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## A protein-enriched rice product from Kum Doi Saket rice, and locally sourced nutrient-rich grains from Northern Thailand

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### Abstract

Rice, recognized as a primary source of carbohydrates, is associated with a high glycemic index, potentially elevating the risk of various diseases, including obesity and diabetes. This research aims to develop a fortified extruded rice product from the low-value broken grain Kam Doi Saket rice through the enrichment of protein and phenolic compounds by the addition of Lablab beans and perilla seeds. In the experiments, the proportion of Lablab bean powder was varied at ratios of 0%, 15%, 35%, and 55%, and the best formula from the initial experiments was used to adjust the quantity of perilla seeds at ratios of 0%, 1%, 3%, and 5%. Results revealed that an increase in the proportion of Lablab beans in the product led to increase protein content, increased levels of total phenolic compounds, and enhanced antioxidant capacities in the fortified rice product. In terms of texture, this formula exhibited the highest hardness values, while cohesiveness, adhesiveness, and chewiness values were comparatively lower than those of other formulas. Moreover, the outcomes of the perilla seed application indicated that the recipe employing Kam Doi Saket rice, Lablab beans, and perilla seeds in a ratio of 42:55:3 resulted in a protein content of 17.02%, total phenolic compounds measuring 0.44 mg GAE/g, an antioxidant capacity percentage of 0.19 mgTE/g, and an overall acceptance sensory score of 5.70. In conclusion, it was determined from the experiments that Lablab beans and perilla seeds can serve as suitable raw materials for the production of protein-fortified rice products from broken Kam Doi Saket Rice.

**Keywords:** Protein-enriched rice; *Lablab purpureus* L.; *Perilla frutescens* L.; Fortified rice grain; Antioxidant activity

## 1. Introduction

Rice (*Oryza sativa* L.) is a staple food highly favored by Thai people, characterized by its carbohydrate content and high glycemic index, which, if consumed regularly, can increase the risk of diseases such as diabetes, obesity, stroke, and heart disease, as well as the accumulation of excess fat (Zheng *et al.*, 2020). Due to these concerns, there is a growing emphasis on health in the present day. Consequently, products like shaped rice fortified with protein have been developed using broken Kam Doi Saket rice. This particular rice variety contains interesting antioxidant compounds, including anthocyanins and gamma oryzanol. Anthocyanins possess antioxidant properties that can prevent oxidative reactions, thus aiding in the prevention of high blood pressure, blood clot formation, reduced inflammation of wounds, and diabetes (Leslie *et al.*, 2023). Gamma oryzanol, on the other hand, exhibits antioxidant properties, reduces cholesterol levels in the blood, increases insulin levels in the blood of individuals with diabetes and reduces the risk of heart disease (Sugihara *et al.*, 1999). However, despite the nutritional benefits of Kam Doi Saket broken rice, it is currently cultivated in relatively small quantities due to its average yield of only 360 to 500 kilograms per hectare. During milling process, the broken rice grain is considered as a waste from the process. The broken rice can be a promising raw material utilized for produce an alternative rice product to increase the value of the waste from milling process. Furthermore, nutritional value is enhanced by increasing protein content, achieved by incorporating Lablab beans (*Dolichos lablab* L.), which contain a high protein content of up to 20-25%, as well as being a source of B vitamins, minerals and dietary fiber. Additionally, Lablab beans have a low glycemic index and contribute to reducing cholesterol levels (Kim and Chung, 2008). Perilla seed (*Perilla frutescens* L.) rich in antioxidants, which consist of phenolic and flavonoid compounds that nourish the heart and blood vessels, reduce blood cholesterol, and enhance the nervous and brain systems (Dhyani *et al.*, 2019). Therefore, the objective of this research is to study the physical and chemical properties of shaped Kam Doi Saket rice and increase its nutritional value by incorporating Lablab beans and perilla seeds.

## 2. Materials and Methods

### 2.1 Sample preparation

Rice harvested from the Doi Saket Research Center for Highland Rice, Chiang Mai University. The broken rice grain was collected and ground into a consistent powder and sieved through a 50-mesh. Lablab bean grown in Fang, Chiang Mai, were soaked in water at the ratio 1:20 w/v for one hour. Afterward, the beans were peeled and dried using a Hot Air Oven at 70°C for 1 h. The dried beans were also finely ground and sieved through a 50-mesh. Finally, the three ingredients were packed in a tightly sealed aluminum foil bag until used.

## 2.2 Formulation of protein-fortified rice grain

Lablab bean flour is used to replace Doi Saket rice grain flour. The quantities of Lablab bean flour varied at four levels: 0%, 15%, 35% and 55% by weight, as indicated in Table 1. The Lablab bean flour was mixed with Doi Saket rice grain flour and 140 grams water until it forms a consistent texture. The mixture is then placed in an extruded pasta machine with a round rice shape mode. Subsequently, the grains were dried in a Hot Air Oven at 70°C for 1 h.

**Table 1** Formulation of protein-enriched rice grain compute with Doi Saket Rice flour and Lablab bean flour

Sample	Doi Saket Rice Flour (%)	Lablab bean flour (%)
Control	100	0
L15	85	15
L35	65	35
L55	45	55

Samples of protein-enriched rice products are finely ground using a grinder, specifically a blender grinder. They are then packed in a tightly sealed plastic bag for use in the subsequent analysis. The treatment contained higher protein content and received the highest sensory acceptance score will be selected for further development.

## 2.3 Formulation of perilla seed-enriched in protein-fortified rice grain

Perilla seed flour was used to replace Doi Saket rice grain starch. The quantities of perilla seed flour was varied at four levels: 0%, 1%, 3% and 5% by weight, as indicated in Table 2. The sesame seeds are mixed with Doi Saket rice grain starch, pea starch, and boiling water (140 grams) until a consistent texture is achieved. The mixture is then placed in a noodle-making machine with a flat rectangular mold. The resulting noodles are cut into individual grains of rice. Subsequently, they are dried in a Hot Air Oven at 70°C for 1 h.

**Table 2** Formulation of protein-enriched rice grain compute with Doi Saket Rice flour, Lablab bean flour and perilla seed

Sample	Doi Saket Rice Flour (%)	Lablab bean flour (%)	Perilla seed (%)
Control	45	55	0
PS1	44	55	1
PS3	42	55	3
PS5	40	55	5

## 2.4 Preparation of cooked sample

The protein-enriched rice products are cooked using a steamer at 100°C. The procedure involves boiling water until it reaches a temperature of 100. The protein-enriched rice products are evenly spread over a steaming tray, steaming the sample until fully cooked. The cooking time depends on the rice flour to Lablab bean flour ratio, with 100% rice starch taking 10 min, 85% rice and 15% pea starch taking 12 min, 65% rice and 35% pea starch taking 17 min, and 45% rice and 55% pea starch taking 65 min.

## 2.5 Analysis

### 2.5.1 Color

Color of raw and cooked samples was measured using a Colorimeter CR-400 (Konica Minolta Inc, Osaka, Japan), reported as color values L\*, a\* and b\*.

### 2.5.2 Texture Analysis

Texture of raw and cooked samples was measured using Texture Analyzer (TA-XT2) (Stable micro system, Surrey, UK)

#### 1) Raw sample

The hardness of the protein-enriched rice products is measured using a cylinder probe with a 35mm diameter (p/35).

#### 2) Cooked sample

Hardness, cohesiveness, adhesiveness, and chewiness of the protein-enriched rice products are measured using the same 35mm diameter cylinder probe (p/35). Test parameters are set as follows: Pre-Test Speed 0.5 mm/s, Test Speed 0.5 mm/s, Post-Test Speed 2.00 mm/s, Strain 90%, Time 5.00 s, Trigger Force (auto) 5 grams, following the method of Tao *et al.* (2019).

### 2.5.3 Chemical Composition

Chemical composition analysis includes moisture, ash, protein, and fat content following AOAC (2000) methods. The analysis of total polyphenols is conducted using a Folin-Ciocalteu reagent modified version of (Singleton *et al.*, 1999). The ability to act as an antioxidant is assessed using the DPPH radical scavenging activity method, which is a modified version of the method by Brand-Williams *et al.* (1995).

### 2.5.4 Sensory Quality Assessment:

A sensory evaluation is conducted with a general panel consisting of 50 untrained participants to assess the sensory characteristics, including appearance, color, aroma, taste, texture, and overall preference. The 9-point hedonic scale is used for scoring, where 1 = "dislike extremely" and 9 = "like extremely."

### 2.5.5 Statistical Analysis:

For the experimental design, a Completely Randomized Design (CRD) is used, and for the sensory evaluation, a Randomized Complete Block Design (RCBD) is employed. Data analysis is conducted using the SPSS computer program with a one-way ANOVA method to compare the means. The differences in the means are evaluated using Duncan's new multiple-range test (DMRT) at a statistical confidence level of 95%.

### 3. Results and Discussion

#### 3.1 Effect of Lablab bean flour on the physicochemical properties and sensory evaluation of protein-enriched rice product

From the study of the color analysis results of protein-enriched rice products with varying proportions of Doi Saket rice flour and Lablab bean flour, as shown in Table 3. It was observed that the  $L^*$ ,  $a^*$ , and  $b^*$  values of the protein-enriched rice products at all ratios were significantly different ( $P < 0.05$ ). Specifically, the  $L^*$  value of protein-enriched rice products before cooking increases when the amount of Lablab bean flour was increased. In other words, the protein-enriched rice products become brighter compared with the control. Meanwhile, different amount of Lablab bean flour added showed non-significant differences in protein-enriched rice grain ( $P > 0.05$ ). In the cooked products, the  $L^*$  values tend to decrease. For the  $a^*$  value of protein-enriched rice products before cooking, there was a trend of decrease when the amount of Lablab bean flour increased. However,  $b^*$  value increases when the amount of Lablab bean flour was increased and the amount of rice flour decreased. This means that the protein-enriched rice products become more yellow. This effect may be due to pigments in the Lablab bean flour added enhance the yellowish of the product.

**Table 3** Color value of raw and cooked protein-enriched rice product

Sample	Raw grains			Cooked grains		
	$L^*$	$a^*$	$b^*$	$L^*$	$a^*$	$b^*$
Control	56.42 ± 0.30 <sup>b</sup>	8.97 ± 0.27 <sup>a</sup>	3.45 ± 0.19 <sup>d</sup>	51.32 ± 2.29 <sup>b</sup>	15.05 ± 0.34 <sup>a</sup>	6.92 ± 0.21 <sup>d</sup>
L15	57.86 ± 1.41 <sup>a</sup>	7.60 ± 0.17 <sup>b</sup>	6.65 ± 0.20 <sup>c</sup>	50.82 ± 0.07 <sup>b</sup>	9.15 ± 0.03 <sup>b</sup>	7.42 ± 0.04 <sup>c</sup>
L35	58.30 ± 1.11 <sup>a</sup>	7.19 ± 0.15 <sup>c</sup>	8.93 ± 0.16 <sup>b</sup>	52.32 ± 0.20 <sup>b</sup>	9.16 ± 0.17 <sup>b</sup>	10.72 ± 0.05 <sup>b</sup>
L55	57.86 ± 1.02 <sup>a</sup>	5.90 ± 0.14 <sup>d</sup>	12.32 ± 0.17 <sup>a</sup>	54.46 ± 0.44 <sup>a</sup>	9.18 ± 0.22 <sup>b</sup>	13.86 ± 0.24 <sup>a</sup>

Note: a-d shows significant difference between samples ( $P \leq 0.05$ ).

From the study of texture characteristics of protein-enriched rice products with varying proportions of Doi Saket rice flour and Lablab bean flour, as shown in Table 4. It was observed that the hardness values, both before and after cooking, tend to increase. This increase of the hardness might due to the addition of Lablab bean flour, as the replacement of rice flour in the formulation with high protein bean flour induce the protein-amylose network which helps to strengthen the structural integrity in the protein-enriched rice products (Li *et al.*, 2023).

**Table 4** Texture profile of raw and cooked protein-enriched rice product.

11	Raw grains		Cooked grains		
	Hardness (g)	Hardness (g)	Cohesiveness	Adhesiveness (g·sec)	Chewiness
Control	9416.98 ± 625.97 <sup>c</sup>	2799.07 ± 644.97 <sup>b</sup>	0.61 ± 0.09 <sup>a</sup>	121.96 ± 68.04 <sup>a</sup>	40.85 ± 25.98 <sup>c</sup>
L15	11469.03 ± 878.44 <sup>b</sup>	2949.89 ± 607.37 <sup>b</sup>	0.57 ± 0.10 <sup>a</sup>	197.02 ± 74.86 <sup>b</sup>	43.55 ± 3.83 <sup>b</sup>
L35	11995.78 ± 1558.48 <sup>ab</sup>	2901.02 ± 882.33 <sup>b</sup>	0.55 ± 0.07 <sup>a</sup>	174.65 ± 89.71 <sup>ab</sup>	51.62 ± 5.51 <sup>a</sup>
L55	12388.23 ± 546.53 <sup>a</sup>	3812.05 ± 779.03 <sup>a</sup>	0.41 ± 0.04 <sup>b</sup>	126.89 ± 68.23 <sup>ab</sup>	43.90 ± 3.76 <sup>b</sup>

Note: a-c shows significant difference between samples ( $P \leq 0.05$ ).

After cooking, it was found that the cohesiveness, adhesiveness, and chewiness value the protein-enriched rice products decreased when reduced the amount of rice flour in the formulation. This is because amylopectin content in Doi Saket rice flour is responsible for the sticky and soft texture of cooked rice product (Karladee *et al.*, 2012). Therefore, reducing the amount of Doi Saket rice flour leads to a decrease in the stickiness and softness of the protein-enriched rice products. Additionally, it also results in a lower sensory score for the aspect of stickiness of the cooked protein-enriched rice product.

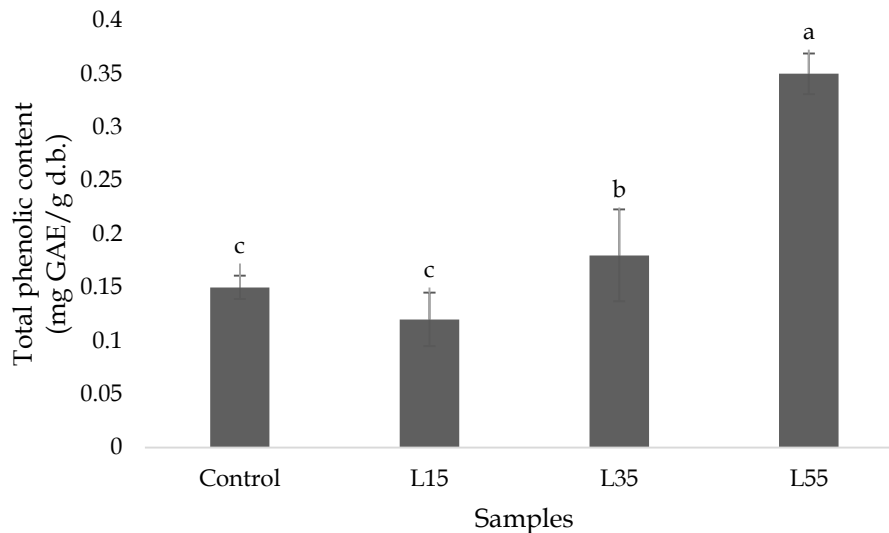
The chemical composition of protein-enriched rice products, as shown in Table 5, it is evident that increasing the amount of Lablab bean flour correlated to higher protein content in the protein-enriched rice product. Following that total protein content in the protein-enriched rice in the formulation of 15%, 35%, and 55% Lablab bean flour were 17.08%, 14.71%, and 12.54%, respectively. This means that increasing the amount of soybean paste in the product results in a higher protein content.

**Table 5** Chemical composition of raw protein-enriched rice product.

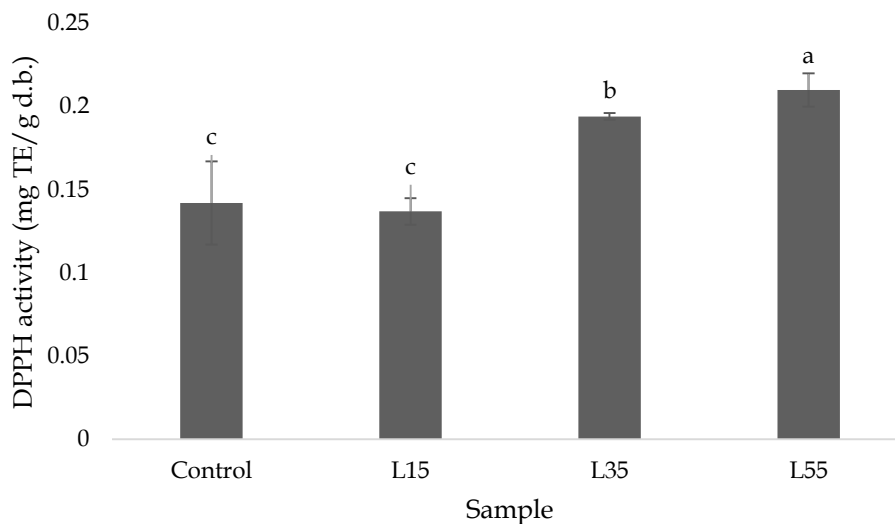
Sample	Chemical composition (% d.b.)				
	Protein	Lipid	Carbohydrate	Moisture	Ash
Control	10.84 ± 0.04 <sup>d</sup>	0.10 ± 0.01 <sup>a</sup>	80.59 ± 0.21 <sup>a</sup>	7.67 ± 0.04 <sup>d</sup>	0.80 ± 0.09 <sup>c</sup>
L15	12.54 ± 0.14 <sup>c</sup>	0.04 ± 0.01 <sup>b</sup>	77.37 ± 0.52 <sup>b</sup>	9.05 ± 0.04 <sup>c</sup>	1.09 ± 0.08 <sup>c</sup>
L35	14.71 ± 0.08 <sup>b</sup>	0.04 ± 0.04 <sup>b</sup>	74.34 ± 0.34 <sup>c</sup>	9.23 ± 0.01 <sup>b</sup>	1.68 ± 0.04 <sup>b</sup>
L55	17.08 ± 0.03 <sup>a</sup>	0.06 ± 0.03 <sup>b</sup>	70.29 ± 0.12 <sup>d</sup>	10.08 ± 0.02 <sup>a</sup>	2.49 ± 0.15 <sup>a</sup>

**Note:** a-d shows significant difference between samples ( $P \leq 0.05$ ).

Analyzing the quantities of total phenolic content and the antioxidant activity of the protein-enriched rice products, found that the protein-enriched rice fortified with 55% Lablab bean flour had the highest total phenolic content and DPPH activity at 0.35 mg TE/g and 0.14 mg GAE/g ( $P < 0.05$ ) (Fig 1). This is consistent indicated that increasing the amount of Lablab bean flour leads to higher levels of antioxidants, due to the consist of polyphenol content as tannin in Lablab bean at 1.8 g GAE/100g (Maheshu *et al.*, 2013) Therefore, increasing the amount of Lablab bean flour in the product increases the antioxidant content of the protein-enriched rice product.



(A)



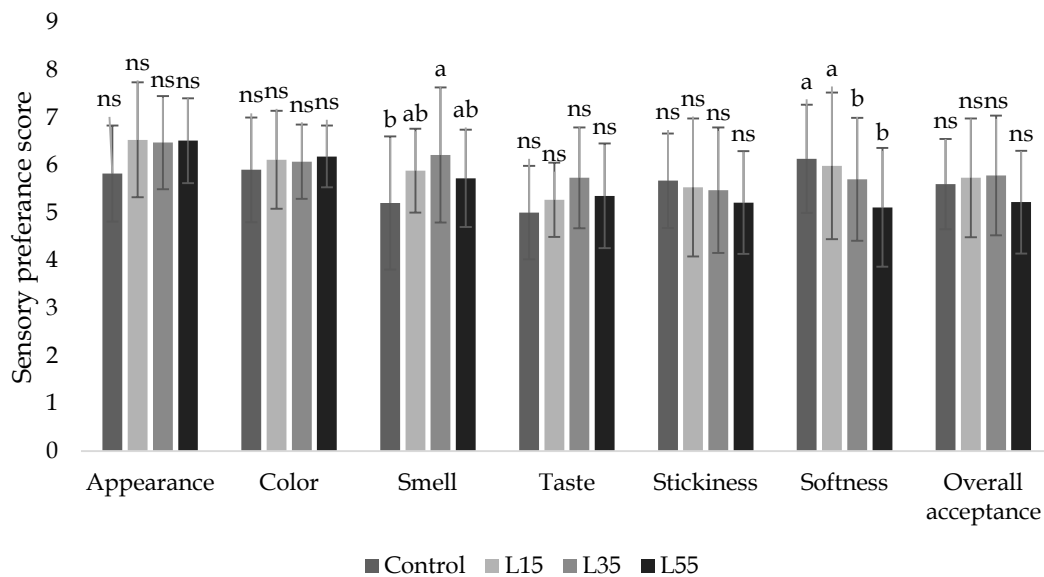
(B)

**Fig 1** Total phenolic content (A) and DPPH activity (B) of protein-enriched rice product.

**Note:** a-d shows significant difference between samples ( $P \leq 0.05$ ).

From Fig 2, the average characteristics of the protein-enriched rice product with Lablab bean flour added showed statistically significant differences in appearance, color, and stickiness ( $P < 0.05$ ). Specifically, the scores for appearance increased with an increase in the high value of Lablab bean flour added. Conversely, the scores for color and stickiness decreased with increasing Lablab bean flour content. As for the attributes of aroma, taste, and tenderness, the acceptance score for all formulations with no statistically significant differences ( $P > 0.05$ ). Overall liking score for all formulations were in the moderate range, with a score of 5. Therefore, the protein-fortified rice with 55% Lablab bean flour was selected for further development by adding perilla seed to increase the quantity of important antioxidants and all phenolic

compounds. Subsequently, a physical, chemical, and sensory analysis was conducted, as described in the following sections.



**Fig 2** Sensory evaluation score of protein-enriched rice product.

Note: a-b shows significant difference between samples ( $P \leq 0.05$ ). ns shows non-significant different between samples ( $P > 0.05$ ).

### 3.2 Effect of perilla seed on the physicochemical properties and sensory evaluation of protein-enriched perilla seed fortified rice product.

The optimal condition of protein-enrichment rice grain with Lablab bean was used as a base formular to fortify with perilla seed to increase total phenolic and antioxidant activity of the fortified rice product. After studying the color analysis of protein-enriched perilla seed fortified rice products with varying proportions of perilla seed as shown in Table 6. It was found that the  $L^*$ ,  $a^*$ , and  $b^*$  values of protein-enriched perilla seed fortified rice products at all proportions differed significantly from each other statistically ( $P < 0.05$ ), except for the  $a^*$  value in all proportions of the protein-enriched perilla seed fortified rice products before cooking, which did not differ significantly ( $P > 0.05$ ). The  $a^*$  value tends to decrease after cooking, while the  $L^*$  value of the products before cooking decreased when the quantity of perilla seed increased. In other words, protein-enriched perilla seed fortified rice products became less bright with an increase in perilla seed quantity. When all products were cooked, it was observed that the  $L^*$  value increased, possibly due to the cooking process causing the removal of pigments present in the rice grains in the boiling water. The  $b^*$  value before cooking tended to increase, meaning that protein-enriched perilla seed fortified rice products had a more yellow color. However, the  $b^*$  value decreased after cooked.

**Table 6** Color value of raw and cooked protein-enriched perilla seed fortified rice products

Sample	Raw grains			Cooked grains		
	<i>L</i> *	<i>a</i> *	<i>b</i> *	<i>L</i> *	<i>a</i> *	<i>b</i> *
Control	57.86 ± 1.02 <sup>a</sup>	5.90 ± 0.14 <sup>ns</sup>	12.32 ± 0.17 <sup>d</sup>	60.64 ± 0.08 <sup>a</sup>	5.65 ± 0.19 <sup>a</sup>	9.86 ± 0.34 <sup>d</sup>
PS1	55.64 ± 0.12 <sup>b</sup>	6.00 ± 0.23 <sup>ns</sup>	14.76 ± 0.26 <sup>c</sup>	60.70 ± 0.21 <sup>a</sup>	4.92 ± 0.24 <sup>b</sup>	10.92 ± 0.19 <sup>c</sup>
PS3	52.10 ± 1.00 <sup>c</sup>	6.10 ± 0.20 <sup>ns</sup>	15.39 ± 0.43 <sup>b</sup>	58.03 ± 1.07 <sup>b</sup>	5.62 ± 0.23 <sup>a</sup>	12.30 ± 0.40 <sup>a</sup>
PS5	51.27 ± 1.74 <sup>c</sup>	5.85 ± 0.24 <sup>ns</sup>	16.70 ± 0.36 <sup>a</sup>	58.21 ± 0.96 <sup>b</sup>	4.28 ± 0.22 <sup>c</sup>	11.45 ± 0.57 <sup>b</sup>

**Note:** a-d shows significant difference between samples ( $P \leq 0.05$ ). ns shows non-significant different between samples ( $P > 0.05$ ).

The study of the texture characteristics of protein-enriched perilla seed fortified rice products with various proportions of perilla seed, as shown in Table 7. The hardness values before cooking tended to decrease, primarily due to an increase in the quantity of perilla seed. This can be attributed to the larger particle size and high fat content of perilla seed, which do not dissolve in water and remain suspended in the protein matrix, leading to a less robust internal structure of the product. As a result, protein-enriched perilla seed fortified rice products became brittle, similar to the findings in the study of the effects of rice bran particle size on the texture characteristics of rice noodles (Zhang *et al.*, 2019).

After cooking the protein-enriched perilla seed fortified rice products, was observed that the hardness values tended to increase. This is a contrasting trend compared to cohesiveness, adhesiveness, and chewiness, which tended to decrease. The increase in hardness after cooking could be related to the gelatinization of starch and other structural changes during the cooking process. Furthermore, the increased hardness of the product also resulted in a reduction in sensory scores related to the product's softness, as depicted in Fig 2.

**Table 7** Texture profile of raw and cooked protein-enriched perilla seed fortified rice products

Sample	Raw grains		Cooked grains		
	Hardness (g)	Hardness (g)	Cohesiveness	Adhesiveness (g·sec)	Chewiness
Control	11872.06 ± 353.46 <sup>a</sup>	278.39 ± 19.11 <sup>c</sup>	0.61 ± 0.09 <sup>a</sup>	59.58 ± 2.16 <sup>a</sup>	40.60 ± 1.69 <sup>c</sup>
PS1	10838.11 ± 240.50 <sup>b</sup>	301.33 ± 31.02 <sup>bc</sup>	0.57 ± 0.10 <sup>a</sup>	66.29 ± 9.19 <sup>b</sup>	42.55 ± 6.18 <sup>b</sup>
PS3	9835.67 ± 350.06 <sup>c</sup>	354.32 ± 28.35 <sup>b</sup>	0.55 ± 0.07 <sup>a</sup>	60.96 ± 2.20 <sup>ab</sup>	45.43 ± 2.51 <sup>a</sup>
PS5	9295.81 ± 486.18 <sup>d</sup>	453.9 ± 22.48 <sup>a</sup>	0.41 ± 0.04 <sup>b</sup>	86.52 ± 4.04 <sup>ab</sup>	42.08 ± 4.07 <sup>b</sup>

**Note:** a-d shows significant difference between samples ( $P \leq 0.05$ ).

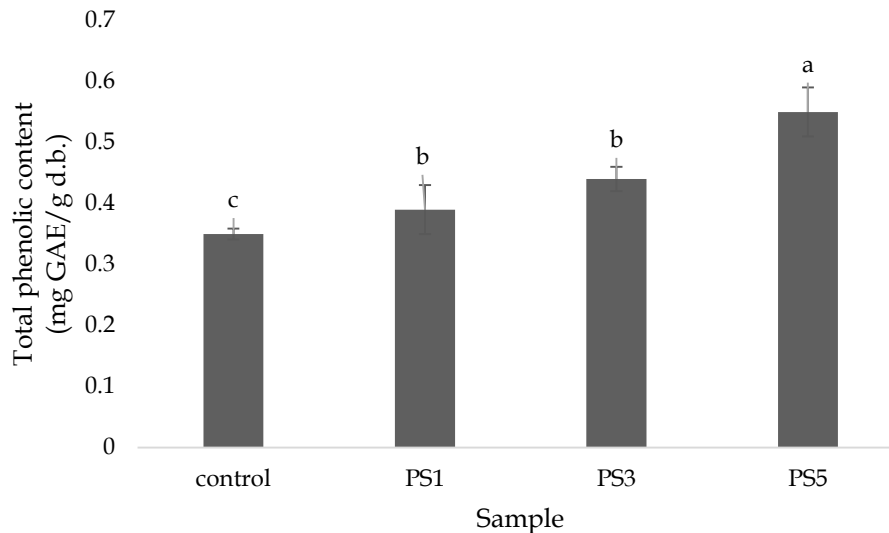
From the study of the chemical composition analysis of the fortified rice products, as shown in Table 8, it can be observed that all four formulations of fortified rice products have statistically similar protein and ash content ( $P > 0.05$ ). The protein content ranges from 16.83 to 17.08, while the fat content ranges from 0.06 to 0.42. Increasing of these protein and lipid corresponded to the increase in perilla seed concentration. In terms of fat content, there is a trend of increase with the addition of perilla seed, as perilla seed is known to have a high fat content of up to 42.27% (Sargi *et al.*, 2013).

**Table 8** Chemical composition of protein-enriched perilla seed fortified rice products.

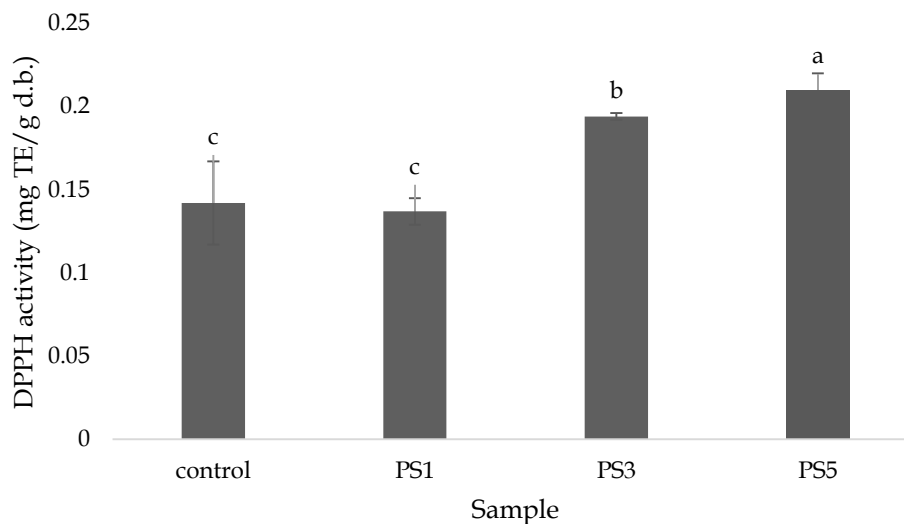
Sample	Chemical composition (% d.b.)				
	Protein	Lipid	Carbohydrate	Moisture	Ash
Control	17.08 ± 0.03 <sup>ns</sup>	0.06 ± 0.03 <sup>d</sup>	70.59 ± 0.11 <sup>ns</sup>	10.08 ± 0.02 <sup>c</sup>	2.49 ± 0.05 <sup>ns</sup>
PS1	16.83 ± 0.25 <sup>ns</sup>	0.19 ± 0.01 <sup>c</sup>	69.49 ± 0.49 <sup>ns</sup>	11.14 ± 0.01 <sup>a</sup>	2.35 ± 0.03 <sup>ns</sup>
PS3	17.02 ± 0.01 <sup>ns</sup>	0.34 ± 0.02 <sup>b</sup>	71.03 ± 0.21 <sup>ns</sup>	9.20 ± 0.10 <sup>d</sup>	2.41 ± 0.02 <sup>ns</sup>
PS5	17.05 ± 0.26 <sup>ns</sup>	0.42 ± 0.01 <sup>a</sup>	69.77 ± 0.23 <sup>ns</sup>	10.27 ± 0.03 <sup>b</sup>	2.49 ± 0.09 <sup>ns</sup>

**Note:** a-d shows significant difference between samples ( $P \leq 0.05$ ). ns shows non-significant different between samples ( $P > 0.05$ ).

Furthermore, the analysis of total phenolic content and antioxidant activity in the fortified rice products revealed significant differences in the DPPH values ( $P < 0.05$ ) for all formulations. It can be observed from the table that the formulation with 5% perilla seed has the highest DPPH activity, as perilla contains significant components with an antioxidant activity of 2.54 mmol TEAC/g (Sargi *et al.*, 2013). Therefore, the addition of perilla seed increases the antioxidant content in the fortified rice products. Regarding the total phenolic compounds, all formulations of fortified rice products also significantly differ ( $P < 0.05$ ), with the 5% perilla seed formulation having the highest content. This is because perilla seed contains a total phenolic compound content of 2954 mg GAE/g (Kongkeaw *et al.*, 2015). Therefore, the addition of perilla seed increases the total phenolic compound content in the protein-enriched perilla seed fortified rice products.



(A)

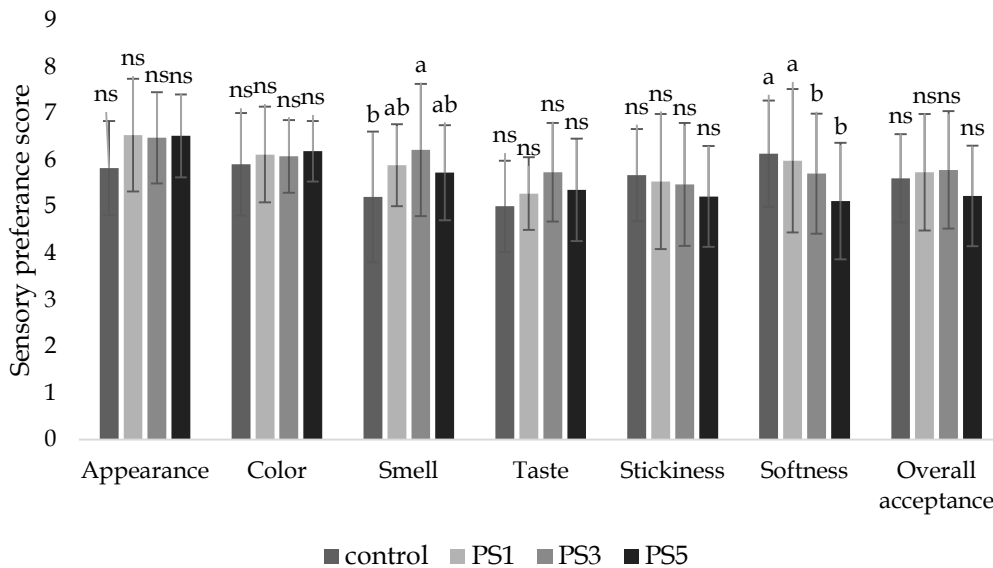


(b)

**Fig 2** Total phenolic content (A) and DPPH activity (B) of protein-enriched perilla seed fortified rice products.

**Note:** a-c shows significant difference between samples ( $P \leq 0.05$ ).

The sensory evaluation score From Fig 3, the average scores for the sensory characteristics of the rice-based protein-fortified products were analyzed. The sensory scores for odor and softness among the different formulations were found statistically significant differences ( $P < 0.05$ ). In contrast, attributes such as appearance, taste, and stickiness did not exhibit significant differences in the acceptance scores assigned by the taste testers ( $P > 0.05$ ). Overall likability scores for all formulations were more than the moderate range at 5 (Wichchukit and O'Mahony, 2015). This implies that the formulations with varied proportions of perilla seed were not significantly different from one another, and the panelists did not exhibit a strong preference for any formulation.



**Fig 3** Sensory evaluation score of protein-enriched of protein-enriched perilla seed fortified rice products.

**Note:** a-b shows significant difference between samples ( $P \leq 0.05$ ). ns shows non-significant different between samples ( $P > 0.05$ ).

Based on the sensory evaluation using the 9-point hedonic scale, it is advisable to choose a formulation that includes 3% perilla seed with the overall acceptance score at 5.71. This might be due to the odor scores for formulations with 1%, 3%, and 5% perilla seed, as well as the softness of 1% and 3% perilla seed samples, did not significantly different from each other. This formulation appears to have a higher quantity of important antioxidants and total phenolic compounds when compared to the formulation with 1% perilla seed.

#### 4. Conclusion

Through the development of rice-based protein-fortified products with Doi Saket rice flour and Lablab bean flour, the key observations were the formulation ratio with 45% of Doi Saket rice flour and 55% of Lablab bean flour had the highest protein content at 17.08%, the highest number of antioxidants at 0.14 mg GAE/g, and the highest total phenolic compounds at 0.35 mg GAE/g compared to other formulations. When the above-mentioned formulation was further adjusted with perilla seed. It was found that the formulation with 3% perilla seed had a protein content of 17.02%, higher antioxidant content at 0.19 mg GAE/g, and increased total phenolic compounds at 0.44 mg GAE/g d.b. Therefore, Lablab bean flour and perilla seed have potential to be used and functional ingredient to increase protein content, total phenolic and antioxidant activity of the protein-enriched perilla seed fortified rice products.

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