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EVALUATION OF THE POTENTIAL OF WATERMEAL (*WOLFFIA ARRHIZA L.*) AS A PLANT-BASED PROTEIN BOOST FOR RICE SEASONING POWDER

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ABSTRACT

Watermeal (*Wolffia arrhiza* L.), known as the smallest aquatic plant in the world, has recently gained attention as a promising plant-based protein source for its high protein content, essential amino acids, minerals, vitamins, and antioxidants. Its rich nutrient profile highlights its potential for use in health-oriented food innovations. This study aimed to investigate the feasibility of incorporating dried watermeal (WM) as a partto enhanced in rice seasoning powder (furikake)to enhance its nutritional value, particularly its protein content. The rice seasoning powders were prepared following a modified standard recipe, which involved heating the seasoning mixture at 90°C, drying at 60°C, cooling, and subsequently blending with either dried seaweed or dried WM before packaging. Five formulations were developed by substituting seaweed with WM at levels of 0%, 3%, 6%, 9%, and 12%, and their physicochemical properties, antioxidant activity, microbial quality, and sensory acceptance were evaluated. The results demonstrated that increasing WM substitution significantly elevated protein, fiber, and mineral contents compared to the control (0% WM). All formulations achieved food safety standards and indicated suitability for extended storage. However, higher WM levels led to notable changes in appearance, aroma, taste, and texture. Among the tested formulations, WM-3 (3% WM) achieved the most desirable balance between nutritional enhancement and consumer acceptability across all sensory attributes. Antioxidant activity was reduced in WM-substituted samples, likely due to thermal and processing effects that influenced the stability of bioactive compounds. Overall, the findings confirm that WM can serve as a functional ingredient that effectively enriches the nutritional profile of furikake without compromising food safety or overall consumer acceptance when used at low substitution levels. The incorporation of WM presents an opportunity to develop plant-based, nutrient-dense seasoning products that align with current market trends toward sustainable and health-oriented diets.

Key words: Watermeal, *Wolffia arrhiza*, Furikake, Plant-Based Protein, Functional Food

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INTRODUCTION

Furikake, a traditional Japanese seasoning, has long been an essential component of Japanese cuisine, known for enhancing the flavor of steamed rice and various other dishes [1]. This seasoning, typically consisting of dried fish, seaweed, sesame seeds, salt, and spices, offers an umami-rich taste and a nutritional boost [2]. Furikake has evolved into a versatile ingredient with diverse applications in modern cuisine [3]. Given its adaptability and rich nutritional profile, the global demand for furikake has steadily grown, particularly in Asian countries. The global furikake market was valued at approximately USD 1.29 billion and is expected to expand to USD 2.15 billion by 2030 [4]. During the forecast period from 2024 to 2030, the market is anticipated to grow at a compound annual growth rate (CAGR) of 7.6% [4]. The increasing availability of Japanese food products in supermarkets and online platforms has further fueled furikake's popularity, prompting interest in innovative variations tailored to regional consumer preferences. The prevailing global market trend is shifting away from meat-based protein toward the consumption of plant-based protein [5]. Consequently, an ongoing effort is to identify plant sources with high protein content as potential ingredients in furikake to address the growing consumer demand.

Watermeal (WM) (*Wolffia arrhiza L.*), is commonly known as duckweed or "Kai Pam" in Thai. As the world's smallest aquatic plant, WM is a protein-rich, highly nutritious food source with a protein content of approximately 20 - 28% of its dry weight [6, 7]. Watermeal surpasses many conventional plant-based proteins source, such as corn grain (13.6%), wheat (13%), brown rice (11%), and pea (24%) [8] while offering essential amino acids, iron, calcium, zinc, vitamins, and antioxidants, making it an attractive option for food innovation [9, 10]. However, it was lower than soybean (39.8%) and whey (80%) [8]. The WM is an aquatic plant investigated for its rapid biomass and high nutritional density [11]. Current studies in Thailand and Africa focus on utilizing plant-based protein sources for human nutrition. Several studies collectively highlight the potential of WM as a valuable ingredient in health-oriented food products [12]. A previous study investigated the incorporation of WM into chocolate chip muffins, demonstrating that they enhanced fiber, calcium, and beta-carotene content without altering sensory attributes [12]. Siripahanakul *et al.* [13] investigated the use of dried WM as a meat substitute in pork meatball products. In the WM-pork meatball formulation, pork was partially replaced, resulting in an optimal composition ratio of 22.50:77.50 WM-to-pork. The final product received the highest preference scores for color, aroma, texture, taste and overall acceptability. A consumer survey revealed that 80% of participants favored the WM-pork meatball and perceived it as a healthier alternative to traditional all-meat pork meatballs due to its incorporation of plant-based ingredients. These findings underscore WM's versatility as a nutrient-rich ingredient with applications in functional foods aimed at promoting human health, especially in least developed and developing countries. Given these trends, integrating WM into furikake presents an exciting opportunity to create a novel, nutrient-dense seasoning that aligns with the growing consumer preference for functional foods and plant-based protein sources.

This study aimed to develop a furikake product that incorporates WM as a primary ingredient, thereby enhancing both its nutritional value and market potential. By investigating the optimal formulation of WM-based furikake and evaluating its sensory attributes, such as appearance, flavor, aroma, texture, and overall consumer acceptance, this research sought to establish a new value-added product that meets the evolving dietary needs of health-conscious consumers.

MATERIALS AND METHODS

Materials

Watermeal (WM) was purchased from Baan Pham Khun Mind's shop in Kalasin Province. Snakeskin Gourami (*Trichogaster pectoralis*) was received from Nakhon Nayok Province, Thailand. The ingredients, including roasted white sesame (Rai Thip®) and seaweed (Masita®) were purchased from a local supermarket. The chemicals used in this study were obtained from Merck, Germany.

Methods

Drying of WM

The WM (5 kg) was rinsed in water to remove dirt and impurities, drained, and placed in an aluminum tray with a thickness of approximately 1 cm. It was then dried using a hot air oven (Model ED 400, Binder GmbH, Germany) at 70°C for 8 h until the moisture content was less than 10%, following the modified method of Prosridee *et al*. [14] and Siriwat *et al*. [15]. After the drying process, the sample was cooled to room temperature to determine the moisture content. Subsequently, analyses were conducted to determine its physicochemical properties (color, moisture content, proximate composition, and antioxidant content).

Preparation of dried shredded fish

Snakeskin Gourami was steamed in a steamer for 30 min. After steaming, the steamed fish meat was meticulously separated from the bones. A mixture of soy sauce, dark soy sauce, sugar, and water was heated in a pan at 90°C until fully dissolved. The boneless fish meat was added to this mixture and stirred continuously for 30 min until it achieved a dried consistency. This mixture was subsequently subjected to additional drying in a hot air oven at 70°C for 30 min. After drying, the dried fish was cooled to room temperature, finely ground, and stored in a sealed aluminum foil bag to prevent exposure to oxygen and moisture.

Preparation of rice seasoning powder

Rice seasoning samples were prepared following the recipe of Mahe *et al*. [16] with some modifications. Light soy sauce, sugar, salt, and water were precisely measured according to the specified recipe (Table 1) and heated at 90°C for 8 min until the mixture fully dissolved. Finely ground dried shredded fish and roasted white sesame seeds were added and thoroughly mixed. The mixture was then poured into an aluminum tray to a thickness of approximately 1 cm and dried at 60°C for 1 h. After drying, the samples were cooled at ambient temperature for 15 min, and then dried seaweed or dried WM was added and evenly blended. The experiment involved adjusting the proportion of rice seasoning powder by substituting dried WM for seaweed at four different levels: 3%, 6%, 9%, and 12% of the components. Subsequently, the rice seasoning samples were packed in sealed plastic bags, and their physical, chemical, and sensory qualities were evaluated.

Water activity and Moisture content analysis

Water activity (a_w) was measured at 25°C in triplicate using a water activity meter (Aqualab 4TE, METER Group, Inc., WA, USA).

Moisture content was determined in triplicates by measuring the weight loss on drying, according to the Association of Official Agricultural Chemists (AOAC) method [17]. The results were reported as a percentage by weight on a dry basis (% db).

Color analysis

Color parameters (L^*, a^*, and b^*) were assessed using a Hunter Lab Digital Colorimeter (Model ColorFlex EZ, Hunter Lab, VA, USA). The L^* value indicates lightness on a scale from 0 to 100. The a^* value denotes redness ($+ a^*$) or greenness ($- a^*$), while the b^* value reflects yellowness ($+ b^*$) or blueness ($- b^*$). Measurements were conducted in five replications.

Proximate and total energy analysis

The samples underwent a chemical composition analysis, including protein, fat, and ash contents, following the AOAC [17] method in triplicate. The determination of protein content employed the Kjeldahl method, while total crude fat content was measured through Soxhlet extraction. To estimate ash content, 5g of the sample underwent incineration in a muffle furnace at 550°C, and calculations were performed as following equation:

$$\text{Crude ash } (\%) = \left(\frac{\text{Weight of ash}}{\text{Weight of sample}}\right) \times 100 \qquad (1)$$

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Where W_1 is the weight of the porcelain crucible and sample after burning, W_2 is the weight of the empty porcelain crucible, and weight of ash = $W_1 - W_2$.

Total energy content was measured using a Bomb Calorimeter (PARR 6200, Parr Instrument Co., IL, USA). The analysis was performed in triplicate, and the results were reported in the form of Kcal per 100 g.

Total phenolic content and antioxidant activity

The rice seasoning samples were extracted with 96% (w/v) ethanol at a solid-to-solvent ratio of 1:10 (w/v), following the method described by Rachmawati *et al.* [18] with some modifications. The mixture was placed in a 250 mL flask and shaken continuously for 24 h at room temperature. The extract was then filtered using Whatman No.1 filter paper. The filtrate was subsequently used to determine the total phenolic content and antioxidant activity.

The total phenolic content (TPC) in rice seasoning extract was analyzed in triplicate using the Folin-Ciocalteu method [19]. The extract (0.40 mL) was mixed with 0.40 mL of Folin-Ciocalteu reagent and 4 mL of 2% (w/v) Na_2CO_3 solution. The test tube was incubated at room temperature for 30 min. Absorbance was measured using a UV-Vis spectrophotometer (Thermo Scientific Evolution 201, USA) at a wavelength of 725 nm. The TPC value was calculated in mg gallic acid equivalent (GAE)/g dry weight (db) ($r^2 = 0.9982$).

The Ferric Reducing Antioxidant Power (FRAP) activity in rice seasoning extract was analyzed with triplicates using the method of Ruengdech and Siripatrawan [20]. The extract (0.40 mL) was mixed with 3 mL of FRAP solution and incubated in a water bath at 37°C for 4 min. The absorbance was measured at a wavelength of 593 nm, and the FRAP value was calculated in mg Trolox equivalent (TE)/g dry weight (dw) ($r^2 = 0.9978$).

Microbiological analysis

The control and WM-3 samples with the highest sensory acceptability scores were packed separately in sterile polyethylene bags, sealed, and stored at room temperature (30 ± 2°C). Aerobic plate count, yeast, and mold were estimated and presented in colony-forming units (CFU)/g. The methods used for all the samples examined were in accordance with the United States Food and Drug Administration, Bacteriological Analytical Manual FDA-BAM [21]. Each analysis was carried out in triplicate.

Sensory analysis

Fifty untrained panelists evaluated the sensory assessment of rice seasoning powder with various WM using a 9-point hedonic scale. The rice seasoning sample was mixed into the cooked rice prior to serving the assessors. All samples were then

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assigned three-digit random codes and randomly served to the assessors. The panelists evaluated the rice seasoning powder for sensory assessment, including appearance, color, aroma, taste, texture, and overall acceptability. The assessment of texture refers to the physical feeling of the rice mixed with seasoning powder. The assessors scored the samples on a scale from 1 to 9 (1= dislike extremely, 9 = like extremely). Ethical permission for human involvement was issued by Suan Sunandha Rajabhat University ethics committee (COE. 1-052/2023 and study code: 66-121-1-1).

Statistical analysis

Data from the physical and chemical quality analyses were statistically analyzed using a Completely Randomized Design (CRD). Sensory evaluation data were analyzed using a Randomized Completely Block Design (RCBD). Differences among means were compared using Duncan's Multiple Range Test at a 95% confidence level. Whenever a significant F value (p<0.05) was found, the Duncan's Multiple Range Test was used to identify significant difference among means. The statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) statistics.

RESULTS AND DISCUSSION

Physicochemical properties of dried WM

The physical and chemical properties of dried WM are presented in Table 2. The color of dried WM was characterized using the Commission Internationale de l'Éclairage (CIE) Lab color system, with L^* at 21.07 ± 0.27, a^* at 0.81 ± 0.04, and b^* at 10.84 ± 0.12. The relatively low L^* value indicated a darker appearance, which might result from pigment transformation during the drying process, particularly chlorophyll degradation or Maillard reactions [22]. The a^* value, being close to zero, suggested a slight reddish-green hue, while the b^* value indicated a noticeable yellowish tone. These color characteristics were important for product development as they could influence consumer perception and preference.

The chemical components were highlighted in its moisture content, macronutrient profile, mineral content, and bioactive compounds. The moisture content of dried WM was found to be 4.58 ± 0.28% (wb), which was relatively low. This reduced moisture level was essential for prolonging shelf life by inhibiting microbial growth and enzymatic activity that could have led to spoilage. Watermeal was rich in protein (19.78±0.22% db), making it a promising plant-based protein source. Previous studies had identified WM as a sustainable protein alternative due to its rapid growth rate and high amino acid profile, comparable to other plant-based protein sources such as soy [9, 23]. The lipid content was moderate (5.25±0.09% db), contributing to its energy value while also potentially providing essential fatty acids [10, 23].

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Regarding its mineral composition, dried WM contained high levels of calcium (1,040.20±0.05 mg) and phosphorus (500.54±0.12 mg), which were essential for bone health and metabolic processes. Moreover, dried WM was a rich source of bioactive compounds, including total polyphenols (1,351.53±0.12 mgGAE/100 g) and total antioxidants (1,721.32±0.54 mgTE/100 g). Polyphenols and antioxidants play a crucial role in reducing oxidative stress, lowering the risk of chronic diseases, and providing anti-inflammatory benefits [24]. The presence of these compounds suggested that WM could have been considered a functional ingredient with potential health-promoting properties.

Physicochemical properties of rice seasoning powder

The data presented in Table 3 illustrated the effects of formulating different levels of dried WM into rice seasoning powder on moisture content, water activity (a_w), and color parameters. The results indicated significant variations in these physicochemical properties as the proportion of WM increased from 0% (control) to 12% (WM-12). The moisture content of the rice seasoning powder was observed to increase with the addition of dried WM. The control sample (0% WM) had the lowest moisture content (1.51±0.18% wb), whereas the highest moisture content was found in WM-12 (2.65±0.14% wb). This trend was attributed to the hygroscopic nature of dried WM, which tended to absorb and retain moisture from the surrounding environment. Previous studies reported that dried aquatic plant materials, such as WM, had a relatively high affinity for water due to their porous structure and composition, which included hydrophilic components such as proteins and polysaccharides [25]. As a result, formulations with higher WM content exhibited elevated moisture levels.

Interestingly, the water activity (a_w) values did not show significant differences among the samples, remaining within the range of 0.22-0.25. Since a_w was directly influenced by the availability of free water in a food matrix, this suggested that although the total moisture content increased, the proportion of free water remained relatively constant. It has been due to the strong binding of water molecules to the structural components of WM, which limited the availability of free water, which could have contributed to microbial growth and chemical degradation [26].

The color parameters (*L**, *a**, and *b**) exhibited noticeable changes with increasing WM concentration. The lightness (*L**) values tended to decrease as WM content increased, with the control sample showing the highest *L** value (41.05±1.59) and WM-9 showing the lowest (38.39±1.52). This suggested that the incorporation of WM led to a darker appearance, which was due to the natural pigments present in dried WM. The redness (*a**) values significantly decreased with increasing WM levels. The control sample had the highest *a** value (9.49±1.21), while WM-6, WM-

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 6
July 2026
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ISSN 1684 5374

9, and WM-12 exhibited significantly lower values in the range of 6.61-7.03. This reduction in redness resulted from the greenish pigmentation of WM, which counteracted the red hue in the seasoning powder. Similarly, the yellowness (b^*) values also tended to decrease with higher WM content, supporting the idea that the color of the seasoning powder was increasingly influenced by the pigments in WM. The color analysis results were consistent with the findings of On-Nom *et al*. [6], who studied the incorporation of dried duckweed (*Wolffia globosa*) in snacks to enhance their nutritional value. It was observed that increasing the amount of dried duckweed tended to decrease the L^* value of the snack. Moreover, higher dried duckweed resulted in a significantly greener color.

Sensory attributes

Sensory evaluation plays a crucial role in determining consumer acceptability and market potential. The results of investigating the sensory attributes (in terms of appearance, color, smell, taste, texture, and overall acceptability) of rice seasoning powder formulated with varying amounts of dried WM are shown in Table 4. The highest appearance score was observed in the control sample (8.20±0.72), with a gradual decrease as WM quantity increased. Figure 1 shows the appearance of dried WM and five formulations of rice seasoning products. A similar trend was noted for the color attribute, where the control sample received the highest rating (8.04±0.75). This decline in preference scores might have been attributed to the darker or greener hue imparted by dried WM, which could have affected consumer perception negatively. Prior studies indicated that the incorporation of dried plant-derived ingredients in snacks could alter the visual appeal of food products, influencing lower consumer preference [27].

The smell scores exhibited a significant (p<0.05) decline from 7.60±0.98 in the control sample to 7.01±1.03 in WM-12. This trend suggested that higher levels of dried WM contributed to a more pronounced vegetal or earthy aroma, which may not have been well-received by all consumers. Similarly, taste scores followed a declining pattern, with the control sample scoring 8.04±0.87 and WM-12 dropping to 7.34±1.04. The incorporation of dried WM in rice seasoning powder affected bitterness or unfamiliar astringent tastes, leading to significantly (p<0.05) lower acceptance. Wirivutthilorn [28] revealed that the corn milk with 3% of dried wolffia powder tasted bitter. The results were consistent with those in the previous reports, which suggested that increasing the amount of dried duckweed powder added to the snack resulted in a significant (p < 0.05) decrease in preference scores from sensory panelists [28]. These phenomena may be explained by the fact that the substitution of plant-based ingredients in food demonstrated that higher concentrations of vegetables often resulted in stronger, sometimes undesirable, sensory attributes [6].

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The texture evaluation of the rice seasoning powder exhibited significant variations across the different formulations, with the control sample receiving the highest rating (7.90±0.86). As the proportion of dried WM increased, a decline in texture scores was observed, particularly in WM-6 (7.22±1.14) and WM-9 (7.24±1.17). The decline in texture preference observed in WM-6 and WM-9 might have resulted from modifications in the granularity of the powder, leading to changes in its dispersibility when mixed with rice. As the particle size distribution shifted, the seasoning exhibited a less uniform spread across the rice surface, potentially causing inconsistencies in sensory perception. Interestingly, at the highest concentration (WM-12), the texture rating showed a slight recovery (7.46±0.97). This improvement could have been linked to the increased fiber content of dried WM, which may have contributed to a more desirable textural experience by enhancing cohesiveness or mouthfeel during consumption.

The overall acceptability scores decreased from 8.18±0.77 in the control to 7.66±0.82 in WM-9, but WM-12 exhibited a slight increase to 7.85±0.85. This suggested that while initial increases in WM concentration negatively impacted sensory perception, the highest concentration (WM-12) might have offered a unique balance of taste and texture that some consumers found acceptable. Similar findings were reported in studies where novel ingredients initially reduced acceptability but gained favor after adaptation to new flavors and textures [29].

The findings suggested that incorporating dried WM in rice seasoning powder impacted sensory attributes, particularly color, smell, and taste. However, moderate concentrations (3% - 6%) maintained relatively high acceptability scores. Based on the sensory evaluation results, the most suitable formulation for rice seasoning powder incorporating dried WM as a seaweed substitute was WM-3 (3% WM) due to its high consumer acceptability, minimal impact on sensory characteristics, and balanced nutritional enhancement.

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Figure 1: **Characteristics of dried watermeal (WM) and rice seasoning powder with various levels of WM**

Chemical properties of WM-3

The chemical composition of the control and WM-3 rice seasoning powder formulations demonstrated significant differences, particularly in protein, fiber, and ash content (Table 5). The incorporation of dried 3%WM in rice seasoning appeared to have enhanced the seasoning's nutritional value, as evidenced by several key compositional changes. A notable increase in protein content was observed in WM-3 (57.47±0.34%) compared to the control (42.40±0.09%). This enhancement was directly related to the high protein composition of dried WM, which contained 19.78±0.22% in dried WM. Similarly, lipid content significantly increased (p< 0.05) in WM-3 (9.04±0.02%) compared to the control (8.36±0.11%), likely due to the natural lipid profile of watermeal, which contained essential fatty acids that contributed to its nutritional quality [27]. The fiber content in WM-3 (0.89±0.15%) was higher than in the control (0.52±0.12%), reinforcing the functional role of dried WM as a fiber-rich ingredient. Furthermore, the ash content, which represented total mineral composition, was significantly higher in WM-3 (14.95±0.10%) than in the control (11.59±0.04%), suggesting an increase in mineral availability. In addition, the consumption of rice seasoning with 3% WM (376.40±0.98 kcal/100 g) can decrease the caloric value compared with the intake of rice seasoning without the presence of WM (393.36±1.01kcal/100g).

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Although the total polyphenol content remained relatively stable between the control and WM-3 formulations, a notable decline in antioxidant activity was observed in WM-3 (44.73±0.79 mgTE/100 g) compared to the control (67.92±1.61 mgTE/100 g). This reduction suggested that adding dried WM did not significantly alter the total polyphenol concentration; however, it might have influenced the functional activity of these compounds. This contributing factor could have been the processing and drying conditions used during seasoning powder preparation [30]. Thermal processing could have led to structural modifications in polyphenols, resulting in either degradation or transformation into less active forms [31, 32]. Given that dried WM was subjected to dehydration processes, some degradation of its native antioxidant compounds might have occurred, ultimately influencing the antioxidant capacity of the final product [33]. Similarly, Jiamjariyatam *et al*. [34] found that the drying temperature in hot air significantly ($p < 0.05$) affected coffee pulp's antioxidant activity content. During the thermal processing of samples, the hydroxyl groups of phenolic compounds present in WM are oxidized to aldehyde, ketone, or carboxyl groups. Since the phenolic compounds can be degraded with oxidation reactions and affected the loss of antioxidant capacity [35]. Increasing the drying temperature from 60°C to 90°C resulted in a 12.7–21.4% reduction in the DPPH of dried coffee pulp. This phenomenon could have been linked to a decrease in chlorogenic acids presented in coffee pulp, predominantly phenolic compounds in coffee pulp.

Microbiological properties

Table 6 shows the results of the microbiological properties of rice seasoning powder that is control and WM-3. Two samples exhibited microbial counts below the detection limit (<10 CFU/g) for Total Viable Count (TVC) and Total Yeast and Mold Count. It means no visible bacterial or fungal colonies grew on the test plate. This suggested that the production process, ingredient composition, and drying conditions effectively prevented microbial contamination. The extremely low microbial counts confirmed that both formulations met food safety standards for dried food products. The low moisture and water activity levels created an inhospitable environment for microbial growth, significantly reducing the risk of spoilage and foodborne pathogens. Both the control and WM-3 formulations demonstrated excellent microbiological safety and stability due to their low moisture content, low water activity, and undetectable microbial counts. These factors suggested that the rice seasoning powders were safe for consumption and suitable for long-term storage [36]. However, maintaining proper packaging and storage conditions (dry and airtight) was essential to preserve their microbial stability and prevent moisture absorption.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This study highlights the potential of dried WM as a valuable plant-based protein source for enhancing the nutritional value of rice seasoning powder. The incorporation of dried WM significantly increased the protein, fiber, and mineral content of the seasoning powder, demonstrating its nutritional benefits. However, higher concentrations of dried WM affected the sensory attributes, particularly in terms of appearance, smell, and taste. The optimal formulation, WM-3 (3% WM), maintained a balance between enhanced nutritional value and consumer acceptability, offering a promising alternative to traditional ingredients in rice seasoning powder. Furthermore, the low microbial counts and stable microbiological properties of the formulations indicated their safety and suitability for long-term storage, ensuring product shelf life and food safety.

The results support the potential of WM as a sustainable, nutrient-dense ingredient for developing novel food products with enhanced health benefits. Future research could focus on optimizing processing methods to preserve the antioxidant activity and explore the potential for expanding the use of dried WM in other food products.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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Table 1: The amount of ingredients in the rice seasoning substituted with dried WM in varied quantities

Ingredients	Amount (g)				
	control	WM-3	WM-6	WM-9	WM-12
Dried Shredded Fish	100	100	100	100	100
Roasted White Sesame	15	15	15	15	15
Light Soy Sauce	20	20	20	20	20
Sugar	15	15	15	15	15
Water	15	15	15	15	15
Salt	1	1	1	1	1
Dried Seaweed	1	-	-	-	-
Dried Watermeal	-	5	10	15	20

WM-3 stands for 3% 6% watermeal supplementation; WM-6 stands for 6% watermeal supplementation; WM-9 stands for 9% watermeal supplementation; WM-12 stands for 12% watermeal supplementation

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 6
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ISSN 1684 5374

Table 2: Physicochemical properties of dried WM

Physicochemical Properties	
Color parameters	
*L**	21.07 ± 0.27
*a**	0.81 ± 0.04
*b**	10.84 ± 0.12
Moisture (%)	4.58 ± 0.28
Carbohydrate (%)	44.09 ± 0.03
Protein (%)	19.78±0.22
Lipid (%)	5.25±0.09
Fiber (%)	19.26±0.18
Ash (%)	11.62±0.03
Calcium (mg/100g)	1,040.20±0.05
Phosphorus (mg/100g)	500.54±0.12
Total polyphenol (mgGAE/100 g)	1,351.53±0.12
Total antioxidants (mgTE/100 g)	1,721.32±0.54

GAE represents gallic acid equivalent; TE stands for Trolox equivalent

Table 3: Physicochemical properties of rice seasoning substituted with dried WM in varied quantities

Attributes	**control**	**WM-3**	**WM-6**	**WM-9**	**WM-12**
Moisture (%)	1.51±0.18^{c}	1.63±0.26^{bc}	2.02±0.32^{b}	2.51±0.08^{a}	2.65±0.14^{a}
Water activity ^{ns}	0.25±0.11	0.24±0.18	0.23±0.15	0.22±0.10	0.22±0.18
Color parameters					
*L**	41.05±1.59^{a}	40.26±1.30^{ab}	38.89±2.12^{b}	38.39±1.52^{b}	39.34±0.82^{b}
*a**	9.49±1.21^{a}	6.99±0.73^{b}	6.61±0.31^{b}	7.03±0.30^{b}	6.86±0.50^{b}
*b**	24.30±0.13^{a}	23.02±0.27^{b}	22.79±0.07^{b}	22.16±0.14^{c}	22.95±0.88^{bc}

Different letters in each row indicate a significant difference at $p < 0.05$ (n = 3); "ns" indicates a non-significant difference at $p < 0.05$

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Table 4: Sensory evaluation of rice seasoning substituted with dried watermeal in varied quantities

Sensory Attributes	control	WM-3	WM-6	WM-9	WM-12
Appearance	8.20±0.72^{a}	8.19±0.74^{ab}	8.10±0.73^{ab}	7.84±0.84^{b}	7.76±0.98^{b}
Color	8.04±0.75^{a}	7.64±0.82^{b}	7.56±1.07^{b}	7.44±1.21^{b}	7.42±1.07^{b}
Smell	7.60±0.98^{a}	7.50±0.97^{a}	7.32±0.84^{ab}	7.16±1.01^{b}	7.01±1.03^{b}
Taste	8.04±0.87^{a}	8.02±0.79^{a}	7.86±0.85^{ab}	7.60±0.80^{bc}	7.34±1.04^{c}
Texture	7.90±0.86^{a}	7.54±0.90^{ab}	7.22±1.14^{b}	7.24±1.17^{b}	7.46±0.97^{b}
Overall acceptability	8.18±0.77^{a}	7.92±0.75^{ab}	7.90±0.93^{ab}	7.66±0.82^{b}	7.85±0.85^{b}

Different letters in each row indicate a significant difference at $p < 0.05$ ($n = 3$)

Table 5: Chemical properties of rice seasoning powder (control and WM-3)

Chemical Properties	control	WM-3
Moisture (%) ^{ns}	1.51±0.18	1.63±0.26
Carbohydrate (%)	37.13±0.15^{a}	16.29±0.34^{b}
Protein (%)	42.40±0.09^{b}	57.47±0.34^{a}
Lipid (%)	8.36±0.11^{b}	9.04±0.02^{a}
Fiber (%)	0.52±0.12^{b}	0.89±0.15^{a}
Ash (%)	11.59±0.04^{b}	14.95±0.10^{a}
Calcium (mg/100g)	0.32±0.01^{b}	0.57±0.02^{a}
Phosphorus (mg/100g) ^{ns}	0.50±0.16	0.65±0.019
Total Energy (kcal/100g) ^{ns}	393.36±1.01	376.40±0.98
Total polyphenol (mgGAE/100g) ^{ns}	0.48±0.22	0.52±0.09
Total antioxidants (mgTE/100g)	67.92±1.61^{a}	44.73±0.79^{b}

Different letters in each row indicate a significant difference at $p < 0.05$ ($n = 3$); "ns" indicates non-significant difference at $p < 0.05$; GAE represents gallic acid equivalent; TE stands for Trolox equivalent

Table 6: Microbiological properties of rice seasoning powder (control and WM-3)

Properties	control	WM-3
Total Viable Count (CFU/g)	<10	<10
Total Yeast & Mold Count (CFU/g)	<10	<10

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