Effect of Mung Bean on Physicochemical Properties of Waffle Premix Flour and Its Sensory Acceptability

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Abstract. This study aimed to determine the physicochemical properties and sensory perception of waffle instant premix added with mung bean flour. Mung bean flour was included as one of the ingredients, substituting wheat flour in varying proportions starting from 20 to 80%. The results showed that bulking density slightly increased as the percentage of mung bean increased, whereas swelling capacity slightly decreased. Water holding capacity had significantly increased from 17.71% to 68.88%. Meanwhile, water activity and moisture content of instant premix flour decreased from 90.73 to 75.27, 0.59 to 0.44, and 9.14 to 4.29%, respectively. Compared with wheat flour, instant premix containing mung bean had higher values of crude protein content. The darkening was noticeable by the panellist, where both instant premix flour and waffle showed a decreasing tendency for the L* value, while a* and b* increased. Using the Just-About-Right (JAR) scale, it is evident that the weakness of the mung bean waffle is its too little fluffiness, which influenced overall liking the most. Nevertheless, the acceptability sensory evaluation showed high panellist acceptance on overall liking of waffles with 20% mung bean addition with a rating of like moderately, seven on a 9-point hedonic scale. Considering these results, the expansion of the mung bean as a potential ingredient to combat malnutrition can be included to produce an instant premix waffle.

Keywords: Legume, Mung Bean, Premix Flour, Waffle.

1.0 INTRODUCTION

There is growing concern about inadequate nutrition and the burden of childhood malnutrition in many countries. Individuals who rely on plant sources to meet energy requirements have a higher risk of protein energy malnutrition. The role of food processing in developing new, healthy foods or freshly prepared foods that are tasty and acceptable to consumers with high nutritional value and low calorie, salt, and fat content is crucial, particularly in the vast snack market [1]. According to Phongnarisorn at al. [2], waffles and pancakes are popular Western-style breakfast and dessert items in Thai cafes. It is often made using the same flour base used in the waffle and pancake preparation, mainly wheat flour [3, 2]. Waffles are currently among the most popular dessert products due to their convenience and ease of consumption. It typically contains wheat flour, eggs, butter, sugar, milk, emulsifiers,

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preservatives, and flavours [1]. Waffles baked from batters or doughs in indented waffle irons show a raised, cake-like texture. The spacing of the waffle pattern is typically more comprehensive than in wafers [3].

Giau et al. [4] reported that the nutritional composition of the existing waffle consists of moisture content (36.9%), carbohydrate (39.1%), resistant starch (0%), protein (8.6%), lipid (10.4%), fibre (3.5%) and ash (0.4%). According to Mahmoud and Megder [5], baked products have been extensively researched and developed in recent decades by supplementing active ingredients such as dietary fibre, vitamins, minerals, and bioactive compounds to increase their nutritional and therapeutic qualities. The transition from animal-based to plant-based consumption necessitates the development of high-quality plant-based food products, such as meat analogues and dairy replacements. Because of their beneficial functional qualities, these plant-based food items are most commonly made from soy [6]. Food diversification is one tool to eliminate protein-energy malnutrition, and pulses hold the potential for their utilisation in cereal-based products to improve protein quality.

Mung beans (*Vigna radiata*) are small, ovoid-shaped legumes that are green in colour. They contain about 24% protein and are also known as green gramme or golden gramme [7]. Mungbean seeds are typically green, ranging from dark green, light yellow, light green, deep green, bright green, dull green, golden yellow, to mottled yellow depending on genetic makeup and storage circumstances, and have a pale-yellow cotyledon [8]. Mung bean flour contains carbohydrates, oligosaccharides, protein, amino acids, dietary fibre, polyphenols [9], vitamin A, B1, B2, niacin, vitamin C, potassium, phosphorus, and calcium and can be combined with other flours. Thus, using mung beans in food manufacturing could provide consumers with a protein-rich food product [7].

Wheat grains have a low total protein content and are often poor in lysine and other amino acids. Legumes low in methionine can be supplemented with cereal grains high in the amino acid. Making composite flour from various flours such as tubers, grains, legumes, and others will aid in producing nutritious food products. Using composite flour in baked goods would also help reduce total reliance on imported wheat [10]. Thus, the objective of this study is to determine the physicochemical properties of premix flour substituted with different percentages of mung bean and to measure the waffle's physical properties and sensory acceptability.

2.0 Methods

2.1 Raw Materials

All ingredients for waffle premix flour, such as mung bean flour, wheat flour, corn starch, castor sugar, milk powder, vanilla powder, dried egg powder, baking powder, salt, and soda bicarbonate, were purchased from a local market and local ingredients supplier. Chemicals such as sulphuric acid, Kjedahl catalyst tablet (potassium sulphate and selenium), sodium hydroxide, boric acid and hydrochloric acid were analytical grade and purchased from Biotek Abadi Sdn Bhd.

2.2 Preparation of Waffle Premix Flour

The amount of dried ingredients for premix flour is similar for all formulations except the ratio of wheat and mung bean flour. Four levels of mung bean flour (20, 40, 60 and 80%) were substituted for wheat flour to prepare waffle premix flour. A formulation of 100% wheat flour was included as a control sample.

2.3 Preparation of Waffle

A hundred grams (100 g) of waffle premix flour was used to make the waffle batter. About 95 g water and 25 g corn oil were mixed with premix flour using a hand whisker until thoroughly combined. The batter was baked in the waffle maker at 180-190°C for 3-5 minutes to achieve a pattern (grid-like) with deep indentations on both sides. Finally, the waffles were cooled at room temperature before being placed in aluminised aseptic bags, sealed, and kept cool and dry.

2.4 Physicochemical Analysis of Premix Flour Colour

The colour of each waffle premix flour was determined using a chromameter (Spectra Magic N.X., Konica Minolta, Tokyo, Japan). $L*$ (lightness), $a*$ (redness), and $b*$ (yellowness) values were determined. The chromameter was calibrated using a white tile. The colour values were L*, a* and b*. The analysis was repeated three times for each formulation, with three different positions of each sample selected for colour measurement.

2.4.1 Bulking density. A 10 ml graduated cylinder was carefully filled with 5 g of sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was a constant. The weight of the sample per unit volume of the sample was used to calculate the bulk density (g/mL) as following formula (1).

$$\text{Bulk density (g/mL)} = \frac{\text{weight of flour used}}{\text{volume of the flour after tapping}} \tag{1}$$

2.4.2 Swelling Power. Swelling power was determined using the modified method by Kusumayanti et al. [11]. One gram was dissolved in 10 mL of distilled water in centrifuge tubes. After that, the tubes were heated at 60 °C for 30 minutes, with intermittent mixing in a water bath. After cooling to ambient temperature, the tubes were centrifuged for 15 minutes at 1600 rpm. The supernatant was removed from the tube, and the wet residue in the tubes was reweighed to calculate the swelling power using the following formula (2).

$$\text{Swelling properties} = \frac{\text{weight of wet sediment (g)}}{\text{Initial weight of flour (db,g)}} \tag{2}$$

2.4.3 Water Holding Capacity. Water holding capacity was determined by centrifugation process [12]. Each centrifuge tube received 1 g of waffle premix flour and mixed with 10 ml of distilled water. Subsequently, the contents were vortexed for 30 minutes to ensure uniform mixing. After allowing the samples to stand at room temperature for 30 minutes, centrifuge for 25 minutes at 3000 rpm. The sediments were then weighed following the complete removal of the supernatant. All samples were collected in triplicate to obtain an average result. The water holding capacity (WHC) calculation followed the formula (3).

$$\text{WHC (\%)} = \frac{(W_2 - W_1)}{W_0} \tag{3}$$

where W_0 is the weight of the sample, W_1 is the weight of the centrifuge tube with sample, and W_2 is the weight of the centrifuge tube with sediments.

2.4.4 Water Activity. The water activity was measured at room temperature (25°C) by placing approximately 3 g of flour in a sample holder of a water activity meter (Aqualab 4TE Decagon, Pullman, USA) calibrated using a potassium chloride standard solution (0.5 mol/kg).

2.4.5 Moisture Analysis. The moisture content was determined using the air oven method as described in AACC (44-15). Homogenised samples were dried at 105°C in a hot air oven (Memmert, Germany) until constant weight was achieved.

2.4.6 Crude Protein Analysis. Nitrogen content was measured using the Kjeldahl method described by AOAC (988.05) to determine crude protein content. The nitrogen content in the sample was multiplied by a factor of 6.25 to estimate the crude protein content.

2.5 Physical Analysis of Waffle

The surface colour of the cooked waffles was measured using a chromameter. Three pieces of waffle obtained from the replication of each formulation with at least eight different positions of each piece were selected for colour measurement. The hardness of the waffle was measured using the texture analyser (TA.XT plus, Stable Macro System Ltd., U.K.). The hardness was performed as follows: probe: HDP/BS, pre-test speed: 1.0 mm/s, test speed: 1.0 mm/s, post-test speed: 10.0 mm/s, distance: 3 mm, trigger type: 5 g, and data acquisition rate: 500 PPS (method modified from Pichaiyongvongdee et al. [1]).

2.6 Sensory Analysis of Waffle

The acceptability of all formulations of waffle containing mung bean flour was tested per the ethical principles and approved by The Faculty Ethics Review Committee (FERC), Faculty of Applied Sciences UiTM (R1/FERC/FSG/007). Forty-one untrained panellists who like to consume waffles were selected among the faculty members. The consent was obtained from all panellists prior to the sensory session. The overall acceptability of waffles was assessed using a 9-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; and 9 = like extremely). In addition, attributes such as crust colour, beany taste, sweetness, crispiness, fluffiness, and moistness were assessed using a "just-about-right" (JAR) bipolar scale of five points range (1 = much less, 3 = Just-About-Right; and 5 = much more). The panellists were presented in a randomised order of 3-digit coded samples, and they were evaluated randomly. After analysing each piece, panellists were given drinking water to rinse their mouths to reduce the taste effect. Samples were served on white plastic platters at ambient temperature and assessed for crust colour, beany taste, crispiness, fluffiness, moistness, and overall acceptability. The mean values of the assessments were calculated.

2.7 Statistical analysis

The experiments were performed in triplicate and the mean value was used for statistical analysis. The data was analysed using one way analysis of variance (ANOVA) using IBM SPSS Statistic version 20 for finding elements causing difference between the samples, then multiple comparison was analysed by Duncan's new multiple range test. The JAR results were analysed by penalty analysis to identify potential directions for product improvement based on consumer acceptability by highlighting the most penalising attributes in liking terms.

3.0 RESULTS AND DISCUSSION

The effect of mung bean flour in the blends on the physicochemical properties of instant premix flour is indicated in Table 1. The appearance of instant premix flour changes dramatically from creamy to brownish with increasing mung bean flour in the formulation (Figure 1). Lightness (L*) decreased from 90.73 to 75.27, whereas redness (a*) and yellowness (b*) increased from 0.04 to 3.60 and 11.54 to 19.88, respectively ($p<0.05$). Like current findings, Rodrigues *et al.* (2022) found that biscuits with different proportions of whole mung bean and wheat flour have a significant effect on L* value. According to Zhao et al. [13], the L* value increases due to the contribution of the dark green color of the grain tegument. The presence of carotenoids (β-carotene and xanthophylls) in cotyledons of mung bean and seed coats[14] could lead to an increase in the a* and b* values of waffle premix flour. Oppong et al. [15] suggested that higher a* and b* values with lower L* values in the flours were negatively correlated to the total phenolic contents of the flours, which was also supported by Keskin et al. [16].

Table 1. Physicochemical properties of instant premix flour.

Sample	Control	IPF20	IPF40	IPF60	IPF80
L*	90.73 ± 1.13^{a}	84.77 ± 0.08^{b}	81.12 ± 0.23^{c}	77.63 ± 0.21^{d}	75.27 ± 0.45^{e}
a*	0.04 ± 0.01^{e}	1.60 ± 0.02^{d}	2.43 ± 0.07^{c}	3.19 ± 0.02^{b}	3.60 ± 0.02^{a}
b*	11.54 ± 0.14^{e}	14.27 ± 0.15^{d}	16.55 ± 0.22^{c}	18.62 ± 0.25^{b}	19.88 ± 0.55^{a}
Bulking density (g/mL)	0.81 ± 0.01^{d}	0.86 ± 0.01^{c}	0.89 ± 0.02^{b}	0.91 ± 0.01^{a}	0.92 ± 0.01^{a}
Swelling properties (%)	5.27 ± 0.07^{a}	5.17 ± 0.05^{a}	5.12 ± 0.16^{a}	$4.92 \pm 0.37^{a,b}$	4.59 ± 0.29^{b}
Water holding capacity (%)	17.71 ± 4.85^{e}	31.91 ± 0.95^{d}	41.89 ± 1.07^{c}	58.77 ± 1.19^{b}	68.88 ± 0.09^{a}
Water activity	0.59 ± 0.01^{a}	0.55 ± 0.01^{b}	0.52 ± 0.01^{c}	0.46 ± 0.01^{d}	0.44 ± 0.01^{e}
Moisture (%)	9.14 ± 0.58^{a}	7.57 ± 1.14^{b}	6.54 ± 0.22^{b}	5.39 ± 0.12^{c}	4.29 ± 0.06^{d}
Crude protein (%)	5.44 ± 0.02^{e}	6.38 ± 0.18^{d}	7.05 ± 0.01^{c}	8.22 ± 0.07^{b}	8.65 ± 0.04^{a}

Results are presented in mean ± standard deviation. Values in the similar row with different superscript letters are significantly different ($p < 0.05$). Control= Instant premix flour with 100% wheat flour; IPF20=Instant Premix Flour with 20% mung bean; IPF40=Instant Premix Flour with 40% mung bean; IPF60=Instant Premix Flour with 60% mung bean; IPF80=Instant Premix Flour with 80% mung bean.

Figure 1. Colour of instant premix flour. (a) Instant premix flour with 100% wheat flour (Control) (b) Instant premix flour with 20% mung bean (IPF20) (c) Instant premix flour with 40% mung bean (IPF40) (d) Instant premix flour with 60% mung bean (IPF60) (d) Instant premix flour with 80% mung bean (IPF80).

Bulking density determines the packaging requirement of flour as it relates to the load the sample could carry if allowed to rest directly on one another. The bulk density of instant premix flour with mung bean substitutions was slightly higher than the control formulation ($p<0.05$), which implied that similar packaging designs and materials could possibly be used.

Swelling power refers to the capacity of starch granules to absorb and retain water when heated, leading to an expansion in its dimensions or overall volume, which is influenced by the concentration of amino acids and starch. The swelling properties of waffle premix flour decrease slightly to 4.59 with 80% substitution of mung bean flour. Similar trends were observed by Melese and Keyata [17] in composite flour consisting of pumpkin, common bean and wheat flour. The protein and fibre found in legume flours could have restricted the available water needed for starch swelling [18], causing the swelling power to decrease as the percentage of mung bean flour added increased. Furthermore, Melese and Keyata [17] stated that the variations in swelling power among flours may be due to factors like the ratio of amylose to amylopectin, as well as the molecular distribution, degree and length of branching, and conformation of amylose and amylopectin. Wheat flours have high swelling power mainly because they contain more amylopectin than amylose.

Instant premix flour with mung bean addition gave an appreciable amount of water-holding capacity, ranging from 31.91% to 68.88%. This may be attributed to its fibre and protein content that interacts with water [18]. The significant water-absorbing ability of proteins is essential in reducing moisture evaporation in thick food items like soups, dough, and baked goods. This property enables proteins to absorb water without suffering protein disintegration, leading to the ideal characteristics of body, thickening, and viscosity. Mohd Dom et al. [12] mentioned that products with high water-holding capacity might retain moisture, improving texture to make it moist and fluffy.

Water activity is a crucial property that is used to predict the stability and safety of food. This study demonstrates a significant drop in water activity as the proportion of mung bean flour increases, as indicated in Table 1. Specifically, the water activity reduces from 0.55 (IPF20) to 0.44 (IPF80). The moisture content of the instant premix flours was considerably low (<10%), which signifies a good keeping quality. A similar pattern was noted in a study by Showkat et al. [19] on the quality of cereal bars prepared using rice and mung bean flour. The study suggested that the reduction in water activity in the product could be linked to the drop in moisture content in the mung bean flour. It was evident from the results that crude protein was significantly affected by the addition of mung bean flour. The highest amount was observed in IPF80 (8.65%), while control formulation was the lowest (5.44%).

Figure 2 depicts the waffle from various percentages of mung bean instant premix flour. As the percentage of added mung bean flour increases, a decrease in the L* (lightness) value and an increase in both a* (redness) and b* (yellowness) were observed (Table 2). Specifically, the L* values decrease from 45.54 (control) to 37.74 (WMB80), indicating a darker hue. Zhao et al. [13] found that the substitution of wheat flour with legumes contributes to a darker crust. Ozkahraman et al. [18] also highlight that legume cakes, including those with mung bean flour, exhibit a significantly higher crust colour than wheat cakes. The increment of redness (a*) value could be attributed to the Maillard reaction [13]. Liu et al. [20] explain that this rise in b* value is related to the internal pigment components of mung bean flour, including native pigments like brown pigments and flavonoids.

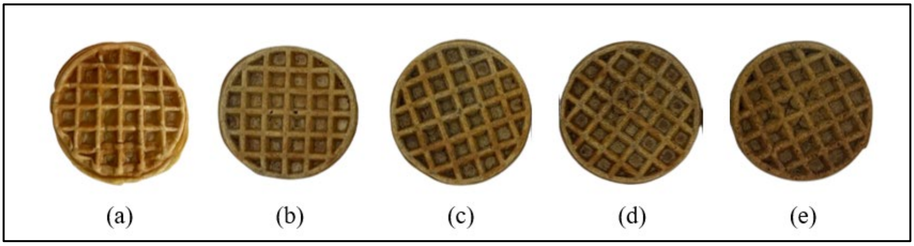

Figure 2. Colour of waffles. (a) Control (b) Waffle with 20% mung bean (c) Waffle with 40% mung bean (d) Waffle with 60% mung bean (e) Waffle with 80% mung bean.

Table 2. Physical properties of waffle with mung bean addition

Sample	L*	a*	b*	Hardness (N)
Control	45.54 ± 0.72^{a}	4.84 ± 0.39^{e}	10.99 ± 0.58^{d}	2323.29 ± 250.62^{a}
WMB20	43.59 ± 0.13^{b}	5.64 ± 0.33^{d}	12.02 ± 0.58^{c}	2184.98 ± 134.94^{a}
WMB40	41.07 ± 0.24^{c}	6.55 ± 0.22^{c}	13.77 ± 0.61^{b}	1836.87 ± 575.92^{ab}
WMB60	39.52 ± 0.65^{d}	7.59 ± 0.30^{b}	14.65 ± 0.61^{b}	1305.16 ± 252.76^{b}
WMB80	37.74 ± 0.61^{e}	8.84 ± 0.16^{a}	16.08 ± 0.10^{a}	1215.19 ± 64.81^{b}

Results are presented in mean ± standard deviation. Values in the similar column with different superscript letters are significantly different ($p < 0.05$). Control= waffle with 100% wheat flour; WMB20=Waffle with 20% mung bean; WBM40=Waffle with 40% mung bean; WMB60=Waffle with 60% mung bean; WMB80=Waffle with 80% mung bean.

Hardness is defined as the force required for a pre-determined deformation of the sample. The results showed that the substitution of mung bean up to 40% did not impart a significant difference. However, as the percentage of mung bean substitution increases, the hardness value was significantly reduced ($p<0.05$) compared to the control formulation. Whole wheat flour might have made the structure more cohesive, resulting in increased hardness, owing to the gluten network. The actual texture of all the treatments was expected to be soft inside and slightly crispy on the crust. However, softer texture in higher substitution of mung bean could be due to the high presence of non-gluten-forming proteins leading to decreased dough cohesion [21].

The JAR (Just-about-right) scale was used to determine the panellist's perception of selected food attributes of the five different treatments of waffles. The data collected from JAR helps product developers understand how specific product attributes need to be altered to achieve acceptability. A penalty analysis was used to describe the non-optimal sensory attributes affected by the addition of mung bean in the samples. An attribute should be considered critical when the percentage of consumers who selected the non-JAR responses was higher than 20%, and the mean drop was greater or equal to 1.0 (a high number of consumers say the attribute level is not right, either too much or not enough, with a significant impact on overall liking) [22].

Analysing the specific data for each waffle sample provides insights into the acceptability of these formulations (Figure 3). Notably, WMB20 exhibited higher appropriateness levels across multiple attributes, including crust colour (51%), sweetness (56%), and moistness (51%). This suggests a favourable reception of 20% of mung bean among panellists regarding these attributes. Further scrutiny of individual attributes reveals distinctive patterns. For example, sweetness levels varied among samples, with WMB40 registering the highest (63%), followed closely by WMB20 (56%). Conversely, WMB80 consistently demonstrated the lowest appropriateness levels across various attributes, with values of 5% for crust colour, 22% for beany taste, 29% for sweetness, 19% for crispiness, 27% for fluffiness, and 15% for moistness. This formulation faced notable penalties for excessive beany taste, insufficient sweetness, lack of crispiness, fluffiness, and excessive dryness, indicating lower overall acceptability,

Fig. 3. The frequencies of JAR and non-JAR levels of sensory attributes for each waffle sample. Control= waffle with 100% wheat flour; WMB20=Waffle with 20% mung bean; WBM40=Waffle with 40% mung bean; WMB60=Waffle with 60% mung bean; WMB80=Waffle with 80% mung bean.

The assessment of overall penalties provides insights into the likability of waffle samples when they deviate from consumer expectations. The comprehensive penalty analysis revealed that fluffiness significantly influenced the overall liking of all samples. Recommendations for improvement varied across samples, suggesting a need to decrease fluffiness for control formulation and enhance it for all formulations containing mung bean as an ingredient. Comparatively, Control, WMB20, and WMB40 samples exhibited no significant differences in overall liking scores of 6.90 ± 1.70, 7.02 ± 1.48, and 6.49 ± 1.47, respectively (Table 3). Notably, the sample with a 0%, 20% and 40% substitution of mung bean flour recorded moderate liking value on the 9-point hedonic scale.

Table 3. Mean drops and penalties of sensory attributes and overall liking of waffle samples.

Attribute	Level	Mean drops/Penalties/Overall liking score				
		Control	WMB20	WMB40	WMB60	WMB80
Crust colour	TL	0.288	0.048	1.308*	0.667*	-
	TM	-	0.048	**1.192**	-0.009	-0.321
	Penalties	0.594	0.919	**0.013**	0.992	0.826
Beany taste	TL	1.090	0.974	0.850	2.150*	1.67*
	TM	-	0.529*	0.577	0.807	**1.989**
	Penalties	0.149	0.064	0.125	0.054	**0.007**
Sweetness	TL	1.201	1.044*	1.082*	**1.114**	1.07
	TM	0.928	-0.593	-0.096*	0.426*	0.750*
	Penalties	0.044	0.927	0.347	**0.046**	0.150
Crispiness	TL	0.825	1.403*	0.843*	0.916	1.05
	TM	-0.333	**1.211**	0.097	0.154*	0.577
	Penalties	0.494	**0.003**	0.632	0.126	0.273
Fluffiness	TL	1.545*	**1.738**	**1.893**	**1.455**	**3.05**
	TM	**1.188**	0.493	0.778	1.011*	1.943*
	Penalties	**0.016**	**0.021**	**0.001**	**0.005**	**<0.001**
Moistness	TL	1.889*	1.603	0.778	0.012	**2.55**
	TM	**1.722**	0.017	-0.079*	-0.217	1.111
	Penalties	**<0.001**	0.114	0.269	0.829	0.011
Overall liking		6.90 $\pm 1.70^{a}$	7.02 $\pm 1.48^{a}$	6.49 $\pm 1.47^{a}$	5.66 $\pm 1.41^{b}$	4.80 $\pm 1.98^{c}$

TL = "too little", TM = "too much". The bold number indicates the significant difference at $\alpha < 5\%$, while the asterisk (*) indicates that the test was not computed since the percentage level is lower than 20%. Control= waffle with 100% wheat flour; WMB20=Waffle with 20% mung bean; WBM40=Waffle with 40% mung bean; WMB60=Waffle with 60% mung bean; WMB80=Waffle with 80% mung bean.

4.0 CONCLUSION

In conclusion, the replacement of wheat flour with mung bean has altered the colour, bulking density, and water-holding capacity of instant premix flour, except for swelling properties. Instant premix flour with a higher addition of mung bean has lower water activity and moisture content; thus, these formulas are less susceptible to microbial spoilage and stable to chemical deterioration over storage time. It is evident that incorporating mung bean has significantly increased the protein content. The waffle's colour demonstrated significant differences among the five formulations. These changes in colour were supported by results from the JAR analysis that determined panellists prefer light yellow colour in waffles rather than dark brown colour. Based on penalty analysis, the weaknesses of the mung bean waffle showed too little fluffiness, which influenced overall liking the most. Based on the overall liking score, this study recommends the use of mung bean as composite flour in instant premix up to 20%. Considering these results, an instant premix waffle alternative can be introduced to present a wider variety of products with the beneficial nutritional characteristics of mung bean.

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Conflict of Interest. The authors have no competing interests to declare that are relevant to the content of this article.

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