

## Physicochemical properties, antioxidant activities, beta-carotene content, and sensory properties of gluten-free pumpkin-fortified egg roll

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### Abstract

Egg roll is a wheat snack popular among Asians, including Indonesians. Efforts to make egg roll a functional food are hindered by the declining domestic supply of wheat flour. It calls for alternative local raw materials such as mocaf and pumpkin flour to make egg rolls. This research investigated the influence of varying pumpkin incorporation levels on the physicochemical properties, antioxidant capacity,  $\beta$ -carotene content, and sensory profile of gluten-free egg rolls. The varying pumpkin additions were 0%, 8%, 16%, 24%, and 32%, with two replicates. The gluten-free egg rolls were subjected to physical analysis (hardness, brittleness, and microstructure), chemical analysis (moisture content, protein, ash, fat, carbohydrates by difference, crude fiber,  $\beta$ -carotene, and antioxidant activity), and panelist sensory test (color, aroma, taste, crispiness, and overall preference). Sensory evaluation results, as reported by panelists, showed that gluten-free egg rolls with 24% pumpkin added received the highest acceptance ratings based on attributes such as color, aroma, taste, crispness, and overall preference. Chemical analysis demonstrated that the addition of pumpkin to gluten-free egg rolls could increase  $\beta$ -carotene levels to 207.74  $\mu\text{g/g}$  and antioxidant activity to 45.89%. Conclusively, gluten-free pumpkin-fortified egg rolls are a potential functional food.

## 1. Introduction

The egg roll, a popular Asian delicacy, is a delicious, oil-fried biscuit made from eggs, wheat flour, sugar, and butter (Ju Tsai and Chiung Liu, 2022), characterized by a distinctive crispy texture (Chan *et al.*, 2020). Despite its fame, egg roll is not a functional food, and it contains wheat gluten, which can trigger allergies in some people (Zheng *et al.*, 2024). As egg roll manufacturers are heavily reliant on imported wheat flour, many are seeking alternatives while incorporating additional ingredients to fortify egg rolls with  $\beta$ -carotene and antioxidants.

Modified cassava flour (mocaf) is a fermented product rich in starch and fiber (Mustika and Kartika, 2020). Bearing similar characteristics to wheat flour, mocaf is the main ingredient in products, such as dry noodles (Afifah and Ratnawati, 2017), analog rice (Wahjuningsih and Susanti, 2018), mocaf and pumpkin

biscuits (Rahmawati and Ismawanti, 2023), noodles (Herlina *et al.*, 2024), and mocaf and pumpkin mix cookies (Indrianingsih *et al.*, 2024; Rohmatningsih *et al.*, 2025). Accordingly, mocaf is also feasible for snack products, such as biscuits and egg rolls.

Pumpkin (*Cucurbita moschata*) is a member of the *Cucurbita* genus, which belongs to the *Cucurbitaceae* family. In its fresh form, pumpkin has a high water content of 80–96% and contains approximately 4.6–6.5% sugar, 0.6–1.8% protein, and 0.5–1.3% dietary fiber (İzli *et al.*, 2022). A good source of nutrition, pumpkin fruit exhibits antioxidant activity and hypoglycemic potential to protect health (Li *et al.*, 2021), is rich in vitamin A and carotenoids, forming the orange color (Ihednachi *et al.*, 2025), and contains other bioactive compounds such as phenolic acids, flavonoids, minerals, and vitamins. Pumpkin is beneficial for health due to its antidiabetic, antioxidant, and anti-inflammatory properties (Hussain *et*

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al., 2022). It has been reported that instant pumpkin porridge can help regenerate pancreatic cell damage in mice (Slamet et al., 2022), and pumpkin cake is a potential source of nutrition and an antidiabetic agent (Adelerin et al., 2023). Polysaccharide compounds in pumpkin can regenerate pancreatic cells in diabetic rabbits (Zhang et al., 2013) and a viable immunomodulators. Previous studies have shown that partially substituting wheat flour with pumpkin flour in rice-based extruded food products can increase protein, crude fiber, and  $\beta$ -carotene content (Alefew et al., 2024).

The quality of egg rolls made with mocaf and pumpkin, which may differ from that of wheat egg rolls, warrants further investigation. Therefore, identifying the optimal level of pumpkin incorporation in gluten-free egg rolls is essential. Accordingly, this research investigates how the inclusion of pumpkin influences its physicochemical characteristics, antioxidant capacity,  $\beta$ -carotene levels, and sensory attributes.

## 2. Materials and methods

### 2.1 Materials

Fresh pumpkin (*Cucurbita moschata*) obtained from Beringharjo Market, Yogyakarta Province, Indonesia, with a 15-20 cm diameter, 8-12 kg weight, orange skin, and no defects. Mocaf Plus flour was purchased from an online market in Yogyakarta, Indonesia, and had the following characteristics: white, soft, and odorless, with a particle size that passed through 80 mesh sieves. The chemicals used in this study were 95% ethanol, petroleum benzene, DPPH solution (2,2-diphenyl-1-picrylhydrazyl), catalyst  $\text{Na}_2\text{SO}_4$ , 3%  $\text{H}_3\text{BO}_3$ , Na-Thio, and 0.02 N HCl, all obtained from the Laboratory of Chemistry and Agricultural Product Technology, Faculty of Agroindustry, Universitas Mercu Buana Yogyakarta, Yogyakarta, Indonesia. The chemical analysis was conducted with Pro Analysis Qualification from Merck and Sigma Aldrich.

### 2.2 Sample preparation

The pumpkin was cut into four parts using a stainless-steel knife, then peeled and seeded, and cut into 2 cm x 2 cm x 2 cm pieces. A total of 500 g of pumpkin was combined with 150 mL of water in a blender and processed at a medium speed setting for 15 min. The resulting pulp was then set aside. This study prepared egg rolls in five formulations incorporating 0%, 8%, 16%, 24%, and 32% pumpkin pulp (Table 1). In each formulation, the ingredients were added to 75 mL of distilled water, mixed using a mixer until homogeneous, and then the batter was spread evenly (1 cm thick) onto an egg roll mold placed on a gas stove. The mold was conditioned by heating it at 130°C for 3 min. The dough,

once partially dried, was rolled into a cylindrical shape using chopsticks, removed from the heat, and allowed to equilibrate at room temperature (30°C) for 10 min. All products were then packed in polyethylene plastic bags.

Table 1. The formulation of egg roll.

Ingredient	A (0%)	B (8%)	C (16%)	D (24%)	E (32%)
Butter	160	160	160	160	160
Sugar	140	140	140	140	140
Salt	1	1	1	1	1
Egg	244	183	122	61	0
Pumpkin	0	61	122	183	244
Mocaf	230	230	230	230	230
Total	774	774	774	774	774

### 2.3 Egg roll characterization

#### 2.3.1 Color testing

Color evaluation of the egg rolls was performed using a chromameter (CR-20, Konica Minolta, Japan), yielding measurements for lightness ( $L^*$ ), the red–green axis ( $a^*$ ), and the yellow–blue axis ( $b^*$ ).

#### 2.3.2 Texture testing

Texture assessment was conducted using a Japanese-manufactured Universal Testing Machine, operating with a load of 0.02 N and a movement rate of 50 mm/min. The probe was pressed 10 mm deep into the egg roll sample at a compression level of 40%. The number displayed on the device represents the texture of the sample.

#### 2.3.3 Sensory test

A total of 25 students enrolled in the Agricultural Product Technology Study Program, Faculty of Agroindustry, Universitas Mercu Buana Yogyakarta, served as panelists. Eligibility requirements included an age range of 18–25 years, a liking for egg rolls, and the absence of allergies to pumpkin or mocaf flour. Sensory tests were conducted to assess the panelists' preferences for the attributes of color, aroma, taste, crispness, and overall preference. The assessment employed a 5-point hedonic scale, ranging from 1 (strongly dislike) to 5 (strongly like) (Duta and Culetu, 2015). Drinking water was provided to the panelists to cleanse their taste buds after they had tasted each egg roll formulation. The sensory assessment was authorized by the Ethics Committee of Universitas Alma-Ata in Yogyakarta, Indonesia, as documented in Reference Number KE/AA/VII/10111967/Ec/2024.

#### 2.3.4 Surface morphology testing

A Scanning Electron Microscope (SEM; Hitachi SU-3500, Japan) was used at an accelerating voltage of 4.0

kV to observe the morphology of the egg roll. The egg roll sample was placed on a specimen holder, then coated with gold powder and observed at 10,000× magnification.

### 2.3.5 Moisture content

The moisture content of the egg roll samples was measured using porcelain dishes in compliance with AOAC Official Method 925.10 (2005). The dishes were first dried until completely dry, then filled with 5 g of egg roll samples and dried again in an oven at 105°C for 24 h with an automatic temperature controller. The moisture content of egg rolls is expressed as a percentage of moisture based on the following formula:

$$\% \text{ Moisture content} = \frac{\text{Loss of weight}}{\text{Initial sample weight of the sample}} \times 100\%$$

### 2.3.6 Protein

Protein content in the egg roll samples was determined following the procedures described in AOAC Official Method 979.09 (2005). A total of 2 g of egg roll samples were then mixed with 3 g of digestion mixture and 25 mL of H<sub>2</sub>SO<sub>4</sub> in a Kjeldahl digestion flask. The Kjeldahl digestion flask was then heated using a digester/distillation apparatus for 4 h. A protein conversion factor of 6.25 was used in calculating the percentage of protein in the sample. The formula for calculating the protein percentage is as follows:

$$\% \text{ Nitrogen} = \frac{T_s - T_b \times \text{Normality of acid} \times \text{meq. } N_2}{\text{Weight of the sample}} \times 100\%$$

### 2.3.7 Ash

The ash content of egg roll products was analyzed using the AOAC Official Method 923.03 (2005). Ash analysis was performed using egg rolls weighing 5 g. The egg rolls were dried, then burned in an electric furnace at a temperature of 550°C until all organic materials had decomposed, leaving a light gray ash. The next step was cooling in a desiccator. The remaining material was weighed until it reached a constant weight. The ash content in egg rolls is calculated based on the ratio of the weight of ash to the initial sample weight multiplied by 100%.

$$\% \text{ Ash content} = \frac{\text{Weight of ash}}{\text{Initial weight of the sample}} \times 100\%$$

### 2.3.8 Fat

The total fat content in egg roll products was determined using the AOAC Official Method 920.39 (2005). A total of 2 g of egg roll sample was placed on a filter paper lined with cotton wool. Both ends were then covered with cotton wool and dried in an oven at a maximum temperature of 80°C for approximately 1

hour. After that, the filter paper was placed in a Soxhlet apparatus connected to a fat flask containing dried boiling stones that had been weighed beforehand. Extraction was carried out using petroleum ether solvent for approximately 6 h. The solvent was then distilled, and the fat extract was dried again in an oven at 105°C, cooled, and weighed until a constant weight was obtained. The fat content is calculated based on the ratio between the weight of the fat obtained and the weight of the sample, then multiplied by 100%.

### 2.3.9 Carbohydrates by difference

The carbohydrate content by difference is expressed as the difference between 100 and the total amount of all other components. The calculation formula is as follows:

$$\text{Carbohydrates by difference} = 100\% - \% (\text{moisture} + \text{protein} + \text{fat} + \text{ash})$$

### 2.3.10 Crude fiber determination

The crude fiber content in egg roll products was determined using the AOAC Official Method 962.09 (2005). This method encompasses insoluble carbohydrate fractions, including cellulose, hemicellulose, and lignin. In this analysis, a two-gram sample of egg roll was boiled in 200 mL of dilute acid solution (1.25% H<sub>2</sub>SO<sub>4</sub>) for 30 min. The egg roll was then removed and boiled again in 200 mL of dilute base solution (1.25% NaOH) for 30 min while maintaining a constant volume. The ash from the residue is subtracted to estimate the digestible fat content. The crude fiber content in egg rolls is expressed as a percentage calculated using the following equation:

$$\% \text{ Crude fiber} = \frac{\text{Weight of residue with crucible} - \text{the weight of ash with crucible}}{\text{Weight of sample (moisture and fat-free)}} \times 100\%$$

### 2.3.11 Beta-carotene measurement

The total β-carotene content in the egg rolls was determined using reverse-phase high-performance liquid chromatography (HPLC; Agilent 1260, Agilent Technologies, Santa Clara, CA). The system operated with OpenLab CDS software and employed a Poroshell 120 EC-C18 column (4.6 × 100 mm, 2.7 μm; Agilent), which served as the nonpolar stationary phase. The mobile phase consisted of an 85:15 (v/v) mixture of acetonitrile and methanol. Detection was performed with a diode array detector set at 450 nm, following the procedure described by Kurniawan et al. (2022). For sample preparation, the egg roll extract (acetonitrile: hexane = 3:7, v/v) was stabilized with butylated hydroxytoluene (BHT) and stored in an amber vial prior to injection. The β-carotene identification was based on a comparison of retention times with the reference standard, while quantification was performed using peak -area integration via the external standard method.

### 2.3.12 Antioxidant activity measurement

The antioxidant activity of egg rolls was determined based on their ability to scavenge DPPH radicals (Galaz *et al.*, 2017). A DPPH stock solution with a concentration of 0.1 mM was prepared and stored at 4°C in a refrigerator. The DPPH stock solution was first diluted with ethanol to a concentration of 0.1 mM and then used for analysis. Antioxidant activity was determined by mixing 1 g of the ethanol extract with 2.5 mL of a 0.1 mM DPPH solution and homogenizing the mixture. The absorbance of the treated sample was then recorded at 517 nm immediately (0 min) and again after 30 min of incubation in the dark. Measurements were carried out using a UV-Vis spectrophotometer (Shimadzu UV-mini 1240). The antioxidant capacity was expressed as the percentage of Radical Scavenging Activity (RSA).

$$\text{Radical Scavenging Activity (\%)} = [1 - (A_T/A_0)] \times 100\%$$

### 2.3.13 Statistical analysis

This study employed a one-factor randomized design with pumpkin substitution levels of 0%, 8%, 16%, 24%, and 32%. Each treatment was produced in three independent batches, and all analytical measurements were performed in triplicate. The data were statistically evaluated using Duncan's Multiple Range Test (DMRT) at  $p < 0.05$ , and all computations were carried out using SPSS for Windows (version 25).

## 3. Results and discussion

### 3.1 Color of the egg roll

Table 2 presents the effect ( $p < 0.05$ ) of varying pumpkin addition on the color lightness ( $L^*$ ), redness ( $a^*$ ), and yellowness ( $b^*$ ) of egg rolls, which yielded scores of 68.64-73.76, 3.93-6.37, and 21.21-24.60, respectively. The lightness of egg roll decreases as the pumpkin content increases because the orange hue derived from carotenoids in the pumpkin flesh lowers the egg roll's brightness. In egg roll making, the roll batter undergoes the Maillard reaction in which heat reacts with high sugar and amino acids in pumpkin (Shi *et al.*, 2013), causing carotenoid oxidation (Fan *et al.*, 2023). It has been reported that the Maillard reaction is a complex interaction between reducing sugars and amino groups that occurs during processing, especially during the heating stage (Liu *et al.*, 2020), resulting in a non-enzymatic browning reaction in pumpkin muffin products and wheat flour (Arifin *et al.*, 2019). The increasing amount of protein and sugar in the ingredients leads to a browning reaction, which decreases the brightness (Widyastuti *et al.*, 2015; Slamet *et al.*, 2019). A higher proportion of pumpkin in bread made of

pumpkin and red bean also leads to less brightness (Melese and Keyata, 2022). Meanwhile, drying pumpkins reduces lightness from 74.61 to 56.50 (Chikpah *et al.*, 2022).

The redness of egg rolls intensified as more pumpkin was incorporated because, according to Hagos *et al.* (2022), pumpkin contained up to 376–451  $\mu\text{g/g}$   $\beta$ -carotene. Egg rolls made of high-protein rice are reported to undergo the Maillard reaction, resulting in less brightness (lightness) and more redness (Chan *et al.*, 2020). Similarly, increased redness was reported in egg rolls containing a high proportion of pitaya puree (Tsai and Liu, 2022), noodles made primarily from pumpkins and sweet potatoes (Farzana *et al.*, 2023), and mocaf cookies comprising a higher proportion of pumpkin flour (Indrianingsih *et al.*, 2024). During drying, the redness of pumpkin flour can increase from 8.47 to 11 (Chikpah *et al.*, 2022).

Table 2. Egg roll colors.

Pumpkin (%)	$L^*$	$a^*$	$b^*$
0	73.76±3.01 <sup>b</sup>	3.93±0.01 <sup>a</sup>	21.21±1.01 <sup>a</sup>
8	73.42±2.76 <sup>b</sup>	4.22±0.08 <sup>b</sup>	22.57±1.01 <sup>b</sup>
16	73.49±1.19 <sup>b</sup>	4.14±0.19 <sup>b</sup>	23.09±0.09 <sup>b</sup>
24	68.09±2.98 <sup>a</sup>	5.52±0.20 <sup>c</sup>	24.28±0.97 <sup>c</sup>
32	68.64±2.62 <sup>a</sup>	6.37±0.06 <sup>d</sup>	24.60±0.74 <sup>c</sup>

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different at the level of 0.05.

The results of this study indicate that the yellowness of egg rolls increases with the percentage of pumpkin puree added to the dough, because pumpkin puree provides a brighter orange color than pumpkin flour. The orange hue is derived from high carotenoid compounds in pumpkins, specifically 35.2 mg/100 g (Hussain *et al.*, 2021); however, the orange hue may fade due to the drying process. Figure 1 shows that adding pumpkin to the egg roll results in a bright orange egg roll, which is visibly more attractive than regular egg rolls in the market. Previous studies have reported that pumpkin enhances the attractive orange color of pumpkin bread (Melese and Keyata, 2022), instant noodles (Nanthachai *et al.*, 2020), and pasta (Minarovičová *et al.*, 2017). In addition, cookies made with a blend of mocaf and pumpkin flour received higher preferences from the panelists (Indrianingsih *et al.*, 2024).

### 3.2 Texture of the egg roll

The texture of egg rolls, including hardness and brittleness (Table 3), was significantly affected ( $p < 0.05$ ) by variations in the addition of pumpkin. The higher the percentage of pumpkin added to the dough,

the softer the egg roll became (5.64–7.78 kg/m<sup>2</sup>), and the less brittle it was (2.15–3.91 mm) ( $p < 0.05$ ). Incorporating more pumpkin in egg roll batter would increase the fiber content but lower other substances, resulting in less crispiness. Fiber binds water and inhibits the gelatinization process of starch (Afifah *et al.*, 2024), which determines the hardness and fracturability of egg rolls. Fracturability, associated with brittleness, is defined as the force that causes a sample to break, fracture, or crumble (Principato *et al.*, 2021). It has been reported that the gelatinization process is determined by the amount and type of starch in the biscuit recipe (Ratnawati *et al.*, 2020). Accordingly, the higher the fracturability, the less brittle the product (Hwang *et al.*, 2016). Buckwheat flour can be used to make gluten-free cookies, which may reduce hardness and fracturability (Farzana *et al.*, 2022).

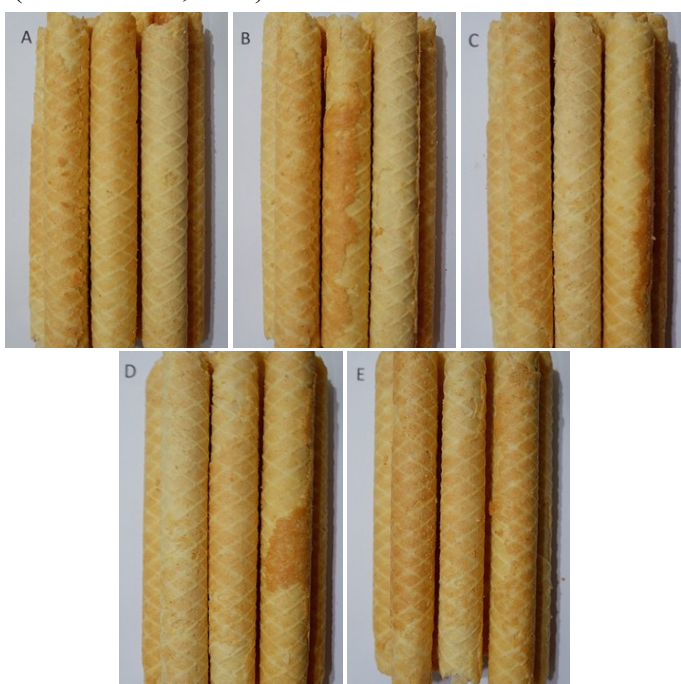


Figure 1. Samples of egg roll. A: pumpkin 0%, B: pumpkin 8%, C: pumpkin 16%, D: pumpkin 24%, E: pumpkin 32%.

Table 3. The texture of egg roll.

Pumpkin (%)	Hardness (kg/m <sup>2</sup> )	Fracturability (mm)
0	7.39±0.24 <sup>d</sup>	3.91±0.00 <sup>c</sup>
8	7.78±0.00 <sup>d</sup>	3.20±0.02 <sup>d</sup>
16	6.01±0.97 <sup>c</sup>	2.86±0.05 <sup>c</sup>
24	5.64±0.13 <sup>b</sup>	2.71±0.00 <sup>b</sup>
32	4.75±0.04 <sup>a</sup>	2.15±0.01 <sup>a</sup>

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different at the level of 0.05.

### 3.3 Preference level of egg roll

The varying levels of pumpkin incorporated into egg roll making significantly affected the panelists' preferences for color, aroma, taste, crispiness, and overall preference ( $p < 0.05$ ). Table 4 shows that the

panelists preferred egg rolls with more vibrant colors, as indicated by the addition of pumpkins, which were samples D and E, with values of 3.80 and 3.65, respectively. Previous studies reported that panelists were more attracted to the attractive color of egg rolls made of composite flour added with pumpkin flour (Fahiera *et al.*, 2021), pumpkin-incorporated cookies (Rošul *et al.*, 2022), pumpkin-fortified powdered drinks (Halim *et al.*, 2024), and instant porridge made from a mixture of pumpkin and brown rice (Slamet *et al.*, 2021).

Table 4 shows that the panelists' preference for egg roll's aroma increased with the percentage of pumpkin added into the batter. The most preferred egg rolls' aroma was samples C and D, scoring 3.85 and 3.90, respectively. The Maillard reaction in food processing can enhance the preference for the aroma of food (Liu *et al.*, 2020), which is a crucial factor in determining the overall quality of food (Cui *et al.*, 2019). Previous studies have reported a higher preference of panelists for pasta made of 10% pumpkin (Minarovičová *et al.*, 2017), pumpkin flour-based cookies (Mustika and Kartika, 2020), and pumpkin-based muffins (Arifin *et al.*, 2019).

In this study, the most preferred egg rolls in terms of flavor were those in sample D, despite a non-significant difference among the samples, because the addition of pumpkin did not significantly affect the taste of the egg rolls. It was the Maillard reaction during the drying process that affected the flavor of the egg roll. The Maillard reaction produces several volatile compounds that enhance the product's flavor (Liu *et al.*, 2020). It has been reported that panelists preferred instant rice cooked at a high temperature (Annan *et al.*, 2023) and instant noodles added with pumpkin flour (Nanthachai *et al.*, 2020).

Regarding crispiness, Table 4 shows that the higher the pumpkin percentage in the batter, the lower the panelists' preference for crispiness. This is because the higher pumpkin proportion in the batter increases the water content and crude fiber, resulting in a less crispy texture. The moisture content of pumpkin ranged between 82.35 and 95.16% (Kulczynski and Michałowska, 2019) and 4.7-5% crude fiber (Farzana *et al.*, 2023). Another study reported that more peanut flour incorporated into extruded snack making would decrease its crispiness (Aussanasuwannakul *et al.*, 2022).

Table 4 shows that egg rolls with 24% pumpkin addition were the most preferred product by panelists based on the attributes of color, aroma, taste, crispness, and overall preference. These results aligned with previous reports that panelists showed overall preference to biscuits made from mocaf flour (Jariyah *et al.*, 2024), pumpkin-based pasta (Minarovičová *et al.*, 2017), snack

Table 4. The preference level of egg roll.

Pumpkin (%)	Parameters				
	Color	Aroma	Taste	Crispiness	Overall
0	3.35±0.02 <sup>b</sup>	3.15±0.12 <sup>a</sup>	3.00±0.05 <sup>a</sup>	4.15±0.13 <sup>d</sup>	2.85±0.07 <sup>a</sup>
8	3.15±0.00 <sup>a</sup>	3.40±0.08 <sup>b</sup>	3.15±0.09 <sup>a</sup>	4.10±0.03 <sup>d</sup>	3.10±0.20 <sup>b</sup>
16	3.45±0.03 <sup>b</sup>	3.85±0.21 <sup>d</sup>	3.75±0.05 <sup>b</sup>	3.50±0.15 <sup>c</sup>	3.70±0.01 <sup>d</sup>
24	3.80±0.01 <sup>d</sup>	3.95±0.03 <sup>d</sup>	3.95±0.07 <sup>c</sup>	3.10±0.11 <sup>b</sup>	4.00±0.05 <sup>c</sup>
32	3.65±0.02 <sup>c</sup>	3.70±0.05 <sup>c</sup>	3.75±0.10 <sup>b</sup>	2.70±0.08 <sup>a</sup>	3.55±0.12 <sup>c</sup>

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different at the level of 0.05.

bars with modified sweet potato flour, and flatbreads made with a mix of flour of sorghum, cassava, and cowpea (Dankwa *et al.*, 2021).

### 3.4 The morphology of egg roll

Figure 2 highlights the significant structural variations among the egg roll samples, demonstrating that the higher the pumpkin percentage in the batter, the tighter the egg roll structure due to less starch content. Starch plays a role in the gelatinization process, which makes the material's structure more open. The gelatinization process in instant porridge products affects the crystallization properties and structure (Yusuf *et al.*, 2022). The fiber content in pumpkin affects the surface appearance of egg roll (Raja and Devarajan, 2024), and pumpkin flour affects the rheological properties of flatbread (Aljahani, 2022). A study revealed that the composition of the biscuit dough influences the microstructure of the biscuits (Ali *et al.*, 2018).

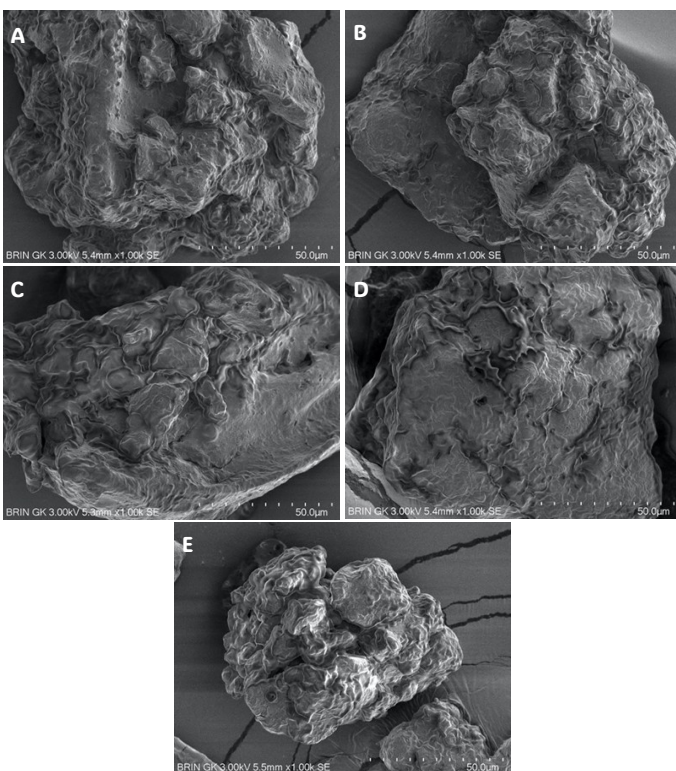


Figure 2. The morphology of egg roll.

### 3.5 Chemical composition of egg roll

Table 5 shows that the egg roll has a moisture content of 2.17-3.02%, which meets the required texture and crispiness criteria for dry food. This result is comparable with previous studies reporting various moisture contents, approximately 2.18 and 3.16% in rice egg rolls added with hydrocolloids (Ho and Atikah, 2024), 2.69-3.14% in egg rolls with hydrolyzed rice protein (Chan *et al.*, 2020), and 4.01% in corn egg rolls (Aini *et al.*, 2023). Slamet *et al.* (2020) reported that the moisture content of instant porridge affected its moisture sorption isotherm and shelf life.

The protein content in egg rolls in this study ranged from 9.78 to 10.59% and increased with the addition of pumpkin as a protein source. Based on Table 5, the protein content in egg rolls with the addition of 24% pumpkin reached 10.67%. The protein content is relatively high, although the egg roll was made of mocaf flour and pumpkin instead of wheat flour, which contains 10-13% protein. These results were comparable with 9.23-10.40% protein contained in egg roll made of hydrocolloid-fortified rice (Ho and Atikah, 2024), 7.47-10.24% in egg roll made of sweet potato (Nurilmala *et al.*, 2024), and 9.79-10.30% in egg rolls made of orange sweet potato and mocaf composite flour (Fahiera *et al.*, 2021).

The ash content in egg roll products differed significantly between samples, with values ranging from 1.17 to 3.45%. The increasing variety of pumpkins affected the ash content of the egg roll. It was attributed to the low ash content of mocaf flour of 1.30% (Mahmudah *et al.*, 2024). The ash content in pumpkin puree in this study was lower than that in pumpkin flour, which has been reported to range from 4.7% to 6.1% (Mohammed *et al.*, 2022).

The fat in egg rolls comes from butter and eggs, not from mocaf or pumpkin, which are low in fat. Mocaf flour contains only about 0.4–0.8% fat, while the fat content in analog rice made from a mixture of mocaf, arrowroot starch, and red bean flour is 1.31% (Wahjuningsih and Susanti, 2018)

Table 5. Chemical composition of egg roll.

Pumpkin (%)	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Carbohydrate by difference (%)	Crude fiber (g/100 g)	$\beta$ -carotene ( $\mu$ g/g)	Antioxidant activity (%)
0	2.20 $\pm$ 0.07 <sup>a</sup>	9.78 $\pm$ 1.09 <sup>a</sup>	1.17 $\pm$ 0.17 <sup>a</sup>	11.06 $\pm$ 1.07 <sup>a</sup>	75.79 $\pm$ 2.09 <sup>c</sup>	0.67 $\pm$ 0.01 <sup>a</sup>	8.37 $\pm$ 1.14 <sup>a</sup>	1.82 $\pm$ 0.26 <sup>a</sup>
8	2.17 $\pm$ 0.00 <sup>a</sup>	9.90 $\pm$ 1.04 <sup>b</sup>	2.01 $\pm$ 0.09 <sup>b</sup>	11.87 $\pm$ 0.98 <sup>d</sup>	74.05 $\pm$ 1.67 <sup>d</sup>	0.69 $\pm$ 0.03 <sup>b</sup>	182.16 $\pm$ 9.52 <sup>b</sup>	25.94 $\pm$ 3.19 <sup>b</sup>
16	2.34 $\pm$ 0.01 <sup>b</sup>	10.07 $\pm$ 0.98 <sup>c</sup>	2.59 $\pm$ 0.07 <sup>c</sup>	11.93 $\pm$ 1.15 <sup>c</sup>	73.07 $\pm$ 2.95 <sup>c</sup>	0.75 $\pm$ 0.01 <sup>c</sup>	197.08 $\pm$ 15.75 <sup>c</sup>	40.26 $\pm$ 5.72 <sup>c</sup>
24	2.49 $\pm$ 0.13 <sup>c</sup>	10.67 $\pm$ 1.78 <sup>d</sup>	2.97 $\pm$ 0.00 <sup>d</sup>	11.67 $\pm$ 1.05 <sup>c</sup>	72.20 $\pm$ 2.15 <sup>b</sup>	0.84 $\pm$ 0.00 <sup>d</sup>	207.74 $\pm$ 12.9 <sup>d</sup>	45.89 $\pm$ 4.96 <sup>d</sup>
32	3.02 $\pm$ 0.10 <sup>d</sup>	10.59 $\pm$ 1.05 <sup>d</sup>	3.45 $\pm$ 0.67 <sup>c</sup>	11.59 $\pm$ 1.41 <sup>b</sup>	71.35 $\pm$ 1.38 <sup>a</sup>	1.15 $\pm$ 0.03 <sup>c</sup>	213.08 $\pm$ 10.5 <sup>c</sup>	48.37 $\pm$ 6.74 <sup>c</sup>

Values are presented as mean $\pm$ SD. Values with different superscripts in the same column are statistically significantly different at the level of 0.05.

Table 5 shows that the carbohydrate content of egg rolls decreased as pumpkin increased in the egg roll batter. The carbohydrate content of the egg rolls, calculated by difference, ranged from 71.35% to 75.79% and originated primarily from mofaf, margarine, and pumpkin. These values were higher than the carbohydrate level reported for mofaf–pumpkin cookies, which contained 45.80% (Indrianingsih *et al.*, 2024); however, they were slightly lower than those of instant pumpkin porridge and arrowroot starch, which were valued at 83.64% (Slamet *et al.*, 2022).

The crude fiber content of egg rolls increased significantly ( $p < 0.05$ ) across treatments from 0.67 to 1.15 g/100 g, with a greater addition of pumpkin in the batter. Other studies reported the crude fiber content of 0.38 - 3.84 g/100 g in noodles enriched with pumpkin and sweet potatoes (Farzana *et al.*, 2023), and 0.2-0.36% in cookies made from a mixture of mofaf flour, carrots, and chicken meat. Previous studies have reported that crude fiber can be sourced from various ingredients, such as pumpkin in pumpkin-based pasta (Minarovičová *et al.*, 2017), fruits in fruit cookies (Krajewska and Dziki, 2023), and sweet potatoes in snack bars made from sweet potato flour (Sunyoto *et al.*, 2019). Mofaf is also a source of fiber, which can remain intact and unseparated from the starch during processing.

The  $\beta$ -carotene content of the egg rolls increased significantly ( $p < 0.05$ ) with the addition of pumpkins. The  $\beta$ -carotene levels in egg rolls incorporated with pumpkin at 0%, 8%, 16%, 24%, and 32% were 8.37  $\mu$ g/g, 182.16  $\mu$ g/g, 197.08  $\mu$ g/g, 207.74  $\mu$ g/g, and 213.08  $\mu$ g/g, respectively. Pumpkin contains a fairly significant amount of  $\beta$ -carotene at 63.4 mg/100 g and a total carotene of 12,814 mmol/kg (Shi *et al.*, 2013). These results were more significant than cookies with mofaf and pumpkin flour (0.5-1.1  $\mu$ g/g) (Indrianingsih *et al.*, 2024). The higher  $\beta$ -carotene content in this study was due to the use of pure pumpkin instead of pumpkin flour.

Antioxidant activity in egg roll increased significantly ( $p < 0.05$ ) with the percentage of pumpkin incorporated in the batter. The antioxidant activity of egg

rolls added with 0% pumpkin was 1.82%, whereas the highest was 48.37% in egg rolls with 32% pumpkin. The antioxidant activity in pumpkin is derived from polysaccharide compounds that can neutralize free radicals (Chen and Huang, 2019), as well as carotenoids that contribute to its attractive colors (Sharma and Bhat, 2021). These results were higher than those of analogous rice made with mofaf (Liu *et al.*, 2020).

#### 4. Conclusion

Incorporating pumpkin into gluten-free egg rolls has increased  $\beta$ -carotene levels and antioxidant activity. Egg rolls with 24% pumpkin added were the product most preferred by panelists based on attributes of color, taste, crispness, and overall preference. The results of the physical analysis showed that the egg roll had a brightness level of 68.09, a redness level of 24.28, a yellowness level of 5.52, a hardness level of 5.64 kg/m<sup>2</sup>, and a brittleness level of 2.71 mm. The chemical properties of the egg roll included a 2.49% moisture content, 10.67% protein, 2.97% ash, 11.67% fat, 72.20% carbohydrates, 0.84% crude fiber, 207.74  $\mu$ g/g  $\beta$ -carotene, and 45.89% antioxidant activity. Conclusively, gluten-free egg roll made of mofaf flour and pumpkin is a feasible functional food that offers health benefits.

#### Conflict of interest

The authors declare that they have no conflict of interest.

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