



Development and nutritional evaluation of freeze-dried instant rice and mung bean meals for emergency food supplementation: a feasibility study

Sheena Marie L. Napata^{1*}, Melvin E. Bernardino^{2*} , Ma. Theresa C. Alcantara¹, Jeanne Carla Bruce²

¹Food Technology, Colegio de San Juan de Letran, Manila 1002, Philippines

²Nutrition and Dietetics, Colegio de San Juan de Letran, Manila 1002, Philippines

***Correspondence:** Sheena Marie L. Napata, Food Technology, Colegio de San Juan de Letran, Manila 1002, Philippines. sheena.napata@letran.edu.ph; Melvin E. Bernardino, Nutrition and Dietetics, Colegio de San Juan de Letran, Manila 1002, Philippines. melvin.bernardino@letran.edu.ph

Academic Editor: Antonio Di Stefano, "G. d'Annunzio" University of Chieti-Pescara, Italy

Received: December 27, 2025 **Accepted:** April 21, 2026 **Published:** May 28, 2026

Cite this article: Napata SML, Bernardino ME, Alcantara MTC, Bruce JC. Development and nutritional evaluation of freeze-dried instant rice and mung bean meals for emergency food supplementation: a feasibility study. *Explor Foods Foodomics*. 2026;4:1010156. <https://doi.org/10.37349/eff.2026.1010156>

Abstract

Aim: This study aimed to develop a rice and sautéed mung bean meal using freeze-drying to preserve its safety, nutritional quality, and sensory attributes, providing a nutrient-dense meal suitable for disaster response and emergency feeding.

Methods: White rice, mung beans, smoked herring, horseradish leaves, and seasonings were prepared, cooked, and freeze-dried. The freeze-dried product was vacuum-packed and evaluated for microbiological safety, physicochemical and proximate composition, micronutrient content (iron and vitamin A), and sensory acceptability by 50 Filipino panelists using a nine-point hedonic scale. Statistical comparisons with the traditional cooked meal were performed using paired *t*-tests.

Results: The freeze-dried meal exhibited low microbial counts water activity, and moisture content, confirming its safety. Proximate analysis showed high protein (21.69 g/100 g), moderate carbohydrates (65.53 g/100 g), low fat (7.03 g/100 g), and total energy of 412.15 kcal/100 g. Micronutrient content per 117 g serving was 0.35 mg iron and 10.56 µg retinol equivalents vitamin A. Sensory evaluation revealed high acceptability for aroma, taste, and texture, while appearance and color showed minor reductions compared to the control, with statistically significant differences ($p < 0.05$) in some attributes.

Conclusions: Freeze-drying effectively produced a safe, nutrient-rich, and sensorially acceptable instant rice and mung bean meal. The product demonstrates strong potential for long-shelf-life and is a convenient option for disaster response and emergency feeding, though further optimization may improve visual appeal.

Keywords

mung beans, instant rice meal, freeze-drying, sensory evaluation, product development, food security



Introduction

The Philippines, located in the typhoon belt of the Western Pacific, experiences an average of 20 typhoons annually, causing severe impacts on agriculture and food security. These events result in approximately Philippine Peso (Php) 607.38 million in crop losses each year, primarily affecting rice, corn, and high-value crops, posing significant threats to food security and farmers' livelihoods [1]. Similar impacts are observed in other typhoon-prone countries, such as Vietnam and Bangladesh [2, 3].

Natural disasters like typhoons disrupt the food supply chain, leading to reduced food production and increased food insecurity, especially among poor and nutritionally vulnerable groups [4–8]. The main nutritional concerns in disasters are acute malnutrition (wasting), micronutrient deficiencies, and chronic malnutrition (stunting), especially in young children. Many Filipinos also face micronutrient deficiencies, particularly in iron, vitamin C, calcium, iodine, and B vitamins. Similar deficiencies, such as iron and vitamin A, are observed in the U.S. and Greece [9, 10]. Producing nutrient-dense instant meals can help address these problems during disasters [11, 12], and when combined with integrated nutrition interventions that leverage locally available resources, the impact can be maximized [13].

Mung bean (*Vigna radiata*), which is a staple, highly abundant [14, 15] and highly cultivated crop in Southeast Asia, is known to be nutrient-dense and climate-resilient, making it essential for nutritional food security in impoverished areas [16]. Mung bean is known to contain significant amounts of dietary fiber [17], minerals [18], plant based-protein, and bioactive compounds which are beneficial for human health [19–21]. According to the United States Department of Agriculture (USDA) Food Data Central, 100 g of cooked, boiled mature mung bean seeds contains 105 kcal, 7.02 g of protein, 0.38 g of fat, 19.2 g of carbohydrates, and 7.6 g of dietary fiber. These nutritional characteristics demonstrate that mung beans are a suitable raw material for the production of nutrient-dense meals [22].

Freeze-drying has gained popularity for preserving food palatability and nutritional content by inhibiting chemical, metabolic, and microbiological activity through freezing [23, 24]. This method retains flavor, aroma, and nutrients, making it useful in food applications. Freeze-dried foods are ideal for calamities due to their long shelf life, high nutrient retention, and ease of preparation with water.

In the Philippine setting, various products have already been produced using the combination of rice and mung bean flours, ranging from baby food to snack products. While various instant meals using rice and mung bean flours have been developed in the Philippines, the combination of a traditional sautéed mung bean dish with rice, preserved through freeze-drying, remains unexplored. This particularly relevant given the increasing intention among Filipino consumers to incorporate more plant-based foods into their diets [25]. This study is therefore novel in integrating a culturally familiar recipe with freeze-drying technology to produce a ready-to-eat, nutrient-dense meal suitable for emergency and disaster contexts. The aim of this study is to formulate an instant rice and sautéed mung bean meal that optimizes the freeze-drying process to preserve its safety, nutritional, and sensory qualities.

Materials and methods

Materials

White rice, mung beans, and other raw materials (onion, garlic, tomatoes, cooking oil, iodized salt, and fish sauce) were bought from a certified food supplier in Manila, Philippines. Horseradish leaves and dried smoked herring were bought from a local distributor in Imus, Cavite, Philippines. Mylar bags and oxygen absorbers were obtained from EntrePouch (Manila, Philippines), a certified supplier of food-grade packaging materials, to maintain product integrity during storage.

Ingredients preparation

Dried mung beans (2.2 kg) were washed to remove floating beans and other foreign materials. The beans were then presoaked in 4 L of water for 3 min, drained, and boiled in 3.5 L of water for 20 min until tender. After boiling, the water was drained from the mung beans. Concurrently, 1 kg of dried smoked herring was deboned, yielding 350 g of fish meat for use in the dish. Garlic (150 g) and onions (60 g) were peeled and

chopped. Tomatoes (450 g) were halved, de-seeded, and cut into 1 cm cubes. Horseradish leaves (110 g) were separated from the stems and prepared for inclusion in the recipe.

A 10 L stainless steel cooking vessel was preheated until residual moisture was eliminated. Subsequently, 150 mL of cooking oil was heated, and chopped onions were sautéed until partially translucent. Minced garlic was then added and sautéed with the onions until aromatic. Deboned, dried, smoked herring was incorporated and cooked until the edges became crisp. Chopped tomatoes were added and sautéed until softened. Pre-drained mung beans were then introduced and mixed thoroughly to ensure uniform incorporation of all ingredients. Two liters of water, 50 mL of fish sauce, and 150 g of iodized salt were added to the mixture and stirred to enhance flavor. The mixture was simmered for 5 min at $80 \pm 2^\circ\text{C}$, after which horseradish leaves were added and further simmered at $80 \pm 2^\circ\text{C}$ for 2 min until slightly tender. The prepared sautéed mung bean mixture was transferred into 3 L microwave-safe containers and allowed to cool at room temperature. Separately, 1 kg of white rice was washed until the rinse water was clear and subsequently cooked over low heat with 1,250 mL of water for 15 min, until an al dente texture was achieved. The cooked rice was transferred into a 3 L microwave-safe container and allowed to cool prior to further use.

Freeze-drying of rice and sautéed mung bean meal

Freeze-drying process was done at Freeze Dry Manila, Quezon City, Metro Manila, Philippines. Boiled rice and sautéed mung beans with horseradish leaves and dried smoked herring were separately stored in the freezer at -5°C for 24 hours prior to freeze drying. Boiled white rice (4.297 kg) and sautéed mung beans with horseradish leaves and dried smoked herring (4.914 kg) were freeze-dried using Harvest Right Home Freeze Dryer in Large size. Primary drying or sublimation phase was done at a shelf temperature of -30°C for 10 hours. Secondary drying or desorption phase was done at 50°C for 5 hours. Both the sublimation and desorption phase were set at a chamber pressure of 300 mTorr. The post-dry weights of the white rice and sautéed mung beans with horseradish leaves and dried smoked herring were 1.327 kg and 1.383 kg, respectively.

Packaging

The freeze-dried instant rice and mung bean meal was vacuum packed in 15×25 cm single serving aluminum and nylon stand up mylar bags with vacuum pressure of 80 mbar and heat seal temperature of 150°C . Each pack contains 1 g pack of oxygen absorber, 49.4 g freeze dried rice, and 67.6 g freeze dried sautéed mung beans with horseradish leaves and dried smoked herring to yield 1 serving of sautéed mung bean (243 g) [25] computed using the drying ratio of 3.6:1. Drying ratio is the ratio of the pre-dried weight of the cooked food and its post-dry weight [26]. After freeze drying, the white rice decreased its weight from 4.297 kg to 1.327 kg. Moreover, the sautéed mung beans with horseradish leaves and dried smoked herring decreased their weight from 4.914 kg to 1.383 kg. The drying ratios of white rice and sautéed mung beans with horseradish leaves and dried smoked herring were 3.2:1 and 3.6:1, respectively. When rehydrated with water, 49.4 g of freeze-dried rice yielded 1 cup of rice (160 g) and 67.60 g freeze-dried sautéed mung bean yielded 1 serving of sautéed mung bean [27].

Sampling and sample size

For microbiological analysis, the freeze-dried product was analyzed in triplicate ($n = 3$) to ensure reliability and reproducibility of results.

For physicochemical, proximate, and micronutrient analyses, single representative samples ($n = 1$) were analyzed to obtain baseline compositional data.

For sensory evaluation, a total of 50 untrained consumer-type panelists were selected using purposive sampling. Each participant evaluated two samples: the control (traditionally prepared rice and Ginisang Monggo) and the experimental (freeze-dried rice and Ginisang Monggo) product.

All samples were immediately sent to the respective laboratories for microbiological, proximate, and nutritional analyses. Samples for sensory evaluation were stored at room temperature at 25°C and were evaluated after securing the microbiological results to ensure safety for consumption.

Microbiological analysis

The microbiological analyses were performed on the freeze-dried instant rice and mung bean meal by Qualibet Testing Services Corporation, Quezon City, Metro Manila, Philippines. The methods used were pour plate method [28] for the aerobic plate count (APC), yeast and mold count, and Compact Dry from Nissui Pharmaceutical Co., LTD. for the *Escherichia coli*, *Salmonella*, and *Staphylococcus aureus*. The results are expressed in colony forming unit per gram (cfu/g) of product.

Physicochemical and proximate analysis

The proximate analyses were performed on the freeze-dried instant rice and mung bean meal by Qualibet Testing Services Corporation, Quezon City, Metro Manila, Philippines. Fat, protein and moisture content, water activity, and ash content were measured based on the standard AOAC methods [29]. The total energy content is computed using the Atwater factor based on the total protein content, fat content, and carbohydrate content of the sample.

Nutritional evaluation

The nutritional evaluation was performed on the freeze-dried instant rice and mung bean meal by Intertek Testing Services Philippines, Inc., Makati City, Metro Manila, Philippines. Iron content was determined using atomic absorption spectrometry (AAS). Vitamin A was determined by high performance liquid chromatography (HPLC). Both analyses were based on the laboratory's in-house procedure.

Sensory evaluation

One package of the freeze-dried, vacuum-sealed product was rehydrated using 181.9 mL of boiling water measured at $100 \pm 2^\circ\text{C}$ using Cooper-Atkins 322-01-1 5 1/2" Probe Thermometer. It was stirred for 20 seconds and allowed to stand for 10 min while covered. Both the rehydrated freeze-dried product and the control sample (traditional rice and sautéed mung bean meal) were cooled to 45°C prior to serving to ensure consistency during evaluation. Sensory acceptability was assessed by panelists based on specific attributes, including appearance, color, aroma, taste, texture, and overall acceptability, using a nine-point hedonic scale (1 = dislike extremely to 9 = like extremely) [30].

A total of fifty panelists were recruited through purposive sampling and randomly assigned, in accordance with predefined inclusion and exclusion criteria. Eligible participants were Filipino citizens, aged 19 years and older, with no known food allergies or sensitivities related to the product. Individuals who did not meet the inclusion criteria, voluntarily withdrew, or failed to complete the sensory evaluation were excluded from the study. Participation was voluntary and supported by an informed consent process, which emphasized the participants' right to decline or withdraw at any stage without penalty. To maintain respondent anonymity, alphanumeric codes were assigned, and no identifying information was recorded on the evaluation forms.

Ethical consideration

The sensory evaluation was conducted in accordance with ethical standards for research involving human participants and was approved by De Los Santos Medical Center Research Ethics Committee [Ethics Review Board (ERB) Protocol Number 2025-020], Quezon City, Manila, Philippines. All participants provided informed consent prior to participation and were informed of their right to withdraw from the study at any time without penalty. Individuals with known food allergies or sensitivities were excluded to ensure participant safety. Participant anonymity and data confidentiality were maintained through the use of alphanumeric codes, and all data were used solely for research purposes.

Statistical analysis

To determine the acceptability of the freeze-dried product compared to the traditional product, a two-tailed paired *t*-test was performed at a significance level of $p < 0.05$ [30].

Results

Microbiological analysis

The microbiological quality of the freeze-dried instant rice and mung bean meal is summarized in Table 1. The APC was estimated at 70 cfu/g. Counts of *E. coli*, *S. aureus*, and yeast and molds were all below 10 cfu/g. *Salmonella* spp. was not detected in the analyzed samples.

Table 1. Microbiological assessment of freeze-dried instant rice and mung bean meal.

Test	Result
Aerobic plate count (cfu/g)	70
<i>E. coli</i> (cfu/g)	< 10
<i>Salmonella</i> spp. (cfu/25 g)	Negative
<i>S. aureus</i> (cfu/g)	< 10
Yeast and mold count (cfu/g)	< 10

All values are expressed in colony forming unit per gram (cfu/g) unless otherwise specified.

Physicochemical and proximate analysis

The proximate composition of the freeze-dried instant rice and mung bean meal, expressed on a dry weight basis per 100 g of sample, is presented in Table 2. The analysis revealed an ash content of 4.20%, crude protein content of 21.69%, fat content of 7.03%, moisture content of 1.55%, and total carbohydrates (calculated by difference) of 65.53%. The estimated total energy value of the product was 412.15 kcal per 100 g of dry sample. Water activity values were at 0.10.

Table 2. Proximate analysis of freeze-dried instant rice and mung bean meal.

Test	Value (per 100 g)
Ash	4.20 g
Total carbohydrates	65.53 g
Moisture	1.55%
Crude protein	21.69 g
Fat	7.03 g
Total energy	412.15 kcal

Values are expressed per 100 g of dry sample. Total carbohydrates were calculated by difference, and total energy was estimated based on the macronutrient composition.

The macronutrient composition of the freeze-dried instant rice and viand is presented in Table 3. On a per-serving basis (117 g individual pack), the product contained 76.67 g of carbohydrates, 25.38 g of protein, and 8.23 g of fat.

Table 3. Macronutrient evaluation of the freeze-dried instant rice and mung bean meal.

Macronutrients	Grams/100 g	Grams/117 g serving	Calories/117 g serving	Total energy/117 g serving (%)
Carbohydrate	65.53	76.67	306.68	63.60%
Protein	21.69	25.38	101.51	21.05%
Fat	7.03	8.23	74.03	15.35%

Macronutrient values per 117 g serving were calculated based on the 100 g composition. Energy contribution was estimated using Atwater factors: carbohydrate and protein at 4 kcal/g, and fat at 9 kcal/g. Percentage of total energy reflects the proportion of calories contributed by each macronutrient relative to the total energy of the serving.

Vitamin A and iron analysis

The micronutrient composition of the freeze-dried instant rice and viand is presented in Table 4. Per 117 g serving (individual pack), the product contained 0.35 mg of iron and 10.56 µg retinol equivalents (RE) of vitamin A.

Table 4. Micronutrient evaluation of the freeze-dried instant rice and mung bean meal.

Micronutrient	Grams/100 g	Content/117 g serving	Contribution to RNI (%)
Iron	0.303 mg	0.35 mg	Male: 8.86% Female: 3.80%
Vitamin A	9.029 µg RE	10.56 µg RE	Male: 4.53% Female: 5.28%

Values per 117 g serving were calculated from the 1 kg composition. Recommended nutrient intake (RNI) per meal represents the RNI for adults aged 19–29 years. Adequacy (%) indicates the proportion of RNI provided by a single 117 g serving. Vitamin A is expressed in retinol equivalents (RE).

Sensory evaluation

The sensory acceptability of the freeze-dried rice and sautéed mung bean meal was assessed using a nine-point hedonic scale, where 9 corresponded to “like extremely” and 1 to “dislike extremely”. The mean scores and standard deviations for each sensory attribute are presented in Table 5. Overall, the product was deemed acceptable by the panelists across all evaluated attributes, with most scores falling within the “like moderately” range (score of 7), indicating favorable sensory perception.

Table 5. Mean hedonic scores and standard deviation for freeze-dried instant rice and mung bean meal.

Sensory attribute	Mean ± standard deviation
Appearance	6.15 ± 1.82
Color	6.15 ± 1.53
Aroma	7.21 ± 1.30
Taste	7.19 ± 1.44
Texture	7.19 ± 1.44
Overall acceptability	6.77 ± 1.52

The sensory evaluation revealed statistically significant differences ($p < 0.05$) between the control and the freeze-dried rice and sautéed mung bean meal for appearance, color, taste, and overall acceptability, as presented in Table 6. These results indicate perceptible changes in these attributes attributable to the freeze-drying process. In contrast, no significant differences were observed for aroma and texture between the two samples.

Table 6. Paired t-test results of sensory attributes between control and freeze-dried instant rice and mung bean meal.

Attribute	Mean difference	Standard deviation	t-value	p-value
Appearance	0.729	1.300	3.885	< 0.001
Color	0.750	1.246	4.169	< 0.001
Aroma	0.146	1.353	0.747	0.459
Taste	0.521	1.353	2.668	0.010
Texture	-0.104	1.640	-0.440	0.662
Overall acceptability	0.563	1.128	3.455	0.001

Discussion

Safety of the food product

Based on the guidelines on the microbiological requirements and assessment of certain prepackaged processed food products [31], the acceptable limits for APC, *S. aureus*, and yeast and mold count are at $\leq 10^2$

cfu/g; ≤ 10 cfu/g for *E. coli*, and negative for *Salmonella* spp. The microbiological results showed low microbial counts and compliance to safety standards, thus considering the product safe for consumption. This low microbial count could be attributed to the heating pre-treatment, low water activity from freeze-drying and absence of oxygen due to vacuum packaging.

Dehydration and freeze-drying (lyophilization) are effective preservation methods as they significantly lower water activity, thereby inhibiting microbial growth and extending shelf life [32–34]. However, freeze-drying primarily suppresses microbial activity rather than eliminating spoilage organisms entirely [35, 36]. Therefore, pre-treatments, such as use of sodium chloride (NaCl), blanching or heat treatment, and post treatment, such as vacuum packaging, are used to further avoid health risks.

Vacuum packaging removes air or oxygen before sealing, thereby slowing oxidative reactions and inhibiting aerobic microbial growth. This is particularly beneficial for foods that are prone to spoilage when exposed to air. By limiting oxygen availability, vacuum sealing reduces the growth of most spoilage organisms, improving food safety and quality [37, 38].

Nutritional quality of the product

The moisture content of the sample was 1.55% while water activity was 0.10. This is the residual moisture content left after freeze drying along with the oil used for sauteing, which was not removed during lyophilization. Freeze drying is known to significantly decrease moisture content and water activity [24, 39, 40]. The low moisture content reduces microbial risk, ensures better shelf stability, and facilitates transportation due to the reduced weight. This characteristic is ideal for food products' long-term storage and for disaster response, as it can be transported easier via land, air or sea for distribution to areas affected by disaster.

The ash content of the sample indicated the presence of various minerals. While not a nutrient itself, ash is an indicator of the presence of various essential minerals like sodium, potassium, calcium, magnesium, etc. The value 4.20% could be from the sodium from the salt and fish sauce added to the product as flavoring, iron (as shown in Table 2), and other minerals from the mung bean, rice, and other ingredients. These minerals are essential for daily body functions like muscle function, oxygen transport, electrolyte balance, and bone health, which could contribute to ensuring food security in impoverished areas [16], especially during times of disasters where food and nutrition are scarce. The sample contains 65.53% carbohydrates, aligning with the Department of Science and Technology-Food and Nutrition Research Institute (DOST-FNRI) recommended carbohydrate intake of 55–75% for adults 19 years old and up. This high carbohydrate percentage is from rice and mung beans, as both are good sources of carbohydrates—starch and fiber [41]. The high carbohydrate content provides an instant yet nutritious source of energy for survival situations such as calamities. It also contained 21.69% protein, significantly exceeding the recommended 10–15% of total protein-based energy requirement for adults based on the Philippine Dietary Reference Intakes (PDRI) [42]. Mung beans and smoked herring (tinapa) [43] are good sources of protein. This high protein content makes the product beneficial for preserving muscle mass and supporting immune function during times of crisis. Furthermore, the fat content of the freeze-dried instant rice and mung bean meal was 7.03%. The low-fat profile of the product makes it less prone to lipid oxidation [44] and be beneficial to people with fat restricted diets.

The computed total energy through Atwater factor was 412.15 kcal per 100 g, which is moderately high in relation to the PDRI [42] where males aged 19–59 years old require 2,420–2,510 kcal per day, and female adults need 1,870–1,930 kcal per day. This is advantageous for emergency nutritional needs, since consuming 117 g serving packs containing 482.21 kcal paired with food items that are good sources of iron and vitamin A or by future micronutrient enrichment can fulfil the daily required energy during times of calamities. The acceptable carbohydrate, protein, and fat energy distribution for Filipino adults are 55–75%, 10–15%, and 15–30%, respectively. Based on its macronutrient distribution, the product was high in protein, within the acceptable carbohydrate range, and acceptable in fat content based on its total energy content.

The proximate composition of the freeze-dried instant rice and mung bean meal was notably preserved, consistent with findings for most freeze-dried foods, where nutrient retention remains high [39, 45–47]. Owing to its nutrient-dense profile, this product has strong potential as a primary meal component in short- to medium-term emergency feeding programs. This presents a significant advantage over commonly distributed relief foods, such as instant noodles and canned goods [48], which are typically less nutrient-dense.

Based on the recommended nutrient intake [42], the product had low adequacy for the two micronutrients, iron and vitamin A. The ingredients used for producing the freeze-dried instant rice and mung bean meal had low vitamin A ranging from 0 to 80 µg RE [49]; however, despite the low vitamin A content and despite undergoing processing, it is notable that iron and vitamin A were retained due to freeze drying similar to previous studies wherein vitamins, minerals and other phenolic compounds were retained [33, 50, 51]. Fortification strategies, particularly for iron and vitamin A, should be considered to improve the nutritional value of the meal and better support the micronutrient needs of affected populations during disasters.

Sensory quality of the product

Sensory attributes such as appearance, color, aroma, taste, and texture are critical determinants of consumer acceptance and overall product quality in food products. Appearance was rated slightly above “like slightly”, indicating that the product’s visual quality was acceptable but with room for improvement. Similarly, color was deemed somewhat acceptable, though it did not elicit strong appeal from the panelists. Aroma received ratings between “like moderately” and “like very much”, suggesting that aromatic compounds were effectively retained, producing a desirable scent comparable to the control. Taste was also rated within this range, indicating that the flavor was largely preserved, albeit slightly less intense than the fresh product. Texture ratings similarly fell between “like moderately” and “like very much”, demonstrating successful rehydration and retention of a satisfactory mouthfeel, an important quality in freeze-dried meals. Overall acceptability was close to “like moderately”, suggesting that while the product was generally well-received, minor deficiencies in appearance and color slightly reduced its overall sensory appeal.

The control product’s superior appearance and color aligned with findings by Uscanga et al. (2021) [52], who reported that higher shelf temperatures in freeze-drying can produce perceivable color changes in orange-based products, detectable through colorimetric measurements expressed in ΔE values. These observations underscore the importance of optimizing freeze-drying parameters to maintain visual quality.

The reduced taste scores in the freeze-dried sample may be due to volatile flavor compound loss. Although freeze-drying generally preserves flavor better than conventional hot-air drying, research on broccoli, carrots, and oranges indicates that aroma is often diminished—likely due to a decrease in volatiles during dehydration [41].

Aroma and texture did not differ significantly between samples. This is consistent with the results for freeze-dried orange snacks, where adjustments to pressure and temperature largely influenced color and crispness, while aroma and texture remained relatively stable [53]. Similarly, studies on freeze-dried berries suggest that when optimal shelf conditions are used, texture can be well preserved, even under varying temperatures [54].

Despite the significant differences between the control and freeze-dried product, overall acceptability of the developed product remained respectable as palatability and color were retained due to freeze-drying, similar to yogurts made from freeze-dried soybean peel powder and mung bean peel powder [46] and consumer acceptance of blackcurrant snacks [24, 47]. However, to approach the control’s acceptance levels, process optimization and improvement of formula is recommended.

Although freeze-drying and vacuum packaging are known to extend shelf-life, the long-term stability of the formulated instant rice and mung bean meal was not directly tested in this study. Future research should include accelerated and real-time shelf-life studies under varying storage conditions to validate the product’s longevity and nutrient retention over time.

Conclusion

The study successfully formulated an instant rice and sautéed mung bean meal that utilized the freeze-drying process. The product is not just another freeze-dried meal, but a culturally familiar, nutrient-dense, ready-to-eat complete meal designed for a specific, vulnerable population, but can also be consumed by the general population, especially during times of disaster when food security is a challenge.

Microbiological analysis confirmed that the product was safe for consumption, while proximate analysis demonstrated that it provides a compact, energy-rich composition with substantial carbohydrate- and protein-based energy, suitable for adult consumption in convenient or emergency contexts. Sensory evaluation indicated that the product was generally well accepted, particularly for aroma, taste, and texture, demonstrating the effectiveness of freeze-drying in retaining key sensory attributes. Minor reductions in appearance and color relative to the control highlight areas for potential improvement, suggesting that further optimization of formulation and processing could enhance visual appeal and overall acceptability. The product also has potential for long shelf-life based on low water activity and microbial counts. As such, future research should include accelerated shelf-life testing to establish product longevity under various storage conditions.

Future direction

Future research should focus on optimizing the visual quality of the product, particularly its appearance and color, to enhance overall sensory acceptability. Accelerated and real-time shelf-life studies are recommended to assess the stability of nutrients, sensory attributes, and microbial safety under various storage conditions. Additionally, strategies to further improve flavor and aroma, such as the use of natural enhancers or aroma-retention techniques, could be explored. Nutritional fortification with micronutrients may also be considered to increase the contribution to recommended daily intake. Scaling up production, evaluating cost-effectiveness, and conducting broader consumer acceptance studies across diverse demographic groups will be essential for potential commercial application. Finally, the product's applicability in emergency relief, institutional feeding programs, or convenience-oriented markets warrants further investigation.

Abbreviations

AAS: atomic absorption spectrometry

APC: aerobic plate count

cfu/g: colony forming unit per gram

DOST-FNRI: Department of Science and Technology-Food and Nutrition Research Institute

ERB: Ethics Review Board

HPLC: high performance liquid chromatography

NaCl: sodium chloride

PDRI: Philippine Dietary Reference Intakes

Php: Philippine Peso

RE: retinol equivalents

RNI: recommended nutrient intake

USDA: United States Department of Agriculture

Declarations

Acknowledgments

The authors would like to thank the Research and Publications Department of Colegio de San Juan de Letran Manila for funding this research. This research project was also made possible due to the support and assistance of the College of Business Administration and Accountancy. The authors would also like to thank the students of the Bachelor of Science in Food Technology Program who served as research assistants for the study.

Author contributions

SMLN: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing—original draft, Writing—review & editing, Visualization, Supervision, Project administration, Funding acquisition. MEB: Conceptualization, Investigation, Writing—original draft, Writing—review & editing. MTCA: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing—review & editing, Supervision, Funding acquisition. JCB: Conceptualization, Validation, Formal analysis, Investigation, Resources, Writing—review & editing. All authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical approval

The development of freeze-dried instant rice and mung bean meal for emergency food applications study was approved by the De Los Santos Medical Center Research Ethics Committee (Protocol code: 2025-020). This study adhered to the ethical principles of the Declaration of Helsinki (World Medical Association) for research involving human subjects. This includes ensuring voluntary participation, obtaining informed consent, minimizing potential risks, maximizing potential benefits, and maintaining the privacy and confidentiality of participant data.

Consent to participate

Informed consent to participation in the study was obtained from all participants.

Consent to publication

Informed consent to publication was obtained from relevant participants.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Funding

The study was funded by the Research and Publications Department of Colegio de San Juan de Letran, Intramuros, Manila. The sponsor financially funded the study to acquire the materials and equipment needed to develop and test the final product. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright

© The Author(s) 2026.

Publisher's note

Open Exploration maintains a neutral stance on jurisdictional claims in published institutional affiliations and maps. All opinions expressed in this article are the personal views of the author(s) and do not represent the stance of the editorial team or the publisher.

References

1. Typhoon Julian's Impact on Agriculture: Crop Losses, Infrastructure Damages, and Price Increases Amid Recovery Efforts [Internet]. Laguna: DOST-PCAARRD; c2024 [cited 2024 Oct 11]. Available from: <https://ispweb.pcaarrd.dost.gov.ph/typhoon-julians-impact-on-agriculture-crop-losses-infrastructure-damages-and-price-increases-amid-recovery-efforts/>
2. Trinh TA, Feeny S, Posso A. Chapter 17 - The Impact of Natural Disasters and Climate Change on Agriculture: Findings From Vietnam. In: Chaiechi T, editor. Economic Effects of Natural Disasters. Academic Press; 2021. pp. 261–80.
3. Yuen KW, Switzer AD, Teng PPS, Lee JSH. Assessing the impacts of tropical cyclones on rice production in Bangladesh, Myanmar, Philippines, and Vietnam [Preprint]. 2022 [cited 2025 Sep 23]. Available from: <https://doi.org/10.5194/nhess-2022-4>
4. Lin HI, Yu YY, Wen FI, Liu PT. Status of food security in East and Southeast Asia and challenges of climate change. *Climate*. 2022;10:40. [DOI]
5. Climate change, calamities affect food security of poor Pinoy households [Internet]. [cited 2026 Mar 28]. Available from: <https://fnri.dost.gov.ph/index.php/publications/writers-pool-corner/57-food-and-nutrition/854-climate-change-calamities-affect-food-security-of-poor-pinoy-households>
6. Nutrition at risk for Typhoon-hit Filipino families, WFP warns [Internet]. Rome: World Food Programme; c2026 [cited 2026 Mar 28]. Available from: <https://www.wfp.org/news/nutrition-risk-typhoon-hit-filipino-families-wfp-warns>
7. Clay LA, Ross AD. Factors Associated with Food Insecurity Following Hurricane Harvey in Texas. *Int J Environ Res Public Health*. 2020;17:762. [DOI] [PubMed] [PMC]
8. Destructive typhoons threaten food security, economic recovery [Internet]. Quezon: Philippine Institute for Development Studies; c2021 [cited 2026 Mar 28]. Available from: <http://www.pids.gov.ph/details/destructive-typhoons-threaten-food-security-economic-recovery>
9. Lopes SO, Abrantes LCS, Azevedo FM, Morais NS, Morais DC, Gonçalves VSS, et al. Food Insecurity and Micronutrient Deficiency in Adults: A Systematic Review and Meta-Analysis. *Nutrients*. 2023;15:1074. [DOI] [PubMed] [PMC]
10. Mitsopoulou AV, Magriplis E, Michas G, Micha R, Chourdakis M, Chrousos GP, et al. Micronutrient dietary intakes and their food sources in adults: the Hellenic National Nutrition and Health Survey (HNNHS). *J Hum Nutr Diet*. 2021;34:616–28. [DOI] [PubMed]
11. Yaşar K, Eke Çiftçi B. Disaster and Emergency Foods: Development and Nutritional Strategies. *Food Sci Eng Res*. 2025;4:29–36. [DOI]
12. Ainehvand S, Raeissi P, Ravaghi H, Maleki M. The characteristic features of emergency food in national level natural disaster response programs: A qualitative study. *J Educ Health Promot*. 2019;8:58. [DOI] [PubMed] [PMC]
13. Pradhan PM, Dhital R, Subhani H. Nutrition interventions for children aged less than 5 years following natural disasters: a systematic review. *BMJ Open*. 2016;6:e011238. [DOI] [PubMed] [PMC]
14. Diatta AA, Abaye O, Battaglia ML, Leme JFDC, Seleiman M, Babur E, et al. Mungbean [*Vigna radiata* (L.) Wilczek] and its potential for crop diversification and sustainable food production in Sub-Saharan Africa: a review. *Technol Agron*. 2024;4:e031. [DOI]
15. Major Vegetables and Root Crops Quarterly Bulletin, April-June 2023 [Internet]. [cited 2026 Mar 28]. Available from: <https://psa.gov.ph/content/major-vegetables-and-root-crops-quarterly-bulletin-april-june-2023-0>

16. Jha UC, Shafi S, Tallury S, Nayyar H, Ciampitti IA, Siddique KHM, et al. Differential physiological and yield responses of selected mung bean (*Vigna radiata* (L.) R. Wilczek) genotypes to various high-temperature stress regimes. *Sci Rep.* 2025;15:1034. [DOI] [PubMed] [PMC]
17. Chauhan S, Kaur H, Aggarwal R, Kaur P, Bains K. Exploring the impact of cooking techniques and storage conditions on resistant starch levels in mung beans and its effect upon blood glucose level and lipid profile in vivo. *Front Nutr.* 2024;11:1424112. [DOI]
18. Bunaka A, Bibiso M, Lelago A. Determination of levels of essential and non-essential metals and nutritional value in mung bean seed (*Vigna radiata* L.) cultivated in wolaita zone, southern Ethiopia. *Indian J Agric Res.* 2023;57:198–202. [DOI]
19. Wang F, Huang L, Yuan X, Zhang X, Guo L, Xue C, et al. Nutritional, phytochemical and antioxidant properties of 24 mung bean (*Vigna radiata* L.) genotypes. *Food Prod Process and Nutr.* 2021;3:28. [DOI]
20. Hou D, Yousaf L, Xue Y, Hu J, Wu J, Hu X, et al. Mung Bean (*Vigna radiata* L.): Bioactive Polyphenols, Polysaccharides, Peptides, and Health Benefits. *Nutrients.* 2019;11:1238. [DOI] [PubMed] [PMC]
21. Zafar SH, Umair M, Akhtar M. Nutritional evaluation, proximate and chemical composition of mungbean varieties/cultivars pertaining to food quality characterization. *Food Chem Adv.* 2023;2: 100160. [DOI]
22. Nasir M, Sidhu JS, Sogi DS. Processing and nutritional profile of mung bean, black gram, pigeon pea, lupin, moth bean, and Indian vetch. In: Siddiq M, Uebersax MA, editors. *Dry beans and pulses: Production, processing, and nutrition.* John Wiley & Sons Ltd.; 2022. pp. 431–52.
23. Liapis A, Bruttini R. Freeze Drying. *Handb Ind Dry.* 2014;259–82. [DOI]
24. Nowak D, Jakubczyk E. The Freeze-Drying of Foods-The Characteristic of the Process Course and the Effect of Its Parameters on the Physical Properties of Food Materials. *Foods.* 2020;9:1488. [DOI] [PubMed] [PMC]
25. Bernardino M, Caisip A, Napata SM. Navigating the adoption of plant-based diet in the Philippines: insights into consumer enablers and barriers. *Explor Foods Foodomics.* 2026;4:1010110. [DOI]
26. Calculating Drying and Reconstitution Ratios for Optimal Food Preservation [Internet]. *Agriculture Notes by Agriculture.Institute*; c2026 [cited 2026 Apr 10]. Available from: <https://agriculture.institute/food-processing-and-engineering-ii/calculating-drying-reconstitution-ratios-food-preservation/>
27. Menu Eval Plus [Internet]. Taguig: Food and Nutrition Research Institute; c2020 [cited 2026 Mar 28]. Available from: <https://i.fnri.dost.gov.ph/login/menueval>
28. Salfinger Y, Tortorello ML, editors. *Compendium of methods for the microbiological examination of foods.* American Public Health Association; 2015.
29. Latimer GW Jr, editor. *Official Methods of Analysis of AOAC INTERNATIONAL (22nd Edition).* New York: AOAC Publications; 2023.
30. Gatchalian MM, Brannan GD, MacFie HJH. *Sensory quality measurement: statistical analysis of human responses.* Quezon: Quality Partner Company; 2009.
31. FDA Circular No.2022-012 || Guidelines on the Microbiological Requirements and Assessment of Certain Prepackaged Processed Food Products Repealing FDA Circular No. 2013-010 entitled “Revised Guidelines for the Assessment of Microbiological Quality of Processed Foods” [Internet]. c2026 [cited 2026 Mar 28]. Available from: <https://www.fda.gov.ph/fda-circular-no-2022-012-guidelines-on-the-microbiological-requirements-and-assessment-of-certain-prepackaged-processed-food-products-repealing-fda-circular-no-2013-010-entitled-revised-g/>
32. Tapia MS, Alzamora SM, Chirife J. Effects of Water Activity (a_w) on Microbial Stability as a Hurdle in Food Preservation. In: Barbosa-Cánovas GV, Fontana Jr AJ, Schmidt SJ, Labuza TP, editors. *Water Activity in Foods.* 2020. pp. 323–55.

33. Bhatta S, Stevanovic Janezic T, Ratti C. Freeze-drying of plant-based foods. *Foods*. 2020;9:87. [DOI]
34. Wang D, Zhang M, Ju R, Mujumdar AS, Yu D. Novel drying techniques for controlling microbial contamination in fresh food: A review. *Dry Technol*. 2023;41:172–89. [DOI]
35. la Gatta B, Liberatore MT, Dilucia F, Rutigliano M, Baiano A, Di Luccia A, et al. Study of Ready-to-eat Omelette enriched with dried and freeze-dried vegetables. *Food Biosci*. 2024;62:105025. [DOI]
36. Alp D, Bulantekin Ö. The microbiological quality of various foods dried by applying different drying methods: a review. *Eur Food Res Technol*. 2021;247:1333–43. [DOI]
37. Amaral RA, Pinto CA, Lima V, Tavares J, Martins AP, Fidalgo LG, et al. Chemical-Based Methodologies to Extend the Shelf Life of Fresh Fish—A Review. *Foods*. 2021;10:2300. [DOI]
38. Onyeaka H, Nwabor O, Jang S, Obileke K, Hart A, Anumudu C, et al. Sous vide processing: a viable approach for the assurance of microbial food safety. *J Sci Food Agric*. 2022;102:3503–12. [DOI]
39. Akther F, Alim MA, Nasrin NA, Khan M, Gomes DN, Suhan M, et al. Effects of different drying methods on the proximate composition, antioxidant activity, and phytochemical content of *Hibiscus sabdariffa* L. Calyx. *Food Chem Adv*. 2023;3:100553. [DOI]
40. Bui LTT, Coad RA, Stanley RA. Properties of rehydrated freeze dried rice as a function of processing treatments. *LWT*. 2018;91:143–50. [DOI]
41. Mohammadi X, Deng Y, Matinfar G, Singh A, Mandal R, Pratap-Singh A. Impact of Three Different Dehydration Methods on Nutritional Values and Sensory Quality of Dried Broccoli, Oranges, and Carrots. *Foods*. 2020;9:1464. [DOI] [PubMed] [PMC]
42. Philippine Dietary Reference Intakes (PDRI) [Internet]. [cited 2026 Mar 28]. Available from: <https://www.fnri.dost.gov.ph/index.php/tools-and-standard/philippine-dietary-reference-intakes-pdri>
43. Malaluan IN, Aytona GL, Peregrino JD, Malonzo CA. Nutritional Analysis of Bicol Region’s Smoked Round Scad (*Decapterus macrosoma*) and Pinangat Products. *BU R&D J*. 2018;21:1–9. [DOI]
44. Wang D, Xiao H, Lyu X, Chen H, Wei F. Lipid oxidation in food science and nutritional health: A comprehensive review. *Oil Crop Sci*. 2023;8:35–44. [DOI]
45. Paul T, Adejumo BA, Nwakuba NR, Ehiem JC. Proximate Composition of Packaged Freeze-Dried Cheeses in Storage. *AgricEngInt CIGR J*. 2021;23:264–72.
46. Mohd Ab Azid S, Safuan S, Wichienhot S, Wan Rosli WI. Nutritional composition and prebiotic properties of freeze-dried selected cucurbit plants as potential functional food ingredients. *Int Food Res J*. 2024;31:56–66. [DOI]
47. Chen W, Chiu HT, Feng Z, Maes E, Serventi L. Effect of spray-drying and freeze-drying on the composition, physical properties, and sensory quality of pea processing water (*Liluva*). *Foods*. 2021;10:1401. [DOI] [PubMed] [PMC]
48. Wentworth C. Unhealthy aid: Food security programming and disaster responses to Cyclone Pam in Vanuatu. *Anthropological Forum*. 2020;30:73–90. [DOI]
49. Food and Nutrition Research Institute [Internet]. [cited 2026 Mar 28]. Available from: <https://fnri.dost.gov.ph>
50. Saleem M, Tahir A, Ahmed M, Khan A, Burak LC, Hussain S, et al. Development of functional yogurt by using freeze-drying on soybean and mung bean peel powders. *Front Sustain Food Syst*. 2023;7:1083389. [DOI]
51. Archaina D, Rivero R, Sosa N, Schebor C. Sensory, physicochemical, and functional stability of freeze-dried blackcurrant (*Ribes nigrum* L.) Snacks. Effect of sweeteners. *Food Sci Technol Int*. 2024;30:583–91. [DOI] [PubMed]
52. Uscanga MA, Salvador A, Camacho MD, Martinez-Navarrete N. Impact of freeze-drying shelf temperature on the bioactive compounds, physical properties and sensory evaluation of a product based on orange juice. *Int J Food Sci Biotechnol*. 2021;56:5409–16. [DOI]

53. Silva-Espinoza MA, Salvador A, Camacho MDM, Martínez-Navarrete N. Impact of freeze-drying conditions on the sensory perception of a freeze-dried orange snack. *J Sci Food Agric.* 2021;101:4585–90. [DOI] [PubMed]
54. Kamanova S, Temirova I, Aldiyeva A, Yermekov Y, Toimbayeva D, Murat L, et al. Effects of freeze-drying on sensory characteristics and nutrient composition in black currant and sea buckthorn berries. *Appl Sci.* 2023;13:12709. [DOI]