Functional Characteristic of Fermented Egg White Powder after Pan-Drying at Different Temperatures and Times

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Research Article

Functional Characteristics of Fermented Egg White Powder After Pan-drying at Different Temperatures and Times

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Abstract

Background and Objective: Eggs, especially egg whites, are high in protein but susceptible to damage, even via fermentation. Thus, it is necessary to preserve them by adding flour. The aim of the present study was to evaluate different drying temperatures and durations to produce fermented egg white powder with optimal functional characteristics. **Materials and Methods:** The present study had a factorial design (3×3) using drying temperature (45, 50 and 55°C) and duration (30, 39 and 48 h) as treatments. All chicken eggs (900) used were obtained from the same farm. Parameters measured were foaming capacity and stability, powder solubility and coagulation time. A pan dryer was used to dry fermented egg whites. **Results:** Neither drying temperature nor time significantly affected the foaming capacity or stability, but there was an interaction between both treatments and foaming capacity. In contrast, drying temperature and duration significantly ($p\leq 0.05$) affected the powder solubility, but there was no interaction with either treatment. Variance analysis showed that drying temperature had significant effect ($p<0.01$) on coagulation time of egg white powder. Drying time was not significant ($p<0.05$), but there was an interaction between the two. **Conclusion:** Pan-drying fermented egg whites at 45°C for 48 h increased the foaming capacity and stability. Moreover, drying at 50°C for 39 h could increase the powder's solubility and coagulation time.

Key words: Egg white fermentation, pan drying, drying temperature, drying time, functional characteristics

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Egg whites have diverse functional properties that are very useful in food processing[1,2]. The natural coagulation of egg white proteins when heated make them excellent thickeners and binders[3] and whipped egg whites can form foams that work well as developers on a cake[4,5]. However, egg whites are susceptible to damage during storage and require further processing to extend their shelf-life. Preservation of eggs, especially egg whites, can be done by various methods, such as fermentation[6,7], but the high protein content still makes them susceptible to damage. As a result, eggs powders have been developed to extend storage times.

Some egg white powder drying methods include spray-, pan- and freeze-drying[6-12]. At present, information related to the effects of pan-drying temperature and duration on the functional characteristics of fermented egg white powder is lacking. Therefore, the current study evaluated different pan-drying temperatures and times in order to optimize the functional characteristics of fermented egg white powder.

MATERIALS AND METHODS

The present study used a completely randomized factorial design (3×3) using drying temperature and duration as treatments with 4 replicates[13]. The analysis of these variants is based on the mathematical model, as follows:

$$Y_{ijk} = \mu+\alpha_i+\beta_j+(\alpha\beta)_{jk}+\varepsilon_{ijk}$$

Where:

Y_{ijk} = Response due to the influence of drying temperature to i and drying time to j

μ = General mean

α_i = Effect of drying temperature to i, i = 3

β_j = Effect of drying time to j, j = 3

$(\alpha\beta)_{jk}$ = Interaction effect of temperature drying to i and drying time to j

ε_{ijk} = Trial error

Sample preparation: Egg whites from 900 chicken eggs (derived from the same farm) were separated from yolks and stirred for 3 min without foaming, then sterilized using ultraviolet light under a laminar flow hood for 15 min. Fermentation was done by adding *Lactobacillus plantarum* type FNCC 0027 in a tube and incubating for 18 h at 37°C[14]. Fermented egg whites were then dried in a pan dryer at three different temperatures 45, 50 and 55°C, respectively and for durations 30, 39 and 48 h, respectively.

Measurement of foaming capacity: Foaming capacity was determined by first dissolving the fermented egg white powder in distilled water (1:7) and calculating the density of the egg whites as Nahariah *et al.*[15]:

$$D = \frac{W}{V}$$

Where:

D = Egg white density

W = Weight of the egg white foam (g)

V = Volume of the egg white foam (mL)

Then, the foaming capacity (FC) was calculated as a percentage:

$$FC\ (\%) = \left[\frac{D \times V \text{ of foam egg white}}{W \text{ of foam egg white}} \times 100\right] - 100$$

Measurement of foam stability: The foam stability is determined by letting the egg white fermentation foam for 1 h at room temperature (27°C). For 1 h the foam will produce seepage water. Furthermore, weight measurement (Wseep) and volume (Vseep) of seepage. The percentage of seep water (L) obtained is then calculated as Nahariah *et al.*[15]:

$$L\ (\%) = \frac{D \times V\text{ seep}}{W\text{ seep}} \times 100$$

Next, the stability of the foam (FS) was calculated as:

$$FS = 100\%\text{-}L$$

Measurement of powder solubility: Fermented egg white powder samples (1 g) were dissolved in 7 mL of distilled water in a warm water bath (40°C) and stored for 24 h at room temperature. The solutions were then centrifuged for 15 min at 15°C and the sediment (i.e., undissolved powder) was put into aluminum foil and dried at 102°C for 24 h. The re-dried powders were weighed and the difference between the initial weight before and final weight after dissolution and drying was calculated to determine the amount of powder that dissolved in solution[15].

Measurement of coagulation time: Fermented egg white samples (1 g) were added to test tubes containing 10 mL of distilled water at 40°C. Immediately after dissolution of powder samples, the test tubes were transferred to another water bath at 80°C to coagulate proteins in solution. The coagulation time was defined as the time it took to begin seeing obvious clump formation after transferring egg white powder solutions to the 80°C water bath[15].

RESULTS AND DISCUSSION

Foaming capacity: Analysis of variance (Table 1) showed that neither drying temperature nor duration significantly affected the foaming capacity, although a significant interaction between the two treatments was observed ($p \leq 0.05$). However, the foaming capacity significantly increased with solutions made from fermented egg whites dried at 45°C for 30 h. Foaming capacity increased with increasing drying time. Although drying egg whites at 50 and 55°C can lower the foaming capacity, there were no significant differences between the three drying times used. This means that this drying temperature did not cause significant damage to the egg white proteins in solution, which would decrease the foaming power, regardless of drying time. Egg white proteins play an important role in the formation of foam[3]. A study by Hintono *et al*.[9] demonstrated that the freeze-drying proteins at a pressure of a certain thickness cause them to undergo structural changes that reduce the foaming power. Although sensitive and coagulated egg whites at a temperature of 54°C[16].

Moreover, egg whites that have been fermented and then dried for 30 h at all treatment temperature levels used indicate an increase in foaming capacity (Fig. 1). However, the addition of 39 and 48 h drying time will decrease the foam capacity. An optimal foam capacity of 505% was obtained after drying at 45°C for 48 h. The foaming capacity obtained was higher than that obtained from a previous study using freeze-dried egg whites (339%)[9] but slightly lower than that of fresh egg whites (526%)[17] and yeast-fermented egg white powder with added sucrose after pan-drying (523%)[15].

Foam stability: Table 2 shows that neither drying temperature nor duration had a significant effect on the foam stability of fermented egg white powder solutions, even though the average foam stability increased with increasing drying temperature. High temperatures can damage proteins in food and protein plays an important role in the stability of foams, which represents a surface active material. Surface active properties include formation and stabilization of the dispersed gas phase[4] as a result of the heating process, which make the foam more stable. Thus, proteins denatured by heating should lead to positive changes in the stability of the foam. However, Koc *et al*.[18] reported that foam stability was reduced due to protein denaturation. The maximum foam stability found in

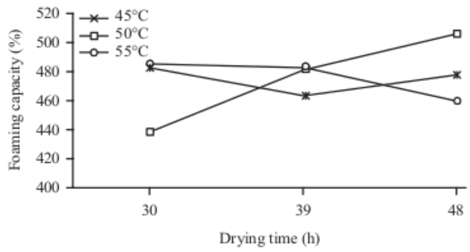

Fig. 1: Relationship between drying time and temperature on the foaming capacity of fermented egg white powder

Table 1: Foaming capacity of fermented egg white powder pan-dried at different temperatures and times

	Time (h)			
Temperature (°C)	30	39	48	Mean
45	437.98±37.31^{ax}	481.08±26.73^{by}	505.73±33.13^{cz}	474.93±41.71
50	482.31±33.13^{by}	463.12±29.36^{by}	477.54±27.83^{by}	474.33±28.61
55	485.20±16.85^{by}	482.80±22.79^{by}	459.55±30.57^{ay}	475.85±24.89
Mean	468.50±35.58	475.67±25.65	480.94±34.21	475.03±31.61

^{a,b,c}Following numbers on the same row and ^{x,y,z}following numbers in the same column indicate significant differences ($p<0.05$)

Table 2: Foam stability of fermented egg white powder after pan-drying at different temperatures and times

	Time (h)			
Temperature (°C)	30	39	48	Mean
45	99.87±0.06	99.81±0.07	99.84±0.09	99.84±0.07
50	99.91±0.06	99.91±0.04	99.85±0.11	99.89±0.08
55	99.86±0.09	99.93±0.02	99.90±0.05	99.90±0.06
Mean	99.88±0.06	99.88±0.07	99.86±0.08	99.88±0.07

Table 3: Solubility of fermented egg white powder after pan-drying at different temperatures and times (g)

Temperature (°C)	Time (h) 30	39	48	Mean
45	0.457±0.06	0.369±0.08	0.402±0.03	0.409±0.07^{a}
50	0.511±0.08	0.351±0.04	0.477±0.11	0.446±0.10^{ab}
55	0.570±0.09	0.484±0.06	0.430±0.11	0.495±0.10^{b}
Mean	0.513±0.09^{b}	0.402±0.08^{a}	0.436±0.09^{a}	0.450±0.10

^{a,b}Following numbers in the same column indicate significant differences ($p<0.05$) and ^{a,b}following numbers in the same row indicate highly significant differences ($p<0.01$)

Table 4: Coagulation time of fermented egg white powder after pan-drying at different temperatures and times

Temperature (°C)	Time (h) 30	39	48	Mean
45	2.217±0.49^{px}	2.342±0.29^{px}	3.467±1.01^{qy}	2.675±0.84^{ab}
50	2.733±0.90^{px}	3.717±0.88^{qy}	2.942±0.31^{px}	3.131±0.81^{b}
55	2.367±0.48^{px}	2.300±0.29^{px}	2.167±0.16^{px}	2.278±0.31^{a}
Mean	2.439±0.63	2.786±0.85	2.858±0.79	2.694±0.77

^{a,b,c}Following numbers in the same column and ^{p,q,x,y}following numbers in the same column and row indicate significant differences ($p<0.05$)

the current study was 100%, which is much higher than that of fresh egg white foam (71%)[17], foam from freeze-dried egg whites (98%)[9] and yeast-fermented egg whites with added sucrose and pan-dried (65%)[15].

Powder solubility: The solubility of fermented egg white powder was assessed by soaking and dissolving samples in distilled water for 24 h[15]. Analysis of variance (Table 3) showed that drying temperature and duration significantly ($p\leq 0.05$) affected the solubility of fermented egg white powder, but there was not a significant ($p>0.05$) interaction between treatments. Current results showed the solubility of fermented egg white powder increased with increased drying temperature. The solubility of the fermented egg powder significantly increased ($p<0.05$) in line with the increased use of drying temperature. Although the solubility of the fermented egg powder using 45 and 55°C was not significantly different from the use of 50°C. Solubility changes at 55°C and 45 may be caused by a drying process that causes the protein to coagulate by heat. The coagulated protein may decrease the solubility value of egg powder. A study by Bergquist[16] suggests that fermented white egg coagulation occurs at 54°C. Microbes in fermentation activity have broken down the structure of the protein macromolecule into a simpler structure, requiring higher temperatures to agglomerate proteins. Thus, heating to a temperature of 55°C does not likely damage the overall structure of the proteins, allowing the resultant egg white powder to still dissolve well.

The solubility of fermented egg white powder decreased significantly with increased drying time. However, there was no significant difference from 39-48 h. This suggests that drying time plays an important role in the solubility of fermented egg white powder; long drying times can result in denaturation of protein, which reduces their solubility. These results are in accordance with that of Legowo and Hayakawa[19], who showed that prolonged heating resulted in protein coagulation which in turn, reduces solubility of the resultant product[20]. The solubility of fermented egg white powder was optimal (57%) after drying for 30 h at 55°C. This solubility percentage is much lower than that reported by Nahariah *et al.*[15] using yeast-fermented egg white powder (78%). This difference was likely caused by treatment differences in each study.

Coagulation time: Analysis of variance (Table 4) showed that drying temperature had a highly significant ($p<0.01$) effect on the coagulation time of fermented egg white powder, while drying time did not. However, there was a significant interaction between the two treatments ($p<0.05$). The results showed that coagulation time on egg white powder fermentation has increased in line with the increasing of drying temperature. A drying temperature of 55°C, on the other hand, markedly decreased the coagulation time so that it was not significantly different from that of fermented egg white powder dried at 45°C. The increased coagulation time of powders dried at 50°C was likely due to incomplete removal of water from the egg whites. Free water molecules in the egg whites will speed up the protein binding process with water, so the coagulation reaction is accelerated by the heating process. This is in accordance with a report by Winarno and Koswara[5], who stated that the formation of protein and water molecular bonds due to heat causes protein clumping or coagulation of proteins. The decrease in coagulation time of egg whites dried at 55°C is in agreement

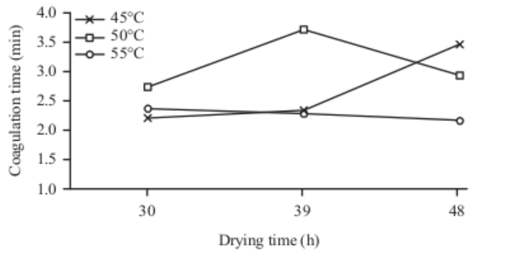

Fig. 2: Relationship between drying time and temperature on the coagulation time of fermented egg white powder

with Winarno and Koswara[5], who stated that higher drying temperatures resulted in decreased coagulation time. There is a long drying tendency to reduce coagulation time. This is in accordance with the opinion of Legowo and Hayakawa[19] that, coagulation is influenced by the duration of heating.

Figure 2 shows the interaction between drying temperature and duration on fermented egg white powder coagulation time. The use of 45 drying temperatures on the manufacture of egg white powder fermentation can increase of the coagulation time. Furthermore, coagulation time will increase if the drying time was longer. While the coagulation time significantly increased as the drying time increased from 30 and 39 h at a drying temperature of 50°C, drying for 48 h at this temperature significantly reduced the coagulation time. However, the coagulation time was not significantly different between powders dried for 30 and 48 h. These results suggest that, in general, increased drying temperature and duration leads to increased coagulation time, but at a certain temperature and drying time will also reduce coagulation time.

Heating results in changes to proteins in food that can lead to coagulation or gelatinized of products. Coagulation is a chemical process that converts liquids into gels[21]. Coagulation is marked by changes in the three-dimensional structure of long-chain molecules. Coagulation time on dried egg white powder fermentation at 50°C for 39 h was 3.717 min, which was faster than fresh egg whites (15 min), dried freeze dried egg (5.33 min)[9], egg whites dried at temperature 77-90°C (7-60 min)[17] and egg white fermented yeast (65.55 min)[15]. Pan-drying at high temperatures for short periods of time and low temperatures for long periods were able to improve the foaming capacity and stability, powder solubility and coagulation time of fermented egg white powder.

CONCLUSION

Fermented egg whites pan-dried at 45°C for 48 h enhance their foaming capacity and stability. However, to improve the powder's solubility and coagulation time, pan-drying should be performed at 50°C for 39 h.

SIGNIFICANCE STATEMENT

The present study determined the precise drying temperature(s) and time(s) needed to produce fermented egg white powder with optimal functional characteristics. This research will aid the development of processed food products based on egg powder. Furthermore, current results will provide an overview of the utilization of other fermented egg powders in future.

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