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Effect of Rice Bran Oil Addition on the Physicochemical, Microstructural, and Antioxidant Properties of Chicken Corned Meat

Ahmed Hafizd Aththoriq[1], Agus Susilo[1*], Herly Evanuarini[1], Dedes Amertaningtyas[1], Khothibul Umam Al Awwaly[1]

[1] Departement of Animal Product Technology, Faculty of Animal Science, Universitas Brawijaya, Malang, Indonesia

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Corresponding Author:
Agus Susilo
agususilo@ub.ac.id

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Abstract: This study aimed to evaluate the effect of rice bran oil (RBO) supplementation on the physicochemical properties, microstructure, and oxidative stability of chicken-based meat emulsion products. RBO is rich in natural antioxidants such as γ-oryzanol and tocopherols, which may enhance product quality. A Completely Randomized Design (CRD) was used with four treatments (0%, 6%, 8%, and 10% RBO) and six replications. Parameters measured included pH, peroxide value (PV), color values (L*, a*, b*), microstructure (SEM), moisture, ash, fat, protein, carbohydrate, water activity (Aw), free fatty acids (FFA), and total acidity. The addition of RBO significantly ($P<0.01$) reduced PV, FFA, and total acidity, indicating improved oxidative stability. It also enhanced protein content, microstructural integrity, and textural properties. Although total fat content increased, the proportion of unsaturated fatty acids improved the lipid profile. Reduction in water activity suggested enhanced shelf stability. These findings demonstrate that Adding 10% rice bran oil (RBO) to chicken meat emulsions improved emulsion stability, reduced lipid oxidation and free fatty acids, enhanced protein retention, and improved microstructure.

Keywords: Chicken meat; Corned; Emulsion; Restructured meat; Rice bran oil

Introduction

Chicken meat emulsion products, such as sausages or canned emulsified meats, are widely consumed processed meat products in Indonesia due to their convenience and protein content. However, their development still faces several quality challenges, including pale color, susceptibility to lipid oxidation, and relatively short shelf life. Lipid oxidation, which leads to rancidity, is a major factor limiting the stability and sensory acceptability of these products. It occurs through oxidative and hydrolytic degradation of fatty acids, particularly in the presence of oxygen, resulting in unpleasant odors, discoloration, and decreased nutritional value (Wang et al., 2023). Moreover, during thermal processing, the degradation of myoglobin contributes to undesirable color changes, often forming brownish metmyoglobin pigments that reduce product appeal (Dissanayake et al., 2024).

To address these issues, numerous studies have explored the incorporation of natural antioxidants into meat formulations as a strategy to improve oxidative stability and extend shelf life. Rice bran oil (RBO), extracted from the aleurone layer and germ of rice grains, has gained attention due to its high content of antioxidant compounds such as γ-oryzanol, tocopherols, and vitamin E, which are known to inhibit lipid peroxidation during both storage and cooking (Das et al., 2025). In addition, RBO offers a favorable fatty acid profile—approximately 22% saturated, 41% monounsaturated, and 37% polyunsaturated fatty acids—which aligns with dietary recommendations for

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cardiovascular health (Dissanayake et al., 2024). Its physicochemical properties, including a high smoke point and oxidative stability, also make RBO a suitable fat source for high-temperature processed meat systems such as emulsified chicken products.

Experimental studies have reported that partial substitution of animal fat with RBO in meat emulsions can improve texture and lipid stability without compromising sensory quality (Martínez et al., 2024). However, research on the specific impact of RBO addition—particularly at varying concentrations—on the quality characteristics of chicken meat emulsion products remains limited. In particular, the effects of RBO on parameters such as peroxide value, microstructure, protein content, and water activity, which are critical to product stability and consumer acceptability, are not yet fully understood.

Therefore, this study aims to evaluate the effect of rice bran oil supplementation on the physicochemical properties, microstructure, and antioxidant activity of chicken meat emulsion products. The novelty of this research lies in the application of RBO as a natural lipid substitute that not only improves oxidative stability but also potentially enhances the functional quality of emulsified chicken products. This research is expected to contribute to the development of healthier, more stable, and functionally enriched meat products, in line with current consumer demands for clean-label and nutritionally balanced processed foods

Method

Materials

The primary material used in this study was skinless, boneless chicken breast (500 g) from broiler chickens, sourced from a traditional market in Malang City, Indonesia. Additional ingredients included tapioca flour (25 g), sugar (10 g), salt (10 g), skim milk powder (25 g), black pepper (2.5 g), shallots (12.5 g), garlic (12.5 g), nutmeg (2.5 g), egg white (60 g), ice cubes (60 g), and isolate soy protein (10 g), all purchased from Superindo Malang. The rice bran oil (according to treatment) used was a commercial product (Sania brand) obtained through an online marketplace. Equipment utilized in the preparation process included an analytical balance (Mettler Toledo AB204-S), a meat chopper (Kenwood), and standard kitchen tools such as baking trays, pots, mixing bowls, knives, cutting boards, gas stoves, spoons, forks, steamers, and spatulas.

Preparation of Corned Chicken with the Addition of RBO

The preparation of chicken corned meat began with thoroughly washing the chicken meat under running water, followed by cutting it into small pieces. The chopped meat was then ground into a fine consistency using a meat chopper, with the addition of salt and ice cubes during the grinding process. Subsequently, other ingredients—tapioca flour, shallots, garlic, egg whites, sugar, black pepper, ISP, skim milk, and rice bran oil—were incorporated into the meat mixture and mixed thoroughly until a homogeneous batter was achieved. The mixture was then placed into baking trays and steamed at approximately 90±2°C for about 30 minutes. After steaming, the samples were cooled to room temperature prior to further analysis.

Research Design

This research is a laboratory experiment using a Completely Randomized Design (CRD) and the data were analyzed using ANOVA with 4 treatments and 6 replications. If different results are obtained between treatments, then it is continued with Duncan's Multiple Range Test (DMRT).

T0: without the use of RBO (control)
T1: Using RBO as much as 6% of the chicken meat used.
T2: Using RBO as much as 8% of the chicken meat used.
T3: Using RBO as much as 10% of the chicken meat used.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software version 24.0. One-way Analysis of Variance (ANOVA) was applied to determine statistically significant differences among treatments at a significance level of $P < 0.01$, based on a completely randomized design comprising four treatments with six replications each. When significant differences were found, Duncan’s Multiple Range Test (DMRT) was used as a post hoc test to further distinguish among the treatment groups.

Physical Quality Testing

The physical quality of the chicken corned meat was evaluated using several key parameters. Measurements of pH and peroxide value (as an indicator of rancidity) were conducted according to standard methods outlined by AOAC (2005). Color parameters (L*, a*, b*) were assessed using a colorimeter in the CIE Lab system, also following AOAC guidelines. In addition, microstructural analysis was performed using a Scanning Electron Microscope (SEM) to observe surface morphology and emulsion stability of the samples.

pH Measurement

The pH value was measured in accordance with the AOAC (2005) protocol. Prior to measurement, the pH meter was calibrated using standard buffer solutions at pH 4 and pH 7. A 1-gram sample was weighed, then ground thoroughly using a mortar and pestle. The ground sample was mixed with 10 mL of distilled water and homogenized for approximately 5 minutes. The homogenate was transferred into a beaker, and the pH was measured by immersing the pH meter electrode into the solution. The pH value was recorded directly from the digital display. After each measurement, the electrode was rinsed with distilled water and dried before the next use.

Rancidity (Peroxide Value)

Rancidity was assessed based on the peroxide value method described by AOAC (2005). A 10-gram sample was placed in a sealed Erlenmeyer flask, followed by the addition of 30 mL of a solvent mixture comprising glacial acetic acid and chloroform in a 3:2 (v/v) ratio. The sample was dissolved and then 0.5 mL of saturated potassium iodide (KI) solution was added. The mixture was shaken gently and left for 1 minute. Subsequently, 30 mL of distilled water was added. The liberated iodine was titrated with 0.1015 N sodium thiosulfate ($Na_2S_2O_3$) using starch as an indicator until the blue color disappeared. The peroxide value was then calculated using the standard Formula 1.

$$Peroxide\ Value\ (meq/kg) = \frac{(Titration\ of\ sample - Titration\ of\ Blank) \times Normality\ of\ Na_2S_2O_3 \times 1000}{Sample\ weight\ (g)} \quad (1)$$

*Color Measurement L*a*b**

Colour analysis was conducted using a colorimeter to determine the brightness and chromatic attributes of the sample. The device was turned on by pressing the power button, and calibrated using a standard white tile. The sample was placed directly on the lens of the instrument. Measurements were recorded using the CIE L*a*b* colour system, where L* indicates lightness, a* represents the red-green axis, and b* corresponds to the yellow-blue axis. The values of L*, a*, and b* were recorded directly from the instrument.

Microstructure Analysis

The microstructure of the chicken corned meat was observed using a Scanning Electron Microscope (SEM). The sample was sliced into sections of approximately 1–2 mm in thickness. The slices were fixed in 2.5% glutaraldehyde solution for about 1 hour, then rinsed with distilled water. After rinsing, the samples were sequentially dehydrated in increasing concentrations of ethanol: 10, 60, 70, 80, 90, and 100%, each for approximately 30 minutes. The dehydrated samples were stored in sealed vials at 4°C until observation. Prior to SEM analysis, the samples were mounted on SEM holders and sputter-coated with gold. Observations were performed using a HITACHI TM 3000 SEM.

Chemical Quality Analysis

The chemical quality analysis included several parameters. Crude fiber content was determined using the enzymatic method in accordance with AOAC (2005). Carbohydrate content was calculated using the by-difference method as described by AOAC (2005). Protein content was measured using the Kjeldahl method AOAC (2005), while ash content was analyzed using the dry ashing method AOAC (2005). Fat content was determined by the Soxhlet extraction method (AOAC, 2005), and moisture content was analyzed using the thermogravimetric method (AOAC, 2005). Water activity (Aw) was measured following standard AOAC procedures (AOAC, 2005). Antioxidant activity was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method in accordance with AOAC (2005).

Crude Fiber Content

Crude fiber was analyzed using the enzymatic method as described by AOAC (2005). Approximately 1 g of ground sample was weighed and placed into a 250 mL Erlenmeyer flask. Then, 100 mL of acidic detergent solution was added and the mixture was refluxed using an Allihn condenser for 1 hour. The mixture was filtered using filter paper, and the residue was washed with approximately 300 mL of hot water in three separate rinses. The residue was then dried in an oven at 105 °C for 8 hours. After drying, the sample was cooled in a desiccator for 30 minutes and then weighed. The percentage of crude fiber was calculated using the Formula 2.

$$Crude\ Fiber\ Content\ (\%) = \frac{Weight\ of\ Residue - Weight\ of\ Filter\ Paper \times 100\%}{Sample\ weight\ (g)} \quad (2)$$

Carbohydrate Content

The carbohydrate content was determined using the by difference method based on AOAC (2005). This method calculates carbohydrate content indirectly by subtracting the sum of moisture, protein, fat, fiber, and ash contents from 100%. The calculation Formula 3.

$$\text{Carb}\ (\%) = 100\% - (\text{Pro}\ \% + \text{Fat}\ \% + \text{Ash}\ \% + \text{Moisture}\ \%) \quad (3)$$

Protein Content

Protein content was determined using the Kjeldahl method in accordance with AOAC (2005). A total of 2 grams of finely ground sample was weighed and dissolved in 20 mL of distilled water in a porcelain dish. The mixture was stirred for 15 minutes and then filtered. A 10 mL aliquot of the filtrate was transferred into an Erlenmeyer flask. Subsequently, 20 mL of distilled water, 0.4 mL of calcium oxalate solution (Ca-oxalate:water = 1:3), and 1 mL of phenolphthalein indicator were added.

After standing for approximately 2 minutes, the solution was titrated with 0.1 N sodium hydroxide (NaOH) until a pink endpoint was reached (first titration).

Then, 2 mL of 40% formaldehyde was added to the same solution, and a second titration was conducted using 0.1 N NaOH until the pink color reappeared (second titration). The volumes of NaOH used in both titrations were recorded, and the nitrogen content was calculated using the Formula 4.

$$\text{Nitrogen Content} = \frac{(\text{A ml aquades} - \text{B ml aquades})}{\text{Weight (g)} \times 10 \times \text{Normality NaOH X } 14{,}008 \times 100\%} \quad (4)$$

$$\text{Protein Content (\%)} = \%\text{ N x Conversion Factor (6.25)}$$

Ash Content

Ash content was determined using the dry ashing method based on the AOAC (2005) procedure. A 10-gram sample was weighed and placed into a porcelain crucible that had been previously dried and weighed. The crucible containing the sample was then incinerated in a muffle furnace at 525 °C until all organic matter was completely combusted, leaving behind a white or grayish residue. After the ashing process was complete, the crucible was cooled in a desiccator to prevent moisture absorption from the air and then reweighed. The ash content was calculated using the Formula 5.

$$\text{Ash Content (\%)} = \frac{\text{Weight of ash residue}}{\text{Initial Weight of Sample}} \times 100\% \quad (5)$$

This analysis reflects the total mineral content of the sample after complete oxidation of organic components.

Fat Content

Fat content was determined using the Soxhlet extraction method in accordance with AOAC (2005). Prior to use, filter paper was dried in an oven at 105 °C for 12 hours, cooled in a desiccator for 15–30 minutes, and then weighed. A 1-gram sample was wrapped in the pre-dried filter paper to form a cylindrical packet. Petroleum ether (PE) was used as the solvent, with 40 mL added above and 60 mL below the sample packet. The extraction was performed using a Soxhlet apparatus for 2–3 hours.

After extraction, the filter paper containing the sample residue was removed, dried again in an oven at 105 °C for 24 hours, cooled in a desiccator for 15–30 minutes, and reweighed. The fat content was calculated based on the weight difference before and after extraction, using the Formula 6.

$$\text{Fat (\%)} = \frac{(\text{filter paper weight} + \text{cotton} + \text{sample after drying}) - \text{Weight of filter paper})}{\text{Sample weight}} \quad (6)$$

Moisture Content

Moisture content was determined using the thermogravimetric method, following the AOAC (2005) protocol. Petri dishes were labeled according to sample identity, dried in an oven at 100–105 °C for 12 hours, then cooled in a desiccator for 1 hour and weighed to obtain a stable initial weight. A sample of 2–5 grams was weighed and placed into the pre-weighed dish. The sample was then dried in the oven at the same temperature for 24 hours. After drying, the dish was again cooled in a desiccator for 1 hour and reweighed until a constant weight was achieved. Moisture content was calculated based on the weight loss before and after drying using the Formula 7.

$$\text{Moisture (\%)} = \frac{(\text{dish + fresh}) \times (\text{dish + dried})}{\text{Sample weight (g)}} x100\% \quad (7)$$

Water Activity (Aw)

Water activity (Aw) was measured using a water activity meter, according to AOAC (2005). Prior to measurement, the device was calibrated using a standard solution of barium chloride dihydrate ($BaCl_2 \cdot 2H_2O$). The calibration solution was placed in the measurement chamber and sealed for approximately 3 minutes until a stable reading was observed. The sample was then placed into the chamber, sealed, and allowed to equilibrate for another 3 minutes or until the reading stabilized. If the room temperature exceeded 20 °C, Aw values were corrected by adding the temperature difference multiplied by a correction factor of 0.002. Conversely, if the temperature was below 20 °C, the correction was subtracted.

Free Fatty Acif

Free fatty acid content was evaluated following the AOAC (2005) protocol. The sample of the material to be analyzed was weighed as much as 10g. Then added neutral alcohol that had been heated as much as 50ml. PP indicator was added. The sample was titrated with a standardized 0.1 N NaOH solution until it turned pink and did not disappear for 30 seconds. Free fatty acid was calculated using the Formula 8.

$$\text{fatty acid (\%)} = \frac{\text{NaOH x norm NaOH x molecular fatty acid)}}{(\text{sample weight x 1000})} x100\% \quad (8)$$

Total fatty acids

Total acid test was conducted using titration method based on AOAC (2005). The sample was dissolved with distilled water up to 50ml, then filtered using filter paper. 20ml of filtrate was added with 2 drops of PP indicator, then titrated with 0.1 N NaOH solution until the color changed. Total acid calculation was calculated using the formula:

$$\text{Total Acid (\%)} = \frac{\text{V1 x N x B}}{\text{V2 x 1000}} \text{ x } 100\% \quad (9)$$

B : Molecular weight of lactic acid (90)
N : Normality of NaOH
V1 : Volume of NaOH used (ml)
V2 : Weight of titrated sample (g)

Result and Discussion

Effect of Rice Bran Oil (RBO) Addition on the Physical Quality of Chicken Corned Meat

Table 1. Effect of rice bran oil (RBO) addition on the physical quality of chicken corned meat

Treatment	pH (%) ± SD	Rancidity (%) ± SD
T0	6.24 ± 0.02[a]	0.39 ± 0.03[a]
T1	6.35 ± 0.03[b]	0.34 ± 0.01[b]
T2	6.45 ± 0.02[c]	0.29 ± 0.01[c]
T3	6.57 ± 0.07[d]	0.24 ± 0.02[d]

Description : [a,b,c,d] Different superscripts in the column indicate a very significant difference (P<0.01)

Effect of Rice Bran Oil (RBO) on pH of Chicken Corned Meat

The statistical analysis indicated that the addition of rice bran oil (RBO) at different concentrations had a significant effect on the pH of chicken corned meat (P < 0.01). The pH values ranged from 6.24 to 6.57, with the lowest value observed in the control group (P0) at 6.24, and the highest in the treatment with 10% RBO (P3) at 6.57. The results showed an increasing trend in pH values with increasing levels of RBO in the formulation.

The use of RBO in broiler chicken feed has been shown to influence the physical quality of the meat, particularly pH, which directly affects the quality of processed meat products. According to Park et al. (2025) in the journal Animals, RBO supplementation in broiler diets significantly reduced both the initial (20 minutes post-mortem) and ultimate (24 hours post-mortem) pH values in breast and thigh meat.

The pH of meat is a critical factor influencing water-holding capacity, juiciness, and the final texture of processed products such as chicken corned meat. High pH values are generally associated with reduced cooking losses, increased juiciness, and softer textures (Hidayah et al., 2019; Mahaputra et al., 2023; Mahmudah et al., 2022)

In addition to pH, feed composition plays a crucial role in meat quality. While vegetable oils such as RBO offer nutritional and oxidative stability benefits, their impact on meat pH must be carefully managed. Formulations incorporating RBO must be optimized to prevent undesirable changes in pH, thus preserving the physical quality of chicken corned meat (Hidayah et al., 2019)

Effect of RBO on Rancidity (Peroxide Value)

Statistical analysis revealed that different levels of RBO in the formulation had a highly significant effect (P < 0.01) on the rancidity of chicken corned meat, as measured by peroxide value. The peroxide values ranged from 0.24% to 0.39%, with the highest value recorded in the control treatment (P0) at 0.39%, and the lowest in the treatment with 10% RBO (P3) at 0.24%. A linear downward trend in peroxide values was observed as the concentration of RBO increased.

This decline in rancidity is closely associated with the presence of natural antioxidants in rice bran oil, such as γ-oryzanol and tocopherols, which are known to inhibit lipid oxidation. These compounds help stabilize lipids during processing and storage. The findings are consistent with those of Zhang et al. (2025), who reported that RBO delays oxidative degradation in meat emulsions, thereby maintaining lipid stability and minimizing the formation of rancid compounds.

*Effect of Rice Bran Oil (RBO) Addition on Color Attributes L a*b**

Table 2. Effect of Rice Bran Oil (RBO) Addition on Color Attributes L a*b* of Chicken Corned Meat

Treatment	Color L a*b*		
	Lightness (L) ± SD	Redness (a*) ± SD	Yellowness (b*) ± SD
T0	62.97 ± 0.88[a]	3.96 ± 0.60[a]	17.84 ± 0.66[a]
T1	59.04 ± 0.73[b]	6.23 ± 0.24[b]	14.50 ± 0.57[b]
T2	55.91 ± 0.76[c]	9.96 ± 0.38[c]	12.61 ± 0.37[c]
T3	53.65 ± 0.84[d]	1.08 ± 0.93[d]	11.55 ± 0.36[d]

Description : [a,b,c,d] Different superscripts in the columns indicate a highly significant difference (P<0.01)

Lightness (L)

Analysis of variance revealed that the addition of rice bran oil (RBO) at varying concentrations had a highly significant effect (P < 0.01) on the lightness (L*) value of chicken corned meat. The L* value decreased consistently as the concentration of RBO increased. The highest lightness value was observed in the control treatment (P0) at 62.97, while the lowest was recorded in the 10% RBO treatment (P3) at 53.65. This decline indicates that the product became darker with higher RBO inclusion levels.

This color shift can be attributed to the chemical composition of rice bran oil, which contains natural antioxidants such as γ-oryzanol, tocopherols, and tocotrienols. These compounds contribute to lipid stabilization and inhibit oxidation during thermal processing and storage. Selim et al. (2021) reported that dietary supplementation with RBO in broiler chickens improved the antioxidant status of muscle tissue, potentially helping to preserve color brightness during storage.

However, Chayawat & Rumpagaporn, 2020) found that substituting defatted rice bran (DRB) in chicken nugget formulations up to 15–20% significantly reduced L* values, likely due to Maillard reactions and caramelization occurring during cooking. Thus, although RBO possesses antioxidant properties that may protect color, careful formulation and process control are essential to maintain a desirable appearance in meat products.

Redness (a)*

The variance analysis demonstrated that RBO addition significantly influenced the redness (a*) value of chicken corned meat ($P < 0.01$). The a* value increased progressively with higher RBO concentrations. The lowest a* value was recorded in the control group (P0) at 3.96, while the highest was found in the 10% RBO treatment (P3) at 12.08. This increase indicates that RBO enhances the red color intensity of the product.

This enhancement is associated with the antioxidant activity of RBO's bioactive compounds—γ-oryzanol and tocopherols—which can inhibit lipid oxidation and protect myoglobin from oxidative degradation during thermal processing and storage. Myoglobin stability is critical, as it determines the red color of processed meat products. Studies by El-Waseif et al. (2022); Selim et al. (2021) reported that RBO can improve tissue antioxidant status and help preserve color stability in meat systems. While specific research on the impact of RBO on a* values in chicken corned meat is limited, the presence of such bioactives suggests strong potential for color enhancement. Further investigation is needed to elucidate the exact mechanisms.

Yellowness (b)*

The analysis of variance also indicated a significant effect ($P < 0.01$) of RBO concentration on the yellowness (b*) value of chicken corned meat. A consistent decline in b* values was observed with increasing RBO levels. The highest b* value was observed in the control (P0) at 17.84, while the lowest was recorded in the 10% RBO treatment (P3) at 11.55. This decrease indicates a reduction in yellow color intensity as RBO concentration increases.

This trend is likely due to the natural properties of RBO, which lacks strong yellow pigments. Additionally, RBO contains bioactive compounds such as polyunsaturated fatty acids (PUFAs), γ-oryzanol, tocopherols, and tocotrienols that primarily function in oxidative stabilization rather than direct coloration. Chayawat & Rumpagaporn (2020) reported that such components contribute to improved lipid stability in animal-based foods.

However, as Murru et al. (2021) noted, increased oxidative stability does not always correlate with enhanced color intensity, particularly when initial pigment levels are low. Furthermore, Kong et al. (2023) explained that replacing animal fats with vegetable oils in meat products may alter color attributes—including b* values—depending on the formulation and processing conditions. These findings suggest that while RBO may offer functional benefits, its influence on yellowness must be managed through precise formulation.

Effect of Using Rice Bran Oil on the Microstructure Quality of Chicken Corned Beef

A Scanning Electron Microscope (SEM) was used to observe the microstructure of chicken corned meat samples treated with various concentrations of rice bran oil (RBO), as shown in Figure 1. The SEM images at 100× magnification revealed distinct structural differences among treatments. The inclusion of RBO led to a more uniform and compact matrix, in contrast to the control sample, which showed looser, more porous structures with uneven protein-fat distribution.

The improved microstructure observed in RBO-treated samples can be attributed to the presence of bioactive compounds in rice bran oil, particularly oryzanol and tocopherols, which possess antioxidant properties that stabilize lipids during thermal processing (El-Waseif et al., 2022). These compounds help prevent excessive lipid oxidation, which would otherwise disrupt protein structures and emulsion stability. Barros et al. (2021) also reported that replacing animal fat with RBO in meat emulsions improved matrix homogeneity, water retention, and overall tissue integrity, contributing to smoother porosity and enhanced emulsion structure.

Mechanism of Antioxidant–Protein Interaction in RBO

Rice bran oil contains several potent antioxidant compounds, including γ-oryzanol, tocopherols, and tocopherol esters, which play a critical role in protecting protein structures during thermal processing such as steaming and mixing. During heating, meat proteins are prone to denaturation and oxidative damage, which can result in peptide chain fragmentation, unwanted cross-linking, and a decline in functional and nutritional quality.

The antioxidants in RBO act by donating hydrogen atoms or electrons to neutralize reactive oxygen species (ROS), thus preventing oxidative attacks on functional groups such as thiols (–SH), amines ($–NH_2$), and carboxyls (–COOH). In particular, γ-oryzanol may engage in hydrophobic interactions with non-polar regions of amino acid chains, helping to stabilize protein secondary and tertiary structures and reduce aggregation. This contributes to better water and fat retention and enhances juiciness and tenderness in the final product.

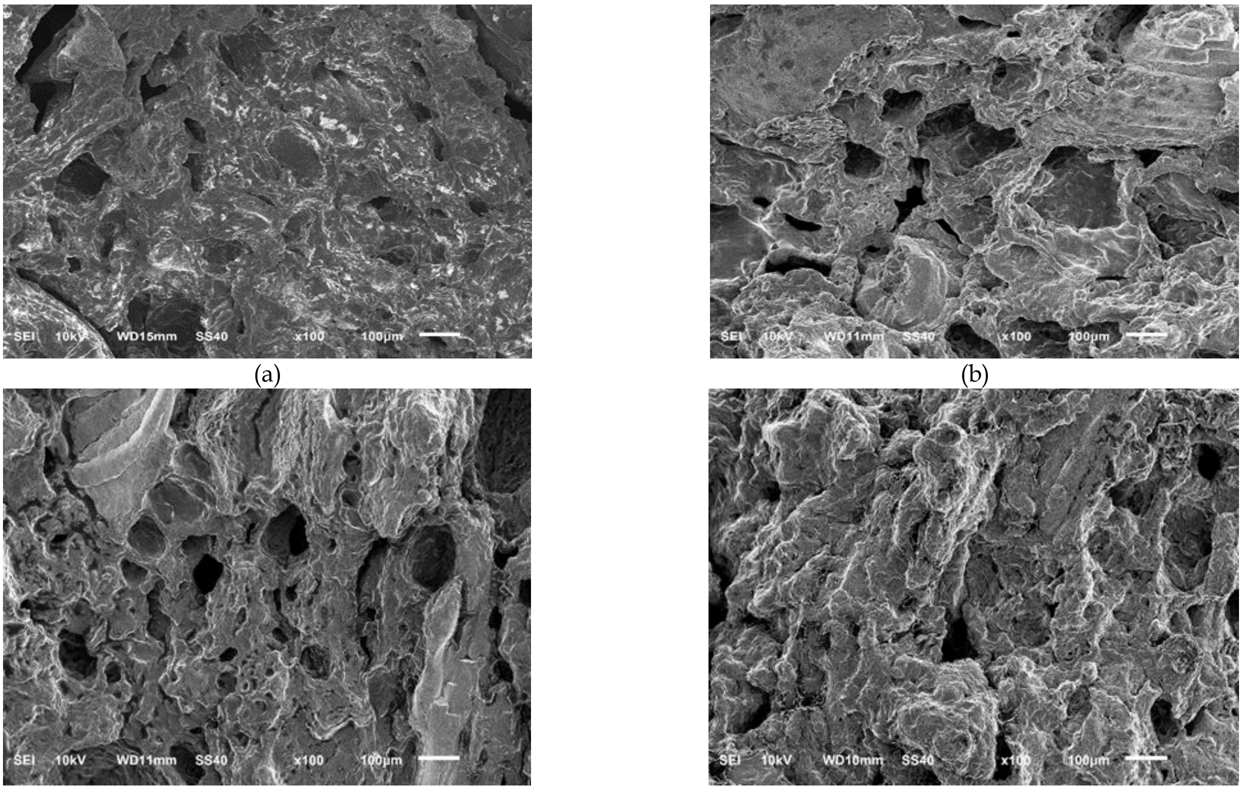

Figure 1. Microstructure of Chicken Corned Meat with RBO (100× Magnification): (a) T0; (b) T1; (c) T2; and (d) T3

Selim et al. (2021) demonstrated that RBO supplementation in meat products resulted in improved emulsion uniformity and reduced heat-induced protein damage. Similarly, Estévez (2021) reported that antioxidants in plant-based oils increased the thermal stability of meat proteins during high-temperature processing. These findings highlight that antioxidants in RBO function not only as lipid protectants but also interact directly with protein molecules to preserve structural integrity and sensorial quality in processed meat products such as chicken corned meat.

Effect of RBO Addition on the Chemical Quality of Chicken Corned Meat

Crude Fiber Content

The analysis of variance showed a highly significant effect (P < 0.01) of increasing rice bran oil (RBO) concentration on the crude fiber content of chicken corned meat. This outcome is likely due to the bioactive components in RBO, such as γ-oryzanol and tocotrienols, which not only provide antioxidant properties but may also contribute to the dietary fiber composition of the final product (Pattananandecha et al., 2019; Shen et al., 2018; Zhu et al., 2023) further supported that these bioactives contribute to oxidative stability, which helps retain nutritional integrity.

The highest fiber content was observed in the 10% RBO treatment (P3) at 0.24%, while the lowest was in the control (P0) at 0.06%. These findings are consistent with other studies showing that ingredients such as rice bran — a source component of RBO — can act as a functional fiber source in food formulations, thereby enhancing product health functionality (Zhu et al., 2023).

Table 3. Quality of Corned Chicken using Rice Bran Oil

Treatment	Crude Fiber (%) ± SD	Carbohydrates (%) ± SD	Protein (%) ± SD	Ash (%) ± SD	Fat (%) ± SD
T0	0.06 ± 0,01[a]	7.13 ± 0.30[a]	13.17 ± 0.30[a]	3.24 ± 0.11[a]	16.73 ± 0.54[a]
T1	0.10 ± 0,01[b]	11.91 ± 0.26[b]	13.86 ± 0.26[b]	3.52 ± 0.07[b]	18.75 ± 0.31[b]
T2	0.18 ± 0,01[c]	15.13 ± 0.66[c]	14.45 ± 0.26[c]	3.73 ± 0.05[c]	20.85 ± 0.76[c]
T3	0.24 ± 0,01[d]	17.55 ± 0.99[d]	15.00 ± 0.19[d]	3.90 ± 0.12[d]	23.76 ± 0.90[d]

Description : [a,b,c,d] Different superscripts in the columns indicate a highly significant difference (P<0.01)

Although RBO is not a primary source of fiber, its incorporation into complex food systems may alter nutrient interactions and enhance the functional benefits of fiber-rich ingredients. As noted by Ghasemzadeh et al. (2018) the antioxidant activity of RBO contributes to the overall nutritional quality, making it relevant for meat-based products like chicken corned meat. However, Agista et al. (2022) highlight the need for further studies specifically on the fiber-enhancing effects of RBO in processed meat applications.

Overall, the use of RBO not only improves the crude fiber content but also offers broader health benefits due to its bioactive profile, including anti-inflammatory properties and chronic disease prevention potential ((Noureen et al., 2021; Pattananandecha et al., 2019)). These attributes make RBO a promising functional ingredient for health-oriented food innovation.

Carbohydrate Content

The analysis of variance demonstrated that the addition of RBO at different levels significantly influenced the carbohydrate content of chicken corned meat ($P < 0.01$). Carbohydrate levels ranged from 7.13% in the control group (P0) to 17.55% in the 10% RBO group (P3), indicating a consistent increase in carbohydrate content with higher RBO inclusion.This increase is not directly due to the carbohydrate content of RBO, which is relatively low, but is likely an indirect result of changes in the product matrix induced by RBO's presence. RBO contains dietary fiber and bioactives that can enhance the structural retention of solids, leading to elevated measured carbohydrate content (Zaini et al., 2022). Selim et al. (2021) noted that in meat product reformulations, RBO improves antioxidant capacity and fiber content, which can influence proximate analysis values.

Furthermore, Mazumder et al. (2023) explained that the water-holding capacity and improved viscosity resulting from soluble fiber in RBO may contribute to higher carbohydrate values measured through gravimetric methods. Hence, the increased carbohydrate content in RBO-treated products reflects a combination of enhanced matrix integrity and fiber-mediated hydration properties.

Protein Content

The analysis of variance indicated a statistically significant effect ($P < 0.01$) of RBO inclusion on protein content in chicken corned meat. Protein levels ranged from 13.17% (P0) to 15.00% (P3), showing a positive trend with increasing RBO concentration.

These results confirm that RBO contributes positively to protein retention, likely through its antioxidative role in preserving protein structures during thermal processing. Compounds such as γ-oryzanol and tocopherols in RBO may prevent protein oxidation and denaturation, thus improving the functional and nutritional integrity of proteins during cooking.

According to the Indonesian National Standard (SNI 3775:2015), the minimum required protein content for poultry corned products is 12%. All treatments in this study met or exceeded this threshold, indicating compliance with national quality standards. These findings demonstrate that RBO can enhance the nutritional value of corned meat while maintaining regulatory quality benchmarks.

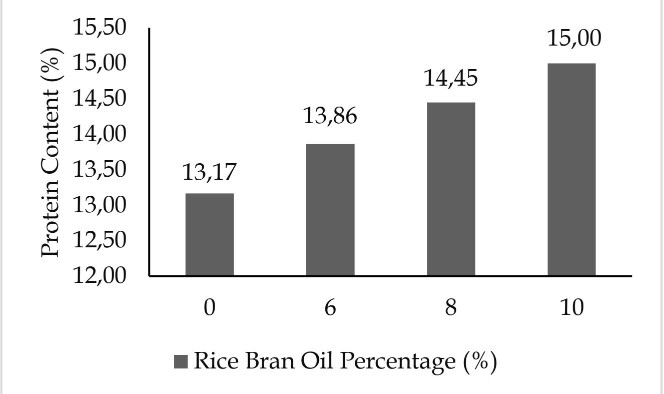

Figure 2. Graph of the effect of adding RBO on protein content

Although rice bran oil (RBO) does not naturally contain protein, its addition to chicken corned meat significantly increased the measured protein content, as illustrated in Figure 2. This phenomenon can be explained through several indirect mechanisms. First, RBO inclusion may reduce the product's moisture content, thereby concentrating solids—including protein—per 100 grams. This is known as the concentration effect, where the absolute amount of protein remains the same, but its relative proportion increases due to reduced water content.

Second, RBO contains natural antioxidants such as γ-oryzanol and tocopherols, which protect proteins from thermal degradation. (Cho et al., 2022) reported that RBO contains γ-oryzanol and certain functional proteins, although their contribution depends on the balance of the final nutrient profile. These antioxidant effects may improve protein retention, resulting in higher analytical values post-processing.

Third, RBO enhances emulsion stability within the corned meat matrix, which helps maintain protein structure throughout processing. Ganesan et al. (2020) found that the use of RBO in meat emulsions improved emulsion uniformity and protein matrix integrity. Similarly, Punia et al. (2021) observed that antioxidants in RBO contribute to structural stability and nutrient retention during heat treatment. Selim et al. (2021) also noted that lipid-based ingredients can affect phase distribution and proximate composition, especially in low-moisture meat products.

Although RBO is not a protein source, its inclusion clearly supports protein content through moisture modulation, antioxidative protection, and emulsification mechanisms. However, other studies suggest that improper use of vegetable oils in poultry diets may lower muscle protein content due to increased fat deposition (Coritama et al., 2021; Nadia et al., 2023), highlighting the importance of balanced formulation in RBO-based corned products.

Ash Content

The addition of rice bran oil at increasing concentrations significantly affected the ash content of chicken corned meat (P < 0.01). Ash values ranged from 3.24% (P0) to 3.90% (P3), showing a linear increase with higher RBO levels. Although RBO is primarily a lipid source, it contains trace minerals such as magnesium, potassium, and phosphorus. However, according to (Tudose et al., 2014), the mineral contribution of RBO in meat products is minimal. Therefore, the observed increase in ash may be due to cumulative effects of non-RBO ingredients, or from changes in the total solid content after thermal processing and drying. Despite the limited impact on mineral composition, the presence of RBO's bioactives, particularly tocopherols and γ-oryzanol, can enhance oxidative stability, indirectly supporting the functional quality of the product (Zhang et al., 2025).

Fat Content

Statistical analysis showed that RBO addition significantly influenced the fat content of chicken corned meat (P < 0.01). Fat levels increased from 16.73% (P0) to 23.76% (P3), with a clear upward trend corresponding to the RBO inclusion level, as presented in Figure 3.

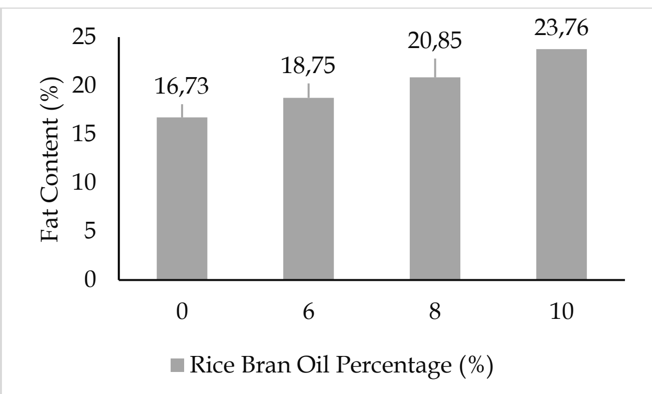

Figure 3. Graph of the effect of adding RBO on fat content

This increase is expected, as RBO is a direct fat source. However, the quality of fat in RBO is characterized by a favorable composition—rich in monounsaturated and polyunsaturated fatty acids, and low in saturated fat—which is considered beneficial for cardiovascular health (Mahmud et al., 2023). Moreover, Park et al. (2025) emphasized that RBO consumption improves lipid profiles in humans by lowering total cholesterol, LDL, and triglycerides.

While the overall fat content increases, the physiological quality of the fat improves due to the shift toward unsaturated lipid profiles. This makes RBO a promising ingredient for reformulating meat products to be healthier, without sacrificing texture or flavor.

The incorporation of rice bran oil (RBO) into processed meat formulations serves not only as a source of plant-derived fat, but also plays a critical role as a natural emulsifying agent, enhancing the structural stability of emulsions during thermal processing. Punia et al. (2021) reported that substituting animal fat with RBO in low-fat meat products significantly improved physicochemical properties, including emulsion stability, final fat content, and textural quality. Although the overall fat content in the product may increase, the resulting lipid composition is physiologically healthier, primarily due to RBO's high concentration of unsaturated fatty acids.

This perspective is reinforced by a meta-analysis conducted by Estévez (2021) which demonstrated that regular consumption of RBO contributes to improved blood lipid profiles, notably by lowering total cholesterol and LDL levels. Thus, the increase in fat content due to RBO inclusion should not be interpreted as a degradation of product quality. Instead, it reflects a functional shift in lipid composition toward a healthier profile, aligning with current nutritional recommendations. Within the context of food reformulation, the strategic use of RBO in meat-based products such as chicken corned meat can help maintain desirable physicochemical integrity while enriching the functional value of the product as a health-oriented food item.

On the other hand, in some contexts, the use of RBO has been shown to reduce total fat content in animal tissues. RBO contains bioactive compounds such as γ-oryzanol and tocopherols with hypolipidemic properties, which may contribute to a more favorable lipid metabolism.

For instance, Kang & Kim (2016) found that supplementation of broiler diets with rice bran oil led to a significant reduction in both fat and cholesterol levels in muscle tissues. These findings suggest the potential of RBO as a viable alternative to animal fats in processed food formulations. Consistently, the meta-analysis by

Punia et al. (2021) confirmed that RBO intake in humans is associated with reductions in total cholesterol, LDL, and triglyceride levels, further validating its use in food products designed to support cardiovascular health and lipid balance.

Effect of Using Rice Bran Oil on the Water Activity of Chicken Corned Beef

The analysis of variance revealed a statistically significant effect ($P < 0.01$) of rice bran oil (RBO) addition at varying concentrations on the water activity (aw) of chicken corned meat. The highest aw value was recorded in the control group (P0) without RBO at 0.92, while the lowest was observed in the 10% RBO treatment (P3) at 0.89. This decreasing trend in water activity suggests an inverse relationship between RBO concentration and the amount of free moisture available in the final product.

Table 4. The effect of RBO use on the water activity of corned chicken

Treatment	Water Activity (%) ± SD
P0	0.92 ± 0.03[a]
P1	0.91 ± 0.02[b]
P2	0.90 ± 0.01[c]
P3	0.89 ± 0.04[d]

Description: [a, b, c, d] Different superscripts in the columns indicate a highly significant difference ($P<0.01$)

This reduction in aw is closely associated with the physicochemical properties of RBO, particularly its content of polyunsaturated fatty acids (PUFA) and bioactive compounds such as γ-oryzanol and tocopherols. These components not only enhance the nutritional profile of the product but may also affect internal moisture dynamics by altering protein structure and water-binding interactions. As reported by Horbańczuk et al. (2019) the antioxidant-rich nature of RBO improves the oxidative stability and nutritional quality of meat tissues. However, Hülsebusch et al. (2025) highlighted that high PUFA levels may accelerate lipid oxidation, potentially leading to protein denaturation and a reduction in water-holding capacity. This decline in bound water subsequently contributes to lower measured aw values in the final product.

Thus, while RBO serves as a beneficial functional ingredient, its influence on water activity underscores the importance of optimizing formulation to ensure microbiological stability and desired textural properties in meat-based products such as chicken corned meat.

Effect of RBO Addition on Free Fatty Acid (FFA) Content in Chicken Corned Meat

The analysis of variance indicated that the addition of rice bran oil (RBO) at varying concentrations had a highly significant effect ($P < 0.01$) on the free fatty acid (FFA) content of chicken corned meat. The measured FFA values ranged from 0.01% to 0.04%, with the highest level observed in the control group (P0) at 0.04%, and the lowest in the 10% RBO treatment (P3) at 0.01%. This linear decrease in FFA values suggests that increasing RBO concentration can effectively reduce the formation of free fatty acids in the final product.

Table 5. Effect of Rice Bran Oil (RBO) Addition on Free Fatty Acid Content of Chicken Corned Meat)

Treatment	*Free Fatty Acid* (%) ± SD
P0	0.04 ± 0.01[a]
P1	0.03 ± 0.00[b]
P2	0.02 ± 0.00[c]
P3	0.01 ± 0.00[d]

Description : [a,b,c,d] Different superscripts in the columns indicate a highly significant difference ($P<0.01$)

Although RBO naturally contains relatively high levels of FFA due to the action of endogenous lipase enzymes, especially in unstabilized rice bran, the use of thermally stabilized or refined RBO can significantly reduce the risk of lipid hydrolysis in processed meat products. Mahmud et al. (2023) noted that inadequate postharvest stabilization can lead to rapid lipase activity and elevated FFA. However, stabilization techniques such as microwave heating and extrusion have been shown to suppress lipase activity and reduce lipid degradation (Zhou et al., 2025). Furthermore, reesterification processes using glycerol in the presence of catalysts like $SnCl_2$ have also proven effective in lowering FFA levels in RBO (Cho et al., 2022).

The reduction in FFA levels observed in chicken corned meat formulated with RBO underscores the importance of using high-quality, stabilized RBO in meat product development. This contributes to improved chemical stability and shelf-life, affirming RBO's suitability as a functional fat substitute in healthier, oxidation-resistant meat formulations.

Effect of Using Rice Bran Oil on the Total Acid of Chicken Corned Beef

The analysis of variance showed that the addition of rice bran oil (RBO) at various concentration levels had a highly significant effect ($P < 0.01$) on the total acid content of chicken corned meat. The measured total acid values ranged from 0.03% to 0.06%, with the highest observed in the control group (P0) at 0.06% and the lowest in the 10% RBO treatment (P3) at 0.03%. This data indicates a negative correlation between RBO concentration and the formation of total acid in the final product.

Table 6. The effect of using RBO on the total acid of chicken corned beef

Treatment	*Free Fatty Acid* (%) ± SD
P0	0.06 ± 0.01[a]
P1	0.05 ± 0.00[b]
P2	0.04 ± 0.00[c]
P3	0.03 ± 0.00[d]

Description : [a,b,c,d] Different superscripts in the columns indicate a highly significant difference (P<0.01)

The decline in total acid content is closely associated with the antioxidative properties of bioactive compounds present in RBO, such as γ-oryzanol and tocopherols, which are known to inhibit lipid oxidation and acid formation during storage and thermal processing (Mazumder et al., 2023). These antioxidant effects contribute to improved chemical stability and extended shelf-life of the product. However, it should be noted that RBO is also rich in polyunsaturated fatty acids (PUFAs), which are chemically more prone to oxidation. Selim et al. (2021) reported that full substitution of palm oil with RBO in broiler diets led to increased PUFA levels in muscle tissue, which in turn may accelerate lipid oxidation and acid formation.

Therefore, while RBO may reduce total acid content through its antioxidative action, the balance between oxidative stability and unsaturated fat content must be carefully considered. Reformulation strategies that combine RBO with other oils or additional antioxidants may be required to ensure chemical and sensory stability in processed meat products such as chicken corned meat.

Effect of Rice Bran Oil Addition on the Organoleptic Quality of Chicken Corned Meat

Figure 4 illustrates that the larger the area of the radar chart, the higher the overall organoleptic quality as perceived by the panelists. The sensory evaluation was conducted using a 5-point hedonic scale, where a score of 1 indicates strong dislike and a score of 5 represents high acceptance. Based on Table 8 and Figure 4, the control treatment (P0) received the lowest scores across all evaluated attributes—color, aroma, taste, texture, and overall acceptance. In contrast, the treatment with 10% rice bran oil addition (P3) yielded the highest scores for all parameters.

Table 8. The effect of using RBO on the organoleptic properties of corned chicken

Treatment	Color (%) ± SD	Scent (%) ± SD	Flavor (%) ± SD	Texture (%) ± SD	Acceptability (%) ± SD
T0	3.60 ± 0.50[a]	3.56 ± 0.51[a]	3.20 ± 0.41[a]	3.12 ± 0.33[a]	3.56 ± 0.51[a]
T1	4.40 ± 0.50[b]	4.12 ± 0.33[b]	4.28 ± 0.46[b]	4.16 ± 0.37[b]	4.08 ± 0.28[b]
T2	4.60 ± 0.50[c]	4.56 ± 0.51[c]	4.64 ± 0.49[c]	4.48 ± 0.51[c]	4.44 ± 0.51[c]
T3	4.88 ± 0.33[d]	4.96 ± 0.20[d]	4.92 ± 0.28[d]	4.80 ± 0.41[d]	4.88 ± 0.33[d]

Description : [a,b,c,d] Different superscripts in columns indicate a very significant difference. (P<0.01)

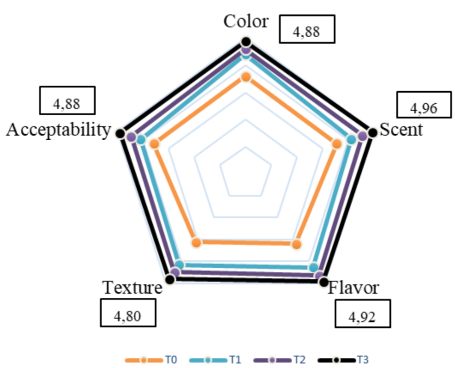

Figure 4. Organoleptic Quality Chart of Chicken Corned Meat with Rice Bran Oil Addition

The improvement in sensory attributes, particularly texture, is presumably related to the emulsifying properties of rice bran oil (RBO), which contribute to a more cohesive product matrix. According to (Mazumder et al., 2023). the incorporation of RBO in meat-based products can positively affect physical characteristics such as tenderness and chewiness, leading to enhanced textural qualities preferred by consumers. The increase in taste and aroma scores may also be associated with the natural volatile compounds and bioactive constituents in RBO, which enhance the sensory profile of the product.

Furthermore, the highest color score was observed in the treatment with 10% RBO addition, suggesting that RBO contributes to a more visually appealing product. Overall, the inclusion of 10% rice bran oil in the formulation of chicken corned meat significantly improved all evaluated organoleptic parameters, making it the most preferred treatment among panelists.

Conclusion

The incorporation of rice bran oil (RBO) into chicken meat emulsion formulations significantly influenced various physicochemical, microstructural, and antioxidant activity parameters. The addition of RBO—particularly at a 10% concentration—enhanced the emulsion matrix integrity, reduced lipid oxidation (as measured by peroxide value), and decreased free fatty acid levels. It also improved protein retention and resulted in a more compact and stable microstructure, as observed through scanning electron microscopy (SEM). Although the total fat content increased slightly, the overall lipid quality improved due to the higher proportion of unsaturated fatty acids and the presence of natural antioxidants such as γ-oryzanol and tocopherols in RBO. Additionally, reductions in water activity (Aw) suggest a potential improvement in shelf stability and microbial resistance, although further testing would be needed to confirm long-term storage effects and microbiological safety. These findings support the use of RBO as a functional fat replacer and natural stabilizer in chicken meat emulsion products. Further research is recommended to evaluate consumer sensory acceptance and the product's behavior during extended storage.

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Conflicts of Interest
The authors declare no conflict of interest.

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