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Physicochemical Properties of Egg White Powder from Eggs of Different Types of Bird

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***Abstract*— The objective of this study was to compare the physicochemical properties of egg white powder from eggs of different types of bird (local kampung chicken, local fighting chicken, local serama chicken, leghorn chicken, turkey, and guineafowl). Eggs were purchased from local farmers. Egg whites were separated from egg yolks manually, blast frozen, freeze-dried, and ground into powder. Moisture and protein content, colour, emulsification activity and stability, foaming capacity and stability, water holding capacity (WHC), and texture profile parameters of the egg white powders were measured in this study. The protein content and foaming capacity of egg white powder from leghorn chickens were significantly ($p < 0.05$) higher than that from the other chicken breeds. The emulsion ability and stability of commercial egg white powder were significantly ($p < 0.05$) lower than those of the powders from the chicken breeds tested, but it formed a stronger gel and had higher WHC. These results indicate that the physicochemical properties of egg white powder differ significantly among eggs from different types of bird.**

***Keywords*— egg yolk powder; local chicken breeds; layer chicken; physicochemical properties; proximate composition**

I. Introduction

Over the past two decades, chicken egg production and consumption have increased dramatically, as eggs are part of a healthy diet due to their protein, essential vitamin, lipid, and mineral content [1]. Egg production in Malaysia increased from 659,664 million tonnes in 2013 to 679,803 million tonnes in 2015. About 90% of these eggs were produced on 3200 farms located in Peninsular Malaysia, with the remainder from farms located in East Malaysia [2].

Egg white, also known as albumin, accounts for approximately 58% of the total weight of an egg, whereas the yolk contributes 31% of the total [3]. Egg white protein consists mainly of ovalbumin, conalbumin (also known as ovotransferrin), lysozyme, ovomucoid, and globulins [4]. As the shelf life of fresh egg white is limited, egg white powder is used in the food industry. The removal of water from the egg white reduces its moisture content, thereby extending its shelf life. Egg white powder also can reduce transportation costs, allows for simple storage, and is convenient for sample preparation [5].

Egg white powder can be produced by freeze drying or spray drying. Prior to drying, desugaring treatment and pasteurization are conducted to remove the last traces of glucose and prevent the Maillard reaction from occurring. Pasteurization at 60 °C for 3.5 min is necessary to eliminate the possibility of contamination with *Salmonella* sp., which causes food poisoning [7]. However, these treatments may alter the functional properties, colour, and flavour of the egg white [6].

Egg white powder is widely used in both non-food and food industries. Non-food applications include acting as a softening and seasoning agent. The foaming and coagulation properties of egg white powder are useful for food applications, and the product is widely used in frozen desserts, bakery mixes, meringues, coatings, and batters. Egg white powder leaves a strong residual flavour in the foam it produces, and the foams have a smooth and long-lasting mouthfeel similar to that of a traditional meringue made from fresh eggs [8]. Egg white powder also can be used to make aerated dishes and functions as a gelling agent when heated. When albumin is beaten, its volume increases six to eight times. As the albumin foam is heated, the protein coagulates and creates a structure around air cells, maintaining a stable structure. Egg white powder can be used to thicken mixtures such as custards and hollandaise sauce, and it can act as leavening agent for angel food cake, meringues, and desserts [3]. It also can be a good batter for deep frying of vegetables, meat, and seafood together with dried milk, as both have binding properties that can coat the surface of food items. Egg white powder can act as a binding agent for fondant and other soft fillings, and it can improve the softness and texture of the product. In the manufacture of wine and some juices, egg white can act as clarification agent [9].

The main hybrid breeds of chicken for egg production are Hisex, Lohmann Brown, H & N Brown Nick, ISA Brown, and Novogen, and the first three constitute about 96.62% of the total parent stock. The parent stock of layer chickens originally was imported from France, Germany, and Holland [10]. Other pure breeds, such as Rhode Island Red, Leghorn, Sussex, and Plymouth Rock, also are known as good layer chickens. To date, there is no reliable evidence that the physicochemical properties of chicken eggs differ among different breeds of chicken or different types of bird. Nevertheless, the public believes that the nutrient content differs among eggs from different breeds and therefore will pay more for some types of eggs. To address this issue, the main purpose of this study was to compare the physicochemical properties of egg white powder from eggs of different types of bird (local kampung chicken, local fighting chicken, local serama chicken, leghorn chicken, turkey, and guineafowl) and compare the results to those of commercial egg white powder.

II. MATERIALS AND METHODS

A. Materials

Eggs from local kampung chicken, local fighting chicken, local serama chicken, leghorn chicken, turkey, and guineafowl were purchased from Kelantan, Malaysia. These eggs were processed to become egg white powder using the freeze-drying method. Commercial egg white powder used as the control was bought directly from SIM Company (Penang, Malaysia).

B. Egg White Powder Preparation

Egg white powder was prepared following the method described by Zhou et al. [11]. The eggshells were cleaned, and egg whites were separated from egg yolks manually. The egg white samples were poured into a plastic container (thickness of sample not more than 1.0 ± 0.5 cm) and blast frozen for 3 h at –40 °C. A LyoAlfa laboratory freeze dryer (Milano, Italy) then was used to freeze dry the samples for 2–3 d at –40 °C until they reached a moisture content of < 5%. The freeze-dried samples were ground using a blender (Retsch ZM 200), Haan, Germany) to form a powder. The powders were packed, kept in airtight glass jars, and stored in the refrigerator at 4 °C prior to analysis.

C. Moisture and Protein Content Analysis

The moisture and protein content of egg white powder were determined using the Association of Official Analytical Chemists method [12].

D. Colour

The colour of powdered samples was analysed using a colourimeter (Minolta Spectrophotometer CM-3500D, Osaka, Japan). The colourimeter was calibrated using a zero calibration plate followed by a white calibration plate. Each egg white sample was placed in a Petri dish specially designed for colour analysis, and the sample was shaken horizontally to shuffle the contents for a more accurate result. The measurement was repeated three times for each sample. The parameters determined were L* (lightness), a* (redness), and b* (yellowness).

E. Foaming Properties

To measure foaming properties, a sample of egg white powder was added to distilled water and homogenized to generate a 10% egg white powder solution. About 20 mL of the solution was transferred to a 200 mL beaker and stirred at 1500 rpm for 3 min. The solution was poured immediately into a 100 mL measuring cylinder, and the volume of foam and egg white powder solution was recorded [11]. Foaming capacity (FC) and foaming stability (FS) of the egg white powder solution were calculated as follows:

$$FC = \frac{V_f}{V_0} \times 100 \quad (1)$$

$$FS = \frac{V_0 - (V_{30} - V_1)}{V_0} \times 100 \quad (2)$$

where V_0 is the volume of the egg white solution before stirring (m^3); V_f is the volume of the bubbles (m^3); V_l is the volume of the egg white solution after stirring (m^3), and V_{30} is the volume of these bubbles after stirring for 30 min (m^3).

F. Emulsification Properties

To evaluate emulsification properties, a sample of egg white powder was added to distilled water and homogenized to prepare a 10% egg white powder solution. About 3 mL of the solution and 1 mL of soybean oil were mixed in a 10 mL centrifuge tube and centrifuged at 2800 rpm for 15 min. Next, 50 mL of the emulsion were mixed with 5 mL of 0.1% sodium dodecyl sulfate solution. The absorbance of the mixture was measured using a UV visible spectrophotometer (Shimadzu Model UVmini-1240, Tokyo, Japan) at 500 nm [11]. The emulsification activity index (EAI) is the absorbance value of the emulsion, and the emulsification stability index (ESI) was calculated using the following equation:

$$\mathrm{ESI} = \frac{A_0}{A_0 - A_{10}} \mathrm{x} 10 \quad (3)$$

where A_0 is the absorbance value of the egg white powder emulsion measured at 0 min, and A_{10} is the absorbance value of the egg white powder emulsion measured at 10 min.

G. Water Holding Capacity (WHC)

WHC of each sample was measured by dissolving approximately 0.25 g of egg white powder in 10 mL of distilled water, and the mixture was shaken for 30 s. The dispersion was stored overnight at 4 °C. The egg white solution was then centrifuged at 2330 x g for 30 min. The supernatant was filtered through filter paper, and the volume was measured [13]. WHC was calculated using the following formula:

$$\text{Water Holding Capacity (\%)} = \frac{\text{Volume of Supernatant (ml)}}{\text{Initial Volume (ml)}} \quad (4)$$

H. Texture Profile Analysis (TPA)

The texture profile of the samples was analysed using the method described by Zhou et al. [11]. A sample of egg white powder was added to distilled water and homogenized to prepare a 10% egg white powder solution. The solution was transferred into a 2 cm diameter casing and then heated in a water bath for 30 min at 90 °C. The resulting gel solution was cooled to 4 °C in a refrigerator for 10 h and then cut into cylinders (height of 2 cm). The gel hardness, springiness, and cohesiveness were determined using a Texture Analyser Model TA-XT2 (Stable Microsystems, Surrey, UK). Before analysis of samples, the texture analyser was calibrated with load cell weight and probe height. The parameters were set as: pretest speed = 5 mm/s, test speed = 2 mm/s, posttest speed = 5 mm/s, strain = 50%, and trigger force = 5 g. The test was carried out in triplicate for each sample, and the average values were used to express the gel strength of the samples.

I. Statistical Analysis

The results were subjected to one-way analysis of variance using IBM SPSS Statistics 20. Duncan's multiple range test was employed to determine the significance level at $p < 0.05$.

III. Results and Discussion

A. Moisture and Protein Content

Table 1 shows the moisture and protein content of the different egg white powders. The moisture content differed significantly ($p < 0.05$) among some of the egg white powders. Commercial egg white powder had the lowest moisture content (2.42%), followed by egg white powder from leghorn chickens (2.43%). The highest moisture content (3.68%) was found in egg white powder from serama chickens. Malaysian Food Regulations [14] state that dried egg white must be produced by drying liquid egg whites and must not contain more than 5% water. All of the egg white powders tested in this study met this standard. Ndife et al. [15] reported the moisture content of dried egg white to be 4.32%, and this higher value may have been due to the oven drying method used in their study.

The protein content of all egg white powders was relatively high (range 88.23–97.52%), but it differed significantly ($p < 0.05$) among some of the powders tested. Egg white powder from serama chickens and leghorn chickens had the lowest and highest protein content, respectively. In all cases, the protein content was much higher than that reported by Miguel et al. [16] for egg white powder from hen's eggs (71.82%). This difference may due to what the chickens were fed, as the nutrient content of chicken eggs depends on the nutrient intake of the chicken [17].

The protein content of commercial egg white powder was among the lowest of the powders tested, and the value likely was related to the composition of the eggs used to produce the powder. Commercial egg white powder also had the lowest moisture content, which likely was due to the drying method used (i.e., usually spray drying).

TABLE I
MOISTURE AND PROTEIN CONTENT OF EGG WHITE POWDERS FROM EGGS OF DIFFERENT TYPES OF BIRD AND COMMERCIAL EGG WHITE POWDER

Samples	**Moisture (%)**	**Protein (%)**
Kampung	2.77 ± 0.16^{b}	96.66 ± 0.22^{d}
Fighting	2.46 ± 0.04^{a}	97.36 ± 0.54^{d}
Serama	3.68 ± 0.04^{d}	88.23 ± 0.19^{a}
Leghorn	2.43 ± 0.08^{a}	97.52 ± 0.34^{d}
Turkey	2.70 ± 0.04^{b}	94.03 ± 1.27^{c}
Guineafowl	3.23 ± 0.08^{c}	92.57 ± 0.17^{b}
Commercial	2.42 ± 0.08^{a}	92.92 ± 0.39^{bc}

Data are expressed as the mean ± standard deviation (n = 3). Different letters in the same column indicate significant differences ($p < 0.05$).

TABLE II
wRESULTS OF COLOUR ANALYSIS OF THE DIFFERENT EGG WHITE POWDERS

Samples	L*	a*	b*
Kampung	92.48 ± 0.02^{e}	0.03 ± 0.03^{d}	15.11 ± 0.03^{d}
Fighting	92.33 ± 0.01^{d}	0.16 ± 0.03^{e}	17.87 ± 0.03^{f}
Serama	91.62 ± 0.03^{a}	0.59 ± 0.02^{f}	17.28 ± 0.01^{e}
Leghorn	92.08 ± 0.01^{c}	–0.17 ± 0.01^{c}	13.44 ± 0.02^{c}
Turkey	92.85 ± 0.02^{g}	0.70 ± 0.02^{g}	10.06 ± 0.02^{a}
Guineafowl	92.77 ± 0.01^{f}	–0.25 ± 0.01^{b}	11.37 ± 0.02^{b}
Commercial	91.70 ± 0.01^{b}	–1.67 ± 0.03^{a}	21.28 ± 0.02^{g}

Data are expressed as the mean ± standard deviation (n=3). Different letters in the same column indicate significant differences ($p < 0.05$).

TABLE III
FOAMING PROPERTIES OF THE DIFFERENT EGG WHITE POWDERS
IV.

Samples	Foaming Capacity (%)	Foaming Stability (%)
Kampung	113.33 ± 2.89^{b}	41.67 ± 10.41^{b}
Fighting	165.00 ± 13.23^{c}	43.33 ± 15.28^{b}
Serama	120.00 ± 8.66^{b}	46.67 ± 15.28^{b}
Leghorn	173.33 ± 7.64^{c}	48.33 ± 14.43^{b}
Turkey	120.00 ± 10.00^{b}	55.00 ± 8.66^{b}
Guineafowl	105.00 ± 8.66^{b}	45.00 ± 10.00^{b}
Commercial	80.00 ± 5.00^{a}	16.67 ± 2.89^{a}

Data are expressed as the mean ± standard deviation (n = 3). Different letters in the same column indicate significant differences ($p < 0.05$).

B. Colour

Table 2 shows the colour analysis results of the different egg white powders. The values for lightness (L*), redness (a*), and yellowness (b*) from all powders differed significantly from each other ($p < 0.05$). Egg white powder from serama chickens had the lowest L* value but scored quite high for a* and b*; these values show that it was darker but had a higher intensity of a* and b* compared to the other egg white powders. Commercial egg white powder had the highest b* value, lowest a* value, and the second lowest L* value. The high b* value of commercial egg white powder may be due to discolouration of the albumin during storage. Coutts and Wilson [18] reported that if eggs are stored for an extended period of time in poor conditions, the albumin will become much more yellow. Rannou et al. [19] noted that a low lightness value of egg white powder might be due to the non-enzymatic browning reaction that results in the formation of dark-coloured compounds upon storage.

C. Foaming Properties

Table 3 shows the foaming properties of egg white powder from eggs of different types of bird and commercial egg white powder. Foaming ability is an important functional property of egg white, particularly in the food confection industry. The FC of commercial egg white powder was significantly lower than that of egg white powder from any of the chicken breeds tested, and significant differences also were detected among some of the chicken breeds ($p < 0.05$). Among the types of bird, FC was lowest for guineafowl egg white powder and highest for leghorn egg white powder. The differences observed likely are due to differences in the composition of egg white protein among the different types of bird, as protein content was high and low in egg white powders from leghorn and guineafowl egg white powders, respectively.

No significant difference ($p > 0.05$) in FS was detected among the different chicken breeds, but the value for commercial egg white powder was significantly lower than that of egg white powder from all six chicken breeds. The high temperature used for spray drying to produce commercial egg white powder likely denatured ovotransferrin, which is one of the major egg white proteins responsible for foaming [20]. Tan et al. [7] previously reported that egg white powder that was pasteurized had lower FS than unpasteurised egg white powder.

D. Emulsification Properties

Table 4 shows the emulsification properties of the different egg white powders tested in this study. Significant differences in the EAI ($p < 0.05$) were detected among some of the egg white powders. Commercial egg white powder had the lowest EAI, followed by egg white powder from guineafowl. Egg white powder from turkey eggs had the highest emulsion activity, which means that it had the best ability to spread at the oil-water interface [19]. Among the other breeds, the EAI was lowest and highest for egg white powder from serama chickens and fighting chickens, respectively. Emulsification properties depend on the proteins present in egg white powder, and egg whites from serama chickens had the lowest protein content among the breeds tested (Table 1).

The low EAI and ESI values for commercial egg white powder likely are due to the spray drying method used to produce the product, as Ndife et al. [15] reported that the temperature used during drying affects the emulsification properties of the powder. They found that egg white powder oven dried at 40 °C had emulsification stability of 14.70%, which was higher than that of powder produced by spray drying. The efficiency at which protein acts as an emulsifier depends on the type and state of the protein, pH of the solution, the presence of other emulsifiers, and ionic strength [21].

TABLE IV
EAI AND ESI VALUES FOR THE DIFFERENT EGG WHITE POWDERS

Samples	EAI (min)	ESI (%)
Kampung	0.093 ± 0.003^{b}	23.983 ± 0.496^{e}
Fighting	0.090 ± 0.005^{ab}	26.218 ± 0.851^{f}
Serama	0.092 ± 0.004^{b}	17.529 ± 0.220^{b}
Leghorn	0.088 ± 0.003^{ab}	21.821 ± 0.168^{d}
Turkey	0.120 ± 0.006^{c}	23.928 ± 0.533^{e}
Guineafowl	0.088 ± 0.004^{ab}	19.341 ± 0.764^{c}
Commercial	0.083 ± 0.007^{a}	14.498 ± 0.305^{a}

Data are expressed as the mean ± standard deviation (n = 3). Different letters in the same column indicate significant differences ($p < 0.05$).

E. WHC and TPA

Table 5 shows the WHC and textural properties of the different egg white powders. Excellent WHC is an important factor in protein gels, as it affects the quality of the gel. WHC differed significantly ($p < 0.05$) among some of the egg white powders. Commercial egg white powder had the highest WHC. Among the different breeds, egg white powder from leghorn and serama chickens had the highest and lowest values, respectively. Ayadi et al. [21] reported that WHC is affected by several factors, including protein concentration, as WHC is due to the partial denaturation and unfolding of the protein. Table 1 shows that egg white powder from serama chickens had the lowest protein content, whereas that of turkeys was higher. This may explain the low WHC of egg white powder from serama chickens. The high WHC of commercial egg white powder was likely due to the high spray drying temperature, which would have increased the surface hydrophobicity of the powder and resulted in better gel texture and less release of water [21].

Table 5 also shows that the texture properties differed significantly ($p < 0.05$) among some of the egg white powders. According to Ayadi et al. [21], gel texture is affected by factors such as protein concentration, with a harder gel forming when more protein is present. Zhang et al. [22] also reported that higher gel strength might be due to the formation of a more compact network when protein content is high. Egg white powder from serama chickens had both the lowest protein concentration and the lowest hardness value (Tables 1 and 5). Commercial egg white powder had the highest hardness value among the powders tested, which might be due to the denaturation and aggregation that occurs during high-temperature spray drying [7].

TABLE V
WHC AND TEXTURAL PROPERTIES OF THE DIFFERENT EGG WHITE POWDERS

Samples	Water Holding Capacity (%)	Hardness (g)	Springiness (mm)	Cohesiveness (mm)
Kampung	64.00 ± 2.00^{b}	391.672 ± 3.05^{b}	0.937 ± 0.01^{b}	0.839 ± 0.01^{c}
Serama	58.67 ± 1.15^{a}	138.838 ± 3.03^{a}	0.953 ± 0.01^{c}	0.554 ± 0.06^{a}
Fighting	72.33 ± 2.52^{c}	444.487 ± 5.83^{c}	0.924 ± 0.01^{a}	0.855 ± 0.01^{c}
Leghorn	72.67 ± 2.31^{c}	563.429 ± 6.51^{d}	0.938 ± 0.01^{b}	0.855 ± 0.01^{c}
Turkey	77.33 ± 1.15^{d}	679.656 ± 6.46^{e}	0.949 ± 0.01^{c}	0.873 ± 0.01^{c}
Guineafowl	70.00 ± 2.00^{c}	443.070 ± 6.25^{c}	0.955 ± 0.01^{c}	0.861 ± 0.01^{c}
Commercial	78.67 ± 1.15^{d}	1075.329 ± 7.47^{f}	0.918 ± 0.01^{a}	0.702 ± 0.01^{b}

Data are expressed as the mean ± standard deviation (n = 3). Different letters in the same column indicate significant differences ($p < 0.05$).

V. CONCLUSIONS

The data from this study show that the functional properties of egg white powder differ among eggs from different types of bird. Egg white powder from leghorn chickens had the highest protein content, WHC, and good foaming ability compared to powders from the other chicken breeds. Egg white powder from turkey eggs had a whiter colour and good emulsification and gelling abilities. Compared to data for the six bird types, commercial egg white powder had lower protein content and emulsifying and foaming ability, but it had better gel-forming ability. It also had the highest WHC among the powders tested. In conclusion, physicochemical properties of egg white powder depend on the source of the eggs.

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