers have invested their efforts in valorizing the by-products of these commodities into premix formulations. In the case of wheat, Jha et al. [32] explored the possibility of incorporating wheat powder and buffalo milk powder as part of the ingredients in a premix formulation for *dalia* dessert by means of a spray drying process at 100 kg/cm² (feed pressure) and 60 kg/h (feed rate). As a substitute agent, varying levels (2%, 3%, and 4%) of wheat powder were applied, and the slurry (mixture) was subjected to a gelatinization treatment at 90 °C for 60, 75, 90, 105, and 120 minutes. The effects of different levels of milk solids and wheat solids were investigated, along with other physicochemical (Table 2) and sensorial properties. Based on their evaluation, the formulation with 17.8% milk solids and 2.9% wheat solids was found to be the most appropriate for the manufacturing of an instant *dalia* dessert premix, for which the predicted scores were 85.4 for mouthfeel, 42.0 for consistency, 67.3 for flavor, and 941.0 for viscosity. Sukhwai & Vyas [22] also proposed a premix formulation for the *mathari* recipe, a popular Indian snack, supplemented with antioxidant-rich agents (Bengal gram and powders of curry leaves and amla), with wheat flour and soybean powder as the main ingredients (Table 2). Highlights of the evaluation revealed that the total polyphenol content of antioxidant-rich premix B was the highest when compared to the other premixes, ranging from 29.3 to 42.3 mg/100 g. The taste of *mathari* prepared with antioxidant-rich formulation A was the most appreciated, scoring 4.2, which was better than the *mathari* prepared with the standard mix, proving that adding curry leaves enhances the taste of the product.

In a different undertaking, Gupta et al. [33] examined the composition of a *shrikhand* dough premix microencapsulated with rice bran oil (RBO) as a fat alternative. *Shrikhand* is a traditional Indian dessert that is sweetened and flavored, typically using ingredients such as sucrose and powdered milk. In this study, the composition of the *shrikhand* premix was determined based on the standard composition of commercial *shrikhand*, containing 62% solids and 38% water (Table 2). The effects of solid content (15–30%), spray dryer temperature (120 to 150 °C in 5 °C intervals), and spray dryer feed rate (100–200 mL/h) were studied to determine the optimal conditions for microencapsulation. The addition of 1% α -tocopherol to RBO prior to microencapsulation enhanced the oxidative stability of the RBO premix powder. It was also observed that the texture of *shrikhand* improved with the use of a blend of xanthan and gellan gum (80:20), closely resembling that of the commercial product.

Table 2. Some of the reviewed premix powder formulations using agricultural by-products and the evaluated quality parameters.

Valorized Product(s)	Application/ Purpose	Applied Formulation(s)/ Treatments	Quality Parameters	References
Wheat Grains	For desserts	• Variations of powder: 2, 3, and 4%.	• PCA	[32]
Spinach	For <i>chapati</i>	• Varying spinach powder concentration at 1 % to 10 % (1, 3, 5, 7, 10) based on wheat flour. 100% wheat flour (control).	• PCA, PRA, TPA	[11]
Strawberry and Pineapple	For ripples	• 27 g (fruit ripple premix base), 12g (strawberry fruit powder), 1.05 g (strawberry tit bits), 0.005g (color) and 0.016 g (strawberry flavor powder).	• PCA, PRA, SE	[17]
Mango	For ripples	• 15.44 g (mango fruit powder), 2 g (mango fruit tit bits), 0.005 g (color), 0.016 g to 27.01 g (mango flavor powder) 0.102 g (Xanthan gum), 0.575 g (Pectin), 0.030 g (Guar gum), 21.33 g (Sugar Powder), 0.004 g (Citric acid) and 7.80 g (Glucose powder).	• PCA, PRA, SE	[16]
Apple Pomace	For muffins	• Standardized recipe: refined wheat flour (100 g), powdered sugar (80 g), milk powder (50 g) and baking powder (4 g) • Fiber-enriched: refined wheat flour was replaced with portions of apple pomace powder varying in the range of 5–50% (5, 10, 15, 20, 25, 30, 35, 40, 45 and 50%). Sample with 100% wheat flour was taken as control.	• PRA, TPA, SE	[15]
Immature Dates	For cake	• Blanch at 95° C for 30 s in water. Production of date powder using cabinet hot air drying (45 ± 5 °C/72 h).	• PCA, TFA, MSA, SE	[20]
Millets, Pulses, and Oilseeds	For flatbread	• Whey protein isolate (11%), Moong flour (21.5%), Chickpea flour (21.5%), Sorghum flour (11%), Pearl millet flour (11%), flax, chia, and pumpkin seeds (5.5% each), turmeric (0.3%), salt (2.9%), cumin, chili, and coriander powder (1.4% each).	• PCA, PRA	[35]
Red Sorghum and Rice	For cake	• Flour blend weight basis: 120% crystal sugar, 30% vegetal shortening, 10% alkalized cocoa powder, 5% natural cocoa powder, 2.2% sodium bicarbonate, 2% emulsifier, 1.1% sodium acid pyrophosphate, 1.1% monocalcium phosphate, 1% salt, 0.5% chocolate and 0.5% orange aromas.	• PRA, TPA	[27]
Overripe Banana	For cake	• 24.36% wheat flour, 24.36% banana powder, 22.25% palm oil, 20.13% castor sugar, 7.42% egg, 0.85% sodium bicarbonate, and 0.64% baking powder.	• PCA, PRA, SE	[14]
Pumpkin, Jackfruit, and Mango	For multi-use	• 100 g premix ratio of 70:30, 60:40, 50:50, and 40:60 out of which 60:40 (best combination on the basis on sensory score).	• PCA, PRE, SLA, SE	[38]
Potato	For <i>parantha</i>	• Four types of ready mixes (P1, P2, P3, and P4) of potato flour and wheat flour as 80: 10, 70: 20, 60: 30 and 50: 40, respectively.	• PCA, PRA, TPA, SLA	[6]
Sorghum, Soybean, Karkade, and Figl	For infants	• Mixture: 40–60% for malted sorghum, 20–30% for blanched soybean, and 10–20% for boiled <i>karkade</i> seeds flour.	• PCA, PRA, SE	[34]
Rice bran	For <i>shrikhand</i>	• Fat powder (25.83 g), skim milk powder (9.56 g), sucrose (26.68 g) and suitable hydrocolloids for texture improvement.	• PRA, MSA, TPA, SE	[33]
<i>Ogbono</i> and <i>Egusi</i> seed	For soup	• Ratios (Sample A-100:0, B-0:100, C-60:40, D-50:50 and E-40:60).	• PRA, TPA, SE	[13]
Corn, Rice, and Cassava	For noodle	• Corn starch, rice flour, cassava starch, hydrocolloid, egg powder and salt, mixed at 400 rpm for 1 min.	• TPA, SE	[45]
Potato	For waffle	• Potato waste (potato mash and peel), refined wheat flour, sugar, baking powder, sodium bicarbonate, and milk powder.	• PCA, TFA	[3]
Potato	For <i>chapati</i>	• Replacing SGF with raw and processed potato powder at the rate of 2.5–10%.	• PCA, PRA, SE, TPA	[31]
Wheat, Soybean, Bengal Gram, and Curry leaves	For <i>mathari</i> premix	• Mix C: 100 g of premix containing 75 g wheat flour, 15 g of Bengal, 10 g of soybean and a constant amounts of other ingredients like salt, ajwain, baking powder and oil. Mixes A & B: wheat flour is modified by substituting curry leaves powder.	• PRA, SE	[22]
Corn silk	For multi-use	• Primary ingredients: Corn silk powder, sugar, skim milk powder, and xanthan gum.	• PCA, TFA, SE, SLA	[23]
Sweet Potato, Chia and Ragi Seeds	For cakes	• Primary ingredients: finger millets, sweet potatoes, chia seeds, wheat flour, soymilk powder, brown sugar, cocoa powder, baking soda, and virgin coconut oil. • Ratios: 60:35:5, 50:40:10, 40:50:10, 30:60:10, 60:30:10 finger millets flour, chia seeds flour, and sweet potato flour, respectively.	• SE	[39]

PCA- Physicochemical analysis; PRA- Proximate analysis; TPA- Textural property analysis; TFA- Techno-functional analysis; SE- Sensory evaluation; SLA- Shelf-life analysis; MSA- Microstructural analysis; SGF- straight grade flour; g- grams, mg – milligrams, min – minutes, hr – hours.

In the case of sorghum, Cayres et al. [27] proposed a gluten-free, cereal-based cake formula using red sorghum and polished rice powders (Table 2). Proximate and techno-functional properties were evaluated, and the results showed that sorghum in both natural and pregelatinized composite powders (containing 87.8% sorghum, 7.2% orange pomace flour, and 5% whey powder) was highly effective in improving the nutritional and functional characteristics of gluten-free cereal-based cakes. These cakes exhibited competitive levels of protein, ash, dietary fiber, total phenolics, and antioxidant capacities compared to their gluten-containing counterparts. Similarly, Keyata et al. [34] optimized the nutritional profile of sorghum-based premix formulations by combining it with soybean and other seeds (Table 2). The study showed that increasing the ratio of blanched soybean and boiled *karkade* seed flour in the blend led to a significant ($p < 0.05$) increase in protein, fat, energy, and mineral content, along with a decrease in tannin and phytic acid content, factors that improve mineral bioavailability, except for the oxalate: calcium ratio in the formulations. The optimal blending ratio was determined to be 45.0% malted sorghum, 26.0% blanched soybean, and 19.0% boiled *karkade* seed flour, plus 10.0% premix. Overall, it can be inferred from both findings that the optimal combination of these traditionally processed ingredients using sorghum by-product has the potential to alleviate protein-energy malnutrition and micronutrient deficiencies, providing a cost-effective alternative to commercial complementary foods available in the market.

Consequently, Kiin-Kabari and Akusu [13] explored the formulation of a premix powder for soup applications using seed flours from Ogbono (*Irvingia gabonensis* var. Excelsa) and Egusi (melon) (*Citrullus vulgaris*) (see Table 2). A sensory evaluation was conducted using a 20-member panel familiar with Ogbono and Egusi soups. The panel assessed soups prepared from each premix sample using a 9-point hedonic scale, ranging from 9 ("like extremely") to 1 ("dislike extremely"), to evaluate color, appearance, thickness, drawability, taste, and overall acceptability. The results showed a significant ($P < 0.05$) difference in crude fat, crude protein, and carbohydrate contents among the five samples (A–E). Additionally, significant ($P < 0.05$) differences were observed in the water absorption capacity and viscosity of the samples. Sample A (100% Ogbono) had the highest water absorption capacity (2.09 g/g) and viscosity (3.17 Pa·s), while Sample E had the lowest water absorption capacity (1.30 g/g), and Sample B (100% Egusi) recorded the lowest viscosity value (1.26 Pa·s). Interestingly, the overall acceptability based on sensory evaluation indicated that the developed premix is suitable for quick soup preparation, particularly for consumers who prefer very thick and drawable soups. Recently, the potential use of millets, pulses, and oilseeds as functional ingredients in a ready-to-cook flatbread premix powder formulation was investigated by Bhoir et al. [35] with formulations in Table 2. A unique aspect of the study was its goal of achieving a target protein content of 25%–30%, aligning with the nutritional objective of creating a high-protein functional food. Physicochemical and techno-functional evaluations revealed that the premix offers a balanced nutritional profile, providing a high protein content (~21%) and delivering 423 kcal per 100 g. The phenolic content was measured at 0.98 mg catechin equivalents per gram of premix, which increased to 1.90

mg catechin equivalents per gram in the cooked product. Through meticulous formulation and evaluation, this premix has been developed to enhance health benefits and meet the growing demand for nutritious and functional dietary options in modern society.

On the other hand, the feasibility of valorizing corn (*Zea mays*) and its by-products, such as corn silk, to develop a premix formula has also been investigated by several researchers. For example, Singh et al. [23] utilized corn silk powder in the development of an instant mix. This innovative approach transforms corn silk, typically discarded as agricultural waste, into a commercially viable product that delivers the nutritional benefits of corn silk to a broader population with formulations shown in Table 2. Based on physicochemical, functional, and nutritional analyses, it was evident that corn silk plays a significant role in influencing parameters such as moisture content, acidity, total phenolic content, bulk density, water absorption index, swelling capacity, and viscosity of the corn silk-based instant premix powder. Increasing the amount of corn silk powder in the instant mix led to an increase in bulk density and a reduction in tapped density. The optimal formulation for the most desirable product was found to include 14.66% corn silk, 10% sugar, and 0.22% xanthan gum in a base of skimmed milk powder (adjusted to 100%). It was also observed that increasing the percentage of corn silk in the instant mix significantly affected the sensory attributes particularly color and appearance of the prepared product. Overall, it can be inferred from the reported literature that agricultural by-products can significantly enhance the nutritional and functional attributes of food products when used as supplements or substitutes in the preparation of instant premix powders. This generally implies that, regardless of the type of agricultural by-product used, their nutritional benefits can be retained, provided that proper formulation practices are carefully followed.

3.3 Premix of Fruits and Vegetables and their by-products

Due to the high perishability and short shelf life of some fruits and vegetables, they can contribute significantly to food waste if not valorized for other purposes [36, 24]. Consequently, several researchers have explored the reuse of these highly perishable yet valuable fruits and vegetables by converting them into value-added products such as instant premixes. For example, Marzlan et al. [14] explored the production of a banana cake premix from overripe banana (*Musa acuminata*) by-products using the foam mat drying process. This foam mat drying process is a cost-effective technique for drying various foods, such as fruits and vegetables. It is considered a productive alternative to heat drying, as fruit powders can be produced on a large scale [37]. In this study, overripe banana puree was subjected to foam mat drying, and the resulting dried powder was used in banana cake production. The banana cake formulation can be seen in Table 2. Several physicochemical parameters were analyzed, revealing significant differences ($p < 0.05$) in sucrose content, pH value, moisture content, and color of the premix powder. Sensory evaluation showed that banana cakes prepared from overripe banana powder, with banana essence added to the batter, had significant differences ($p < 0.05$) in aroma, appearance, flavor, and aftertaste. In contrast, no significant differences ($p \geq 0.05$) were observed in the texture attribute across all

banana cake samples. Nonetheless, the best-selected overripe banana powder was obtained from banana puree that underwent foam mat drying at 70 ° C and was ground for 30 seconds. On the other hand, the processing and harvesting date fruit (*Phoenix dactylifera*) generates a substantial amount of by-product waste, which has significant potential for value addition due to its rich nutritional profile. The study by Attri et al. [20] aimed to develop and assess the effect of incorporating date powder, prepared from immature dates, into a cake premix by substituting refined sugar. In their study, immature dates were washed and sorted to remove dirt and foreign particles, then blanched at 95 ° C for 30 seconds in water. The blanched dates were loaded onto trays and dehydrated in a crossflow hot air cabinet dryer at 45–50 ° C for 48 hours, achieving a final moisture content of 45% and total soluble solids (TSS) of 40 ° B. Accordingly, the formulated date cake premix (Table 2) was found to be rich in natural sugars, minerals, and bioactive compounds. It was observed that the date cake premix formulated with 100% replacement of refined sugar (CP4) achieved the highest overall acceptability on a 9-point hedonic scale, along with the highest fiber (7.54%), ash (3.03%), total phenolics (249.38 mg GAE/100 g), antioxidant activity (61.12%), and reduced total sugars (33.52%) content. Meanwhile, storage of the CP4 formulation at ambient temperature (25 ± 1 ° C) significantly (p < 0.05) influenced the quality attributes of the prepared premix. The study demonstrated that date powder can be used as a natural sweetener at a 100% replacement level in cake premix while maintaining desirable texture, functional properties, and organoleptic quality.

Conversely, apple (*Malus domestica*) pomace, the solid residue from apple processing, is a rich source of dietary fiber that can be effectively incorporated into bakery products to enhance their nutritional quality. Instead of discarding this by-product, Negi et al. [15] proposed a valorization method by using it as an ingredient in the development of a fiber-enriched muffin premix powder (Table 2). The prepared premixes were packed in polyethylene and aluminum-laminated pouches and stored at ambient conditions for further analysis. The evaluation results showed that the fiber-enriched muffin premix was highly acceptable to sensory panelists based on a 9-point hedonic scale. Proximate analysis revealed that the apple pomace-supplemented premix had significantly higher crude fiber (6.40%) and total dietary fiber (10.48%) content compared to the control. Thus, the study affirmed that incorporating apple pomace powder into bakery products can substantially improve their nutritional quality. In the context of fruit ripple premix, several perishable fruits have also been investigated for value addition through ripple premix formulation. Fruit ripple typically refers to a swirl or streak of fruit sauce or purée that is mixed into another product, most commonly ice cream, yogurt, or desserts. To cite a few examples, Nalawade and Chavan [17] developed a ripple premix using strawberry (*Fragaria ananassa*) and pineapple (*Ananas comosus*). The fruit ripple premix was designed by employing response surface method (RSM) in optimizing the use of fruit ripple premix base, fruit powders, titbits, flavors and colors. The strawberry fruit ripple and pineapple fruit ripple were then analyzed for

physicochemical and sensory attributes. The sensory evaluations of ripples were carried out on samples which were prepared and stored 10 ° C for 24 hours and thawed until 25 ° C for 30 minutes prior to evaluation. Based on the optimization process, the optimized solution for strawberry fruit ripple premix consisted of 27 g (fruit ripple premix base), 12 g (strawberry fruit powder), 1.05 g (strawberry tit bits), 0.005 g (color) and 0.016 g (strawberry powder). Meanwhile, for preparation of pineapple fruit ripple premix, the optimum solution consisted of 30.99 g (fruit ripple premix base), 16 g (pineapple fruit powder), 1.18 g (pineapple tit bits), 0.009 g (color) and 0.011 g (pineapple flavor powder). Similar observations were also obtained by Nalawade et al. [16] in the development of fruit ripple premix from mangoes (*Mangifera indica*) by optimizing some of the response variables during formulation such as sweeteners, gums, acid regulator, fruit powders, titbits, flavors and colors. Thus, the study concluded that the developed ripple premixes from strawberries, pineapples, and mangoes can be very useful for bakery and confectionary applications like fillings and toppings.

In a similar manner, the underutilized green leafy vegetable spinach (*Spinacia oleracea*) has also been explored as a functional ingredient in premix powder formulations. Given its short shelf life, appropriate processing and preservation techniques can help reduce wastage and enhance its availability in the diet during the off-season. For example, in the study by Khan et al. [11], chapati premixes were developed by fortifying wheat flour with dehydrated spinach powder. The researchers evaluated the impact of this fortification on the physicochemical, rheological, nutritional, and sensory characteristics of the product with formulations listed in Table 2. Other ingredients such as powdered sugar (3.0%), salt (2.2%) and milk powder (2.0%) were kept constant across all formulations based on the wheat flour to spinach powder ratio. The analysis revealed that peak viscosity and breakdown viscosity significantly decreased, while peak time and dough tenacity increased with higher concentrations of spinach powder (from 1% to 10%) in the chapati premixes. Additionally, the incorporation of spinach powder notably influenced the textural qualities of the chapatis. Among all the formulations, a 5% substitution of spinach powder was found to be the most optimal for chapati preparation, balancing both nutritional enhancement and sensory acceptability. Hence, from the above discussions, it is evident that dehydrated fruits and vegetables can be effectively valorized in the formulation of instant premixes to meet nutritional and functional requirements, rather than being discarded as waste.

3.4 Premix of Multiple Agricultural by-products

The primary goal of combining multiple agricultural products in the formulation of premix powder is to create a nutrient-dense, value-added product. This approach also supports the valorization of food waste, contributing to food security and sustainability efforts [34, 19]. Within this framework, several research undertakings have been conducted to facilitate the value addition of agricultural by-products and to offer nutrient-rich, commercially available formulations at low cost and can be accessible in the local markets.

One example is the multigrain premix powder developed by Garg et al. [38], in which the premix was formulated by blending powders from the seeds of sorghum (jowar), pearl millet (bajra), finger millet (ragi), barley (jau), mango (*Mangifera indica* Linn.), pumpkin (*Cucurbita pepo*), jackfruit (*Artocarpus heterophyllus* Lam.), along with other ingredients such as cardamom and sugar. In their study, 100 g of premix was prepared using different proportions (Table 2). Among these, the 60:40 ratio was selected as the best combination based on sensory scores. The study revealed that the incorporation of multiple millets along with seeds from fruits and vegetables significantly increased the nutritional value of the premix. Since millets were used in the formulation, the premix contained non-gluten-forming proteins, making it suitable for individuals with gluten intolerance. Moreover, as millets are a good source of insoluble starch and have a low glycemic index, the premix may also be beneficial for diabetic patients. In summary, the use of multiple powders derived from various agricultural by-products can enhance both the nutritional and functional properties of the formulated premix.

To illustrate further, Gupta et al. [39] formulated a multi-source cake premix powder using three major ingredients: sweet potato (*Ipomoea batatas*), chia seeds (*Salvia hispanica*), and finger millet (*Eleusine coracana*). In their experiment, the ragi (finger millet) and chia seeds were dried, sieved, powdered, and stored for further use. Different formulations were prepared (Table 2). Cakes were then made from these flour blends, which also included soymilk powder, flavoring agents, brown sugar, and virgin coconut oil. The mixtures were baked at 150 °C in a preheated oven for 40 minutes, then allowed to cool and were depanned after one hour. Based on sensory analysis, the T5 sample, comprising 60% finger millet, 30% sweet potato flour, and 10% chia seed flour, received the highest scores for appearance, aroma, taste, texture, and overall acceptability. Overall, only minor differences were observed among the five formulations, all of which demonstrated acceptable sensory profiles. These results suggest that increasing the levels of these functional powders may positively influence overall acceptability. However, the authors recommended further analysis, as the study was limited to sensory evaluation.

4. CHALLENGES & FUTURE DIRECTIONS

According to Bancal & Ray [2], the significant obstacle in achieving mitigation of post-harvest losses is the lack of precise knowledge of the actual magnitudes of losses, which makes it impossible to measure progress against any loss reduction targets. Aside from that, and despite being instrumental in achieving a green environment and supporting circular economic approaches, the valorization of food waste from agricultural products faces significant challenges, as it involves biological and mechanical methods and therefore entails substantial financial requirements [37, 44]. In the context of by-product valorization for instant premix formulations, consumer acceptance and powder storage stability present significant challenges due to its either hydrophilic or hydrophobic nature [40, 41]. Thus, when repurposing any fruit or vegetable waste for value

addition, careful consideration of their valuable powder properties must be given prior to food product development, so as not to forfeit the main purpose of providing a nutrient-dense new product.

Moreover, in repurposing agricultural by-products for premix formulation, researchers and food processors typically produce either flour or powder from them after dehydration, to potentially replace commonly used flours such as refined wheat, corn, or rice flour. As a result, the challenge of surpassing the nutritional profile of these mainstream ingredients presents certain implications. In addition, the functional attributes of the resulting flour or powder depend on the physicochemical properties of the raw materials, post-harvest processing steps, and the degree of grinding. Post-harvest operations such as drying, milling, aging, roasting, and puffing can alter starch and protein conformations, potentially affecting their functional properties [42]. Therefore, it is not enough to explore only the physicochemical and techno-functional properties of the powder prior to application; the effects of its incorporation into the final product, along with its behavior during processing, must also be carefully considered. In like manner, regarding instant premix formulations, determining the optimum formula poses a significant challenge for researchers and food processors, as it requires considerable time and effort, particularly in quantifying the extensive list of quality variables or parameters in the laboratory prior to mass production. Nonetheless, with the introduction of various optimization and statistical techniques for decision-making, the tedious and labor-intensive qualitative analysis can be streamlined and supported by rapid and enhanced methods [23, 27, 32].

On the other hand, although a wide range of agricultural products has been valorized for premix powder formulations as reported in the literature, as most of which are derived from materials high in macronutrients such as carbohydrates, proteins, and fibers, there is limited reporting on the potential use of husks or shells from agricultural sources, such as coffee silver skin and cocoa bean shells, which are known to be rich in polyphenolic compounds and methylxanthines [43]. Therefore, future efforts focused on formulating premix powders using these by-products may be of interest, as they could contribute valuable data on their potential to enhance texture, moisture retention, and fiber content in valorized beverages or food products.

5. CONCLUSION & RECOMMENDATIONS

A brief review of the available literature on the functional composition, applications, and processing methods of valorized agricultural wastes and their by-products for premix powder formulation has been conducted. This review offers a valuable overview of various analytical and qualitative considerations involved in utilizing agricultural wastes for functional food innovations, such as instant mix formulations for flatbreads, cakes, muffins, snack foods, desserts, and other bakery products. However, despite the number of published papers focused on instant premix formulations utilizing food wastes, there is limited literature on storage stability, the complementary effects of different powdering techniques, and the development of value-added snack foods using

advanced technologies such as extrusion and high-pressure processing. Nonetheless, the current review highlights important insights into dehydration processes for powder production, a range of premix matrix formulations based on target food products, optimization strategies, and corresponding quality indices. These findings can inform future research initiatives focused on premix formulation. Continued research is recommended on the techno-functional properties and the effects of powdering processes on valorized wastes to enhance the texture, flavor, nutritional value, shelf-life, and sustainability of new food products.

6. ACKNOWLEDGEMENT

This research was supported by the German Academic Exchange Service (DAAD) and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). The authors also extend their sincere appreciation to Universiti Putra Malaysia (UPM) for providing the necessary facilities and resources, and to Caraga State University (CSU) for granting study leave privileges to Assoc. Prof. Engr. Philip Donald C. Sanchez.

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