



Characteristics of Arabic Chicken (*Gallus turcicus*) Egg Flour with Different Drying Methods

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ABSTRACT

Eggs of Arabic chicken (*Gallus turcicus*) have a high nutritional value and distinct traits, although they have a short shelf-life (about 17 d) and are prone to contamination. To address this issue, drying methods such as oven-drying, spray-drying, and freeze-drying can be employed to convert eggs to flour. This study investigated the physicochemical and microbiological properties of Arab chicken egg flour produced using various drying procedures to give comparative data and aid in the development of novel egg-based products. The study found that different drying processes had substantial ($p < 0.05$) effects on color (L^* , a^* , b^*), moisture, ash, fat, and protein contents. The freeze-drying method produced the best results, including color with a brightness level (L) of 66.69, redness (a^*) of 22.73, and yellowness (b^*) of 51.23; moisture of 1.53%; ash content of 7.04%; fat of 36.94%; protein of 51.73%; and total microbial contamination of 1.2×10^2 cfu/g. The freeze-drying process fulfills the Indonesian National Standard (SNI) and the United Nations Economic Commission for Europe (UNECE) Standard, making it a useful reference for drying procedures that preserve the quality and shelf life of Arabic chicken eggs.

Keywords: Arabic chicken, drying, egg powder, microbiology, physicochemistry

INTRODUCTION

Aside from milk and meat, eggs are the main livestock product. Eggs are a nutritionally dense food with 12.8% protein, 11.8% carbs, and 12.8% fat (Abreha *et al.* 2021); a reasonably cheap source of protein. Eggs' nutritional and nutrient content make them not only a nutritious food element (Pirkwieser *et al.* 2022), but also a filler, adhesive, coloring, leavening agent, tenderizer, and softener (Pérez-Reyes *et al.* 2021).

The Arabic chicken (*Gallus turcicus*) is a type of poultry that has physical traits with free-range chickens (*G. domesticus*). Arabic chicken eggs have egg size, eggshell color, and taste that are comparable to free-range chicken eggs (Sodak 2011). In addition to these similarities, Sumiati (2022) suggested that Arab chicken eggs can be utilized as an alternative for free-range eggs due to their higher nutritional content and economic worth. When selecting new egg-based processed products, it is important to evaluate the chemical and physical properties of chicken eggs. Chicken eggs have a rather short shelf life and should be consumed within 17 d. According to Kurniawan *et*

al. (2014), storing eggs for more than 17 d could promote bacterial and microbial growth, resulting in worse egg quality.

Making egg powder is one innovative way to process chicken egg-based products while keeping egg quality, having a longer shelf life, easy distribution, and practical usage. The manufacturing of egg powder requires a drying process. Drying methods for flour production include spray drying (Koç *et al.* 2011, Jin *et al.* 2022, Vargas-Del-Río *et al.* 2022), freeze-drying (Su *et al.* 2023), and electrohydrodynamic drying (Zafar *et al.* 2023). Some drying techniques concentrate on specific components of the egg, such as the white or yolk. As a result, there are still very few studies that compare the physical and chemical properties of whole egg powder. The purpose of this study was to assess the physicochemical and microbiological properties of egg powder processed utilizing a variety of drying methods, comprised of oven drying, spray drying, and freeze drying. It is envisaged that the findings of this study would be able to provide information and comparison results, resulting in an egg-based innovative product with physical, chemical, and morphological properties that meet market criteria.

METHODS

Sample Preparation

Samples of 6–7-month-old gold-colored Arabic chicken eggs were collected from the Sumber Makmur

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and Mitra Ternak Juara livestock groups in Wonomerto District, Probolinggo Regency, East Java. The research was carried out at BRIN's Research Center for Technology and Food Processing Laboratory. Egg samples were collected at a uniform age of 1-day, with white shells, a diameter of ± 4 cm, and dirt-free. Before being delivered to the laboratory, the egg samples were conditioned on wooden racks to minimize cracking throughout the research process.

Preparing Egg Powder

The separated chicken egg samples were pasteurized at 60 °C for 3 min, with continual swirling to prevent clumping. The samples were then homogenized for one minute with a Miyako HM-620 mixer set at medium speed. The samples were then dried using three different ways. The first approach utilized a spray dryer (Buchi B-290) with an inlet temperature of 118–120 °C, an exit temperature of 60–70 °C, and a speed of 15 m/s. The second approach involved using a freeze drier (Buchi Lyovapor L-200) with a vacuum setting of 0.08–0.10 mbar and a temperature of –50 °C. The third method utilized a laboratory oven (Mettler UN450) at a temperature of 45–50 °C and a material layer thickness of 6 mm.

Color Testing

Color was assessed using a spectrophotometer (CM-5 Konica Minolta) and expressed in the following parameters: brightness (L^*), redness (a^*), and yellowness (b^*). The sample was made using a glass plate. The spectrophotometer was turned on, and the sample was brought near the photo lens. Purwadi *et al.* (2016) measured the brightness (L^*), redness (a^*), and yellowness (b^*) of the printed layer.

Chemical Testing

Chemical testing involved measuring the moisture content of each sample using the gravimetric technique (AOAC 2005). The bottles were weighed and heated in an oven to 105 °C for one hour. The weight was taken after 20 min of cooling in a desiccator (w_0). One gram of sample (s) was placed in the empty bottles (w_0), which were subsequently dried in an oven for 24 h at 105 °C. Next, weighed the bottle containing the sample and recorded the weight (w_1) after cooling the bottle in a desiccator for 20 min. To repeat the procedure, the weighing bottle with the sample back was placed in the oven at 105 °C for an hour, then cooled in a desiccator for another 20 min, weighed and recorded the weight again until the difference between successive weights was less than 0.0002 g, yielding a constant weight (w_1). The formula for calculating moisture content was: $(\%) = [(w_0 + s) - w_1]/s \times 100$.

The ashing method for determining ash content (AOAC 2005). The first stage was to heat crucibles in a muffle furnace for 24 h at 550 °C. Crucibles were then placed in a desiccator and allowed to cool for 30 min, weighed the crucibles and recorded the weight (w_0).

Three-gram samples were placed into each crucibles of known weight for 24 h and placed the crucibles containing the samples in a muffle furnace heated to 550 °C. After turning off the muffle furnace and letting it cool, the crucibles were cooled in a desiccator for 30 min, weighed and recorded the weight. The procedure was repeated by putting the weighing bottle and sample back in the oven for an hour at 105 °C, cooling it for another 20 min in a desiccator, and recording the weight again until the difference between successive weights was less than 0.0002g, yielding a constant weight (w_1). The formula to calculate ash content was: $(\%) = (w_1 - w_0)/s \times 100$.

The fat content was determined using Soxhlet method (AOAC 2005). Boiling stone-filled Soxhlet flasks were heated in an oven at 105 °C for an hour, cooled in a desiccator for 20 min, and weighed (w_0). One gram of the sample was placed in a Soxhlet apparatus after being wrapped in filter paper. When the extraction was ready, the solvent was poured into the Soxhlet flask, heated for 24 h at 105 °C, cooled in a desiccator for 20 min, and reweighed. The heating of the flask containing the sample to 105 °C was repeated for an hour before cooling it in a desiccator for an additional 20 min, reweighed and recorded the weight again until the difference between successive weights was less than 0.0002 g, yielding a constant weight (w_1). Fat content was calculated using the following formula: $(\%) = (w_0 - w_1)/s \times 100$.

Protein content was calculated using the Kjeldahl technique (AOAC 2005). The material was crushed, placed in a Kjeldahl flask, and destructed by adding strong acid H_2SO_4 . The sample was then distilled with NaOH and phenolphthalein indicator till alkaline, then titrated with HCl. Protein content (%) equals nitrogen content multiplied by the conversion factor (6.25). Nitrogen content (%) = titration volume \times HCl normality (0.02N) \times nitrogen atomic weight (14.008) \times 100% conversion factor of 6.25.

Microbiological Testing

Microbiological testing followed the total plate count procedure (SNI 2897:2008). A 5 g sample was diluted in sterile saline to 10^{-4} before plating on PCA medium. Colonies were enumerated using a colony counter after 48 h of incubation at 37 °C.

Statistical Analysis

The results of the test were evaluated using the One-Way ANOVA method at the 5% level to assess the differences in physical, chemical, and microbiological properties of egg powder between the three drying procedures (spray-drying, freeze-drying, and oven-drying). If differences were discovered, Duncan's Multi-Range Test was used to compare the three drying processes. The data was processed using the computer application SPSS 25 for Windows.

RESULTS AND DISCUSSION

Color

Color is an indicator of quality and increases the attractiveness of food goods. Table 1 shows the color analysis findings for Arabic chicken flour dried using oven, spray, and freeze-drying processes. The L*, a*, and b* tests are established procedures for determining light and color. The Commission Internationale d'Eclairage (CIE) developed this method by performing picture segmentation (Waskale *et al.* 2017). L, a*, and b* values are significant for egg powder because they indicate visual appeal, consumer approval, and quality (Koc *et al.* 2010). Different drying processes significantly affected the color of Arabic chicken egg flour ($p < 0.05$). The color of the egg flour indicated that the L* value for each drying process was 87.82 for spray-drying, 67.62 for oven-drying, and 66.69 for freeze-drying. The oven and freeze-drying procedures had higher a* values than spray-drying, with an a* of 22.13 for the oven-drying, 22.73 for freeze-drying, and 8.22 for spray-drying. Meanwhile, the b* value in the oven-drying and freeze-drying procedures was higher than that of spray-drying, with oven-drying values of 50.29 and freeze-drying of 51.27, respectively, compared to the spray-drying of 26.02. The L*, a*, and

b* values showed that the L* in spray-drying was the highest, indicating that it is close to 100 or close to white (Anam *et al.* 2023). A positive a* indicates that the color was likely to be red, and a positive b* indicates that the egg powder is yellow or brilliant

Freeze-drying generated relatively insignificant color change because the lower temperature inhibits the enzyme activity that causes the brown color, resulting in a more stable color (Habibi *et al.* 2019). According to Nurwanto and Suswantinah (2021), spray-drying flour resulted in a lighter (whiter) color than that of oven-drying. The lighter hue achieved with spray-drying may be owing to the shorter heat exposure compared to oven-drying. Prolonged heat exposure can induce browning due to the Maillard process. Figure 1 provides a visual interpretation of the test results in Table 1.

Moisture Content

The drying process tries to minimize the material's moisture content. Moisture influences shelf life because it impacts the material's susceptibility to microbial destruction (Kusumaningrum and Noor-Asikin 2016). Table 2 shows that drying processes have a significant impact on moisture content ($p < 0.05$). The oven drying procedure yielded the maximum moisture (4.57%). The spray and freeze-drying

Table 1 Average color of Arabic chicken egg flour under different drying methods

Drying Method	L*	a*	b*
Oven	67.62b ± 0.03	22.13b ± 0.02	50.29b ± 0.07
Spray	87.82a ± 0.01	8.22c ± 0.02	26.02c ± 0.03
Freeze	66.69c ± 0.06	22.73a ± 0.01	51.27a ± 0.04

Remarks: ^{a,b,c} Different superscripts in the same column indicate significant differences ($p < 0.05$). Color Analysis L*, a*, and b*.

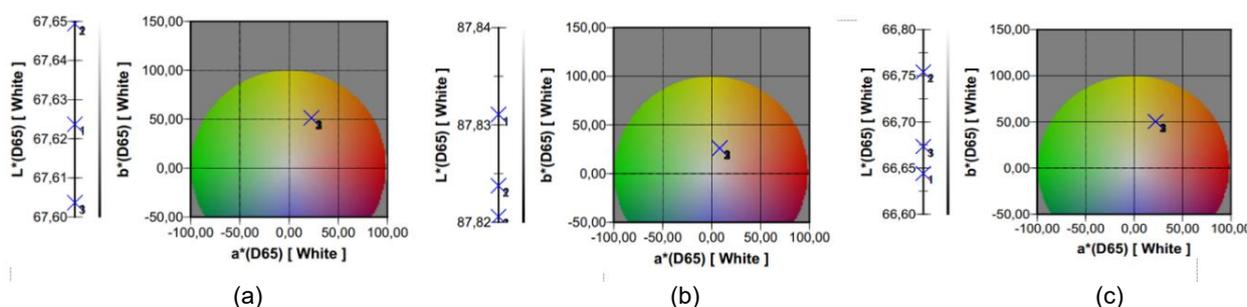


Figure 1 Color plot graph of testing Arabic chicken egg flour with different drying methods. a) Oven-dried; b) Spray-dried; and c) Freeze-dried.

Table 2 Chemical composition and microbial contamination of Arab chicken egg flour under different drying methods

Parameter	Over drying	Spray drying	Freeze drying
Moisture ^s (% DW)	4.57a ± 0.10	2.33b ± 0.07	1.53c ± 0.04
Ash ^s (% DW)	7.99b ± 0.02	8.37a ± 0.13	7.04c ± 0.15
Fat ^s (% DW)	36.61a ± 0.05	35.37b ± 0.08	36.94a ± 0.33
Protein ^s (% DW)	49.17b ± 0.64	550.01b ± 0.31	51.73 ± 1.01
Total microbe (cfu/g)	1.2 x 10 ⁴	1.1 x 10 ³	1.2 x 10 ²

Remark: ^{a,b,c} Different superscripts in the same column indicate significant differences ($p < 0.05$).

procedures had lower moisture, at 2.33% and 1.53%, respectively. These findings are consistent with those of Abreha *et al.* (2021), that the moisture of Ferenji whole egg powder was higher with the oven method than with the spray method, at 4.3% and 3.4%, respectively. The moisture of the egg powder produced by the three drying techniques fulfilled the SNI 01-4343-1996 standards for egg white powder, which were around 8%.

Freeze-drying had the lowest value, which was consistent with the findings of Bui *et al.* (2018), that the freeze-drying process has an advantage due to its very low moisture. According to Daud *et al.* (2017), the smaller the dried particle size, the larger the contact surface area with heat, resulting in faster water evaporation and better results. This is consistent with this experiment results, that the moisture content in the spray-dry approach was lower than in the oven-dry. This is also consistent with the findings of Lisa *et al.* (2015) and Ibrahim and Albaar (2020), that the temperature and time of the drying process influenced the material's ability to release water. The amount of water evaporated or lost rises with temperature and drying time (Du *et al.* 2022). Different findings occur primarily because drying procedures range in temperature, duration, and water removal mechanisms, all of which have a direct impact on the stability and preservation of the numerous nutritious substances found in egg powder.

Ash Content

Table 2 illustrates that different drying processes significantly affected ash content ($p < 0.05$). The spray drying method had the highest ash level, 8.37%, followed by the oven method (7.99%) and freeze-drying (7.04%). The ash content of the three drying processes exceeded SNI 0-4343-1996's allowed limit of 5% for egg white. Andriyani *et al.* (2023) found that the ash concentration of whole, unsalted free-range chicken egg flour was 4.85%. The ash level of salted free-range chicken egg flour was 6.48%. Another study (Wulandari and Arief 2022), found that the ash percentage of whole laying hen egg flour using the oven drying was 1.02%. The low ash level of egg flour is due to the reduced mineral content of laying hen eggs compared to free-range and Arabic hens.

The ash level of Arabic chicken egg flour exceeded that of free-range chicken or laying hen egg flour. The high ash concentration of egg flour is assumed to be caused by insufficient mineral ashing. According to Liu (2019), temperature is not the only relevant component in dry ashing; ashing time and sample size are also significant. Some minerals are lost in ash analysis because of crucible reactions, volatilization, or incomplete combustion. The optimal ashing temperature was 500–550 °C for complete combustion with minimal loss (Liu 2019). Arabic chicken contains high levels of essential elements such as calcium, phosphorus, potassium, iron, and zinc. "Oven and

spray drying may reduce mineral levels, while freeze-drying best preserves them (Liu 2019, Kurniawan *et al.* 2025)." Low temperature, short time, and big sample size can all produce incomplete combustion, resulting in higher ash content than expected. Testing the ash level of food items is one method for determining their nutritional worth. A variety of inorganic compounds, including minerals that are difficult to burn when ashed, are used to calculate the ash composition of food items (Mumtazah *et al.* 2021).

Fat Content

Table 2 explained that different drying processes significantly affect fat content ($p < 0.05$). The fat content of Arab chicken egg flour utilizing oven and freeze-drying processes was higher than that of spray drying. Table 2 displayed the fat content for each drying method: oven, freeze-drying, and spray-drying were 36.61, 36.94, and 35.37%, respectively. The fat content levels for each drying technique fall below the UNECE standard for whole egg products (2010). UNECE requires a minimum fat content of 39% in whole egg flour products. According to Abreha *et al.* (2021), the fat contents of Ferenji chicken eggs dried by spray or oven were 37.4% and 36.3%, respectively. This is in line with Andriyani *et al.*'s (2023) findings, suggesting that the fat content of whole, unsalted, free-range chicken egg flour was 31–32%.

After testing three different drying procedures, the freeze-drying approach had the highest fat content. This is supposed to be because it does not require high temperatures and has the least amount of water. Despite the increased moisture level, the oven method had a higher fat content than the spray drying approach, which is assumed to be since fat is not significantly degraded at a temperature of 50 °C. According to Apriliyanti (2010), drying at high temperatures could cause fat degradation and convert chemical components into volatile compounds such as alcohols, aldehydes, and ketones. Nurdin *et al.* (2018) found that the lipid content of tofu flour decreases as temperature rises. At 50, 60, and 70 °C, the fat content were 18.41, 17.26, and 10.75%, respectively.

Protein Content

The research data (Table 2) revealed substantial differences in protein content between the three drying procedures ($p < 0.05$). The freeze-drying process had the most protein (51.73%), followed by the spray drying (50.01%) and the oven method (49.17%). According to UNECE (2010), egg flour must contain at least 45% protein. The protein content levels for the three drying techniques exceed the UNECE standard. According to Abreha *et al.* (2021), the protein content of whole Ferenji chicken eggs dried by spray or oven was 45.9% and 47.5%, respectively. Pérez-Reyes *et al.* (2021) also agreed that whole egg flour from Hoosier Hill Farm LLC, USA, had a protein level of 46.4%. Furthermore, Andriyani *et al.* (2023) reported that the

protein content of whole, unsalted, free-range chicken egg flour was 55–57%. Heating could cause changes in amino acid structure, leading to decreased protein content (Mumtazah *et al.* 2021). Heating can degrade dietary components, particularly carbs and proteins. Protein breakdown causes amino acids to evaporate quickly. This is consistent with study by Lisa *et al.* (2015) and Munte *et al.* (2019), that high temperatures employed in the drying process caused protein denaturation by destroying amino acids, the building blocks of protein, resulting in lower protein concentration.

Microbial Contamination

The maximum total bacteria in egg flour, according to SNI 01-4343-1996, is 1×10^3 colonies/g. The freeze-drying method (1.3×10^2) met the standard requirements, while the spray drying method's total number of microbes was close to the standard value (1.1×10^3) and the oven's total microbial value was far higher than the standard (1.2×10^4) (Table 2). This is similar with previous research (Kurniawan *et al.* 2014) on spray drying egg flour, that the total number of microorganisms in egg white flour was 1.5×10^3 and in egg yolk flour was 6.4×10^2 . A variety of conditions, including temperature and moisture content, can promote microbial development. According to Purnomo *et al.* (2023), microorganisms needed a suitable temperature for development. There are three categories of bacteria based on their development temperature: psychrophilic (10–20 °C), mesophilic (20–40 °C), and thermophilic (50–60 °C).

Microbial contamination utilizing the oven method yielded the maximum contamination because microorganisms cannot be killed or inactivated at temperatures ranging from 45 to 50 °C. According to Kusumaningrum and Noor-Asikin (2016), microorganisms have an influence on moisture and shelf-life. Microbial activity might rise when moisture increases, resulting in a decline in product quality. This is consistent with the results of the three drying processes, with freeze-drying having the lowest moisture content. Egg flour quality was best preserved by freeze-drying; however, spray-drying is the most employed in industry due to its speed and low cost (Du *et al.* 2022).

CONCLUSION

The physicochemical and microbiological properties of Arabic chicken (*Gallus turcicus*) egg flour vary depending on whether it is spray-, freeze-, or oven-dried. The freeze-drying gave products with consistent color, denser morphology, the lowest density, and a covering area of more than 50. In addition, the moisture contents were $1.53 \pm 0.04\%$, ash $7.04 \pm 0.15\%$, fat $36.94 \pm 0.33\%$, and protein $51.73 \pm 1.01\%$. The overall

microbial contamination in the freeze-drying process was less (1.3×10^2 cfu/g). Overall, freeze-drying met SNI and UNECE criteria, making it a superior method of egg quality preservation and shelf-life extension. However, further refinement is required to make the samples more useful in processed food product applications.

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