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Effect of Drying Methods on the Characteristics of Albumin Powder as a Rigid Foam-Forming Agent Based on Gambir Extract

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Abstract

The utilization of natural biomaterials as environmentally friendly alternatives to synthetic materials has gained increasing attention. One potential biomaterial is albumin derived from duck egg white, which has good foaming properties and can be used as a foaming agent in the production of bio-based foam materials. This study aimed to evaluate the effect of drying methods on the characteristics of albumin powder derived from duck egg white. Two drying methods were applied, namely pan drying and foaming drying. The albumin powder obtained from each method was analyzed for moisture content and foaming capacity. The results showed that duck egg white had a pH of 8.87 with a foaming capacity of 341.37%. Albumin powder produced using the pan drying method had a moisture content of 11.69% and a foaming capacity of 182.85%, while the foaming drying method produced albumin powder with a moisture content of 10.04% and a foaming capacity of 144.74%. These results indicate that the drying method influences the functional properties of albumin powder, particularly its abilit y to form foam. Pan drying was found to better preserve the foaming properties of albumin compared to foaming drying. Therefore, pan drying can be considered a suitable method for producing albumin powder intended for foam-based biomaterial applications.

Keywords: Albumin powder, duck egg white, foaming capacity, pan drying, foaming drying

1. Introduction

Gambier plant is one of the plants with a high content of bioactive compounds, especially catechins and tannins. These compounds possess antioxidant activity and have various potential applications in both food and non-food fields (biomass-based materials). One of these applications is in the production of biomolecule-based materials, namely the development of natural foam or biofoam as an environmentally friendly alternative to synthetic materials. The development of foam based on natural materials requires structural components capable of forming a porous and stable matrix. One of these components is albumin protein. Albumin is a globular protein that acts as a surface-active agent and is capable of forming and stabilizing foam through air–water interactions. This structure allows the formation of a protein network that can retain air bubbles, resulting in a stable and porous foam structure. This property makes albumin a suitable agent in foam production [4].

In food processing and biomaterial applications, albumin is usually first converted into powder form in order to improve stability, extend shelf life, and facilitate handling in formulation processes. This process is one of the most important stages in albumin powder production because it can affect the physical, chemical, and functional properties of the protein. Different drying methods can produce different characteristics of albumin powder, such as solubility, foaming capacity, and foam stability. Therefore, selecting an appropriate drying method is an important factor in determining the quality of albumin powder as a foam-forming material [7].

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A commonly used simple drying method is pan drying. This method uses direct heating in an oven, where the material is spread on the surface of a tray or flat container (pan). The relatively high temperature used in pan drying may cause protein denaturation, which can affect the functional properties of albumin. In addition to pan drying, another method is foam-mat drying, in which albumin is first mixed to form foam, and the foam is then dried in a thin layer at a relatively low temperature. The porous foam structure increases the evaporation surface area, thereby accelerating the drying process and reducing drying time compared to conventional methods. Furthermore, this method helps maintain the functional properties of proteins because the temperature used is relatively lower [4].

Besides the characteristics of foam-forming materials, the drying method also plays an important role in determining the final quality of the protein powder produced. The drying process can affect the protein structure, which in turn determines functional properties such as solubility, foaming capacity, and foam stability [3]. Excessive protein denaturation during the drying process can cause the protein to lose its ability to interact with tannins from gambier, which will ultimately affect foam formation. Therefore, selecting an appropriate drying method is very important to maintain the surface activity of proteins so that their functionality as a foam-forming agent can be preserved.

The development of biofoam based on biomass (natural materials**)** can serve as an alternative to synthetic materials such as polyurethane or petrochemical based products, which are difficult to degrade in the environment. Natural materials such as Gambir are rich in polyphenolic compounds and have the potential to be combined with proteins in foam formation, which can produce environmentally friendly porous materials. However, studies on the use of albumin powder as a foam forming agent in biofoam systems based on Gambir extract are still very limited, particularly regarding the effect of drying methods on the characteristics of the resulting albumin powder.

2. Literature Review

2.1. Albumin

Albumin is a component that receives significant attention due to its biochemical properties related to egg quality. Albumin is the main source of protein containing niacin and riboflavin [11]. Albumin is a type of globular protein commonly found in egg white, blood plasma, and several other food materials. This protein has a relatively low molecular weight and a flexible structure, allowing it to easily interact with both the aqueous and air phases. These properties make albumin act as a surface active agent that can reduce surface tension and serve as a component in foam formation [3].

The interfacial properties of proteins in foam formation may undergo partial denaturation when located at the air water interface. In this condition, protein molecules partially unfold so that hydrophobic and hydrophilic groups can interact with different phases. This process forms an elastic protein layer around air bubbles, enabling the formation of a stable foam structure [6]. Therefore, albumin is frequently utilized as a foaming agent in various food applications as well as protein-based biomaterials.

The functional properties of albumin are influenced by processing conditions, particularly during the drying stage. The drying process can cause changes in the protein structure, which subsequently affect its solubility, viscosity, and foaming capacity [5]. Therefore, selecting an appropriate drying method is an important factor in maintaining the functional properties of albumin so that it remains optimal when used as a foaming agent.

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3. Methodology

3.1. Preparation of Albumin Powder

Albumin powder used as the foaming agent in this study was prepared from duck egg white using two different drying methods, namely pan drying and foaming drying. The procedures were adapted and modified from [9].

3.1.1 Pan Drying Method

The pan drying method was carried out without prior whipping of the egg white. Fresh duck eggs were first separated between the egg white and yolk. The egg white was then poured into a stainless-steel tray measuring 25.5 cm × 25.5 cm with a material thickness of approximately 6 mm. The tray containing egg white was placed in a drying oven and dried at a temperature of 85 ^{o}C for approximately 26 hours until a dry sheet was formed. After the drying process was completed, the dried egg white was removed from the oven and allowed to cool at room temperature. The dried material was then ground using a laboratory grinder and sieved through an 80 mesh sieve to obtain fine albumin powder.

3.1.2 Foam Drying Method

In the foaming drying method, the egg white was first converted into foam before the drying process. Duck eggs were separated to obtain the egg white, which was then whipped using a mixer at speed level 3 (approximately 800–900 rpm) for about 20 minutes until a stable and homogeneous foam was formed. The foamed egg white was then transferred into a tray measuring 25.5 cm × 25.5 cm and spread evenly. The tray was placed in an oven and dried at 85 °C for approximately 12 hours. After drying, the dried foam material was removed and cooled at room temperature. The dried product was then ground and sieved using an 80 mesh sieve to obtain albumin powder with a uniform particle size.

3.2. Powder Preparation

The albumin powder obtained from both drying methods was stored in airtight containers at room temperature until further use. This powder was later used as the main raw material in the preparation of rigid foam based on gambier extract.

3.3. Equations

The quantitative data obtained in this study were calculated using several mathematical equations to determine the characteristics of egg white foam and albumin powder produced by different drying methods.

3.3.1 Foam Expansion (Foaming Capacity)

Foam expansion describes the ability of egg white protein (albumin) to form foam after the whipping process. The foaming capacity was calculated using Equation (1).

$$Foaming\ capacity\ (\%) = \frac{Vf - Vi}{Vi} x\ 100\%$$

Vf = volume of foam after whipping (mL)
Vi = initial volume of egg white before whipping (mL)
A higher foaming capacity indicates a better ability of albumin to trap air and form a stable foam structure.

3.3.2 Moisture Content

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The moisture content of albumin powder produced from each drying method was determined using the oven drying method. The moisture content was calculated using Equation (2).

$$Moisture\ content\ (\%) = \frac{W1 - W2}{W1}\ x\ 100\%$$

W1 = initial weight of the sample before drying (g)
W2 = final weight of the sample after drying (g)

This parameter indicates the amount of water remaining in the albumin powder after the drying process.

3.3.3 Foam Stability

Foam stability indicates the ability of the formed foam to maintain its structure over time. Foam stability was calculated using Equation (3).

$$Foam\ stability\ (\%) = \frac{Vt}{Vo}\ x\ 100\%$$

V0 = initial foam volume (mL)
Vt = foam volume after a certain storage time (mL)

Higher foam stability indicates stronger protein interactions and better foam structure.

3.3.4 Bulk Density of Albumin Powder

Bulk density describes the compactness of albumin powder particles produced by each drying method and was calculated using Equation (4).

$$Bulk\ density\ (g/mL) = \frac{W}{V}$$

W = weight of powder sample (g)
V = volume occupied by the powder (mL)

Bulk density is important for determining the handling, packaging, and application properties of the powder.

3.2. Results and Discussion

3.2.1 Characteristics of Duck Egg White as Raw Material

Duck egg white was used as the main raw material in the production of albumin powder for rigid foam formation. The duck eggs used in this study were Tegal duck eggs (*Anas javanica*) characterized by bluish-green eggshells. The average egg weight obtained in this study was 64.16 g, which is relatively similar to the results reported by [1] who reported an average weight of 64.04 g, and [9] who stated that the average duck egg weight is 66.6 g. In general, duck eggs with a weight greater than 60 g contain approximately 36 mL of egg white, which represents about 56% of the total egg weight. The characteristics of duck egg white observed in this study are presented in Table 1.

Table 1. Foaming Capacity of Duck Egg White (Albumin)

Sample	pH	Foam Volume (mL)	Foaming Capacity (%)
Egg white	8.87	132	341.37

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Based on Table 1, the pH of duck egg white obtained in this study was 8.87, which is close to the value reported by [1], namely 9.04. The pH of duck egg white tends to be higher than that of chicken egg white due to differences in egg weight and eggshell characteristics. According to Scott and Silversides (2000), duck eggs generally have larger pore numbers and surface areas in the eggshell, which increases CO_2 evaporation, leading to an increase in egg white pH.

The increase in pH occurs due to the decomposition of sodium bicarbonate ($NaHCO_3$) into NaOH, which subsequently dissociates into Na^+ and OH^- ions, thereby increasing the alkalinity of the egg white. Chicken egg white typically has a pH ranging from 7.6–8.5 [12], which is slightly lower than that of duck egg white. Egg white constitutes the largest fraction of an egg. In this study, egg white accounted for 56.11% of the total egg weight, which is consistent with the findings of [8], who reported that approximately 60% of egg weight consists of egg white.

Egg white itself consists of several layers including the outer thin layer (23.2%), outer thick layer (57.3%), inner thin layer (16.8%), and the chalaziferous layer (2.7%) [10]. Differences in viscosity among these layers are mainly caused by differences in water content and protein structure. The foaming capacity of duck egg white obtained in this study was 341.37%, which is comparable to the value reported by [1], namely 345%. Foaming capacity reflects the ability of egg white proteins to incorporate air during whipping and form stable foam structures. According to [10], foam formation occurs when protein molecules unfold during whipping, allowing air to be trapped between the protein chains, thereby increasing foam volume.

However, the foaming capacity of duck egg white is generally lower than that of chicken egg white, which ranges between 617.02%–850.00%. This difference is mainly attributed to the higher pH of duck egg white compared to chicken egg white. Optimal foam formation typically occurs at a pH of around **8.0**, while foam stability tends to increase at pH values slightly below this level [9].

3.2.2 Moisture Content and Foaming Capacity of Albumin Powder

Albumin powder was produced using two different drying methods, namely pan drying and foaming drying. These methods were applied to evaluate their effect on the moisture content and foaming capacity of the resulting albumin powder. The results of albumin powder analysis are presented in Table 2.

Table 2. Characteristics of Albumin Powder Produced by Different Drying Methods

Sample (Albumin Powder)	Moisture Content (%)	Foaming Capacity (%)
Pan drying	11.69	182.85
Foaming drying	10.04	144.74

Based on Table 2, albumin powder produced using the pan drying method showed a higher foaming capacity (182.85%) compared to the foaming drying method, which produced a foaming capacity of 144.74%. This indicates that the drying technique influences the functional properties of albumin powder, particularly its ability to form foam.

The moisture content of albumin powder produced by pan drying was 11.69%, while the foaming drying method resulted in a slightly lower moisture content of 10.04%. According to [10], the moisture content of albumin powder produced by pan drying generally ranges between 6–14%, while albumin powder produced by foaming drying has a moisture content around 12.16%. Therefore, the results obtained in this

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study are still within the acceptable range. This indicates that the albumin powder produced using both drying methods still falls within the normal range of foaming capacity for duck egg albumin.

Foaming capacity is strongly influenced by whipping conditions, especially whipping time. During whipping, the number and size of air bubbles continuously change. Excessive whipping can cause foam breakdown due to damage to the protein structure that stabilizes the air bubbles. In general, the results indicate that pan drying tends to better preserve the foaming properties of albumin protein, whereas foaming drying results in lower foaming capacity, possibly due to structural changes in the protein during the drying process.

Foam capacity and stability are influenced by several factors, including the age of the egg, the beating process, and the addition of chemical substances or stabilizers. The transformation of egg white into foam is caused by protein denaturation, which alters the molecular structure of the protein without breaking the covalent bonds, Figure 1.

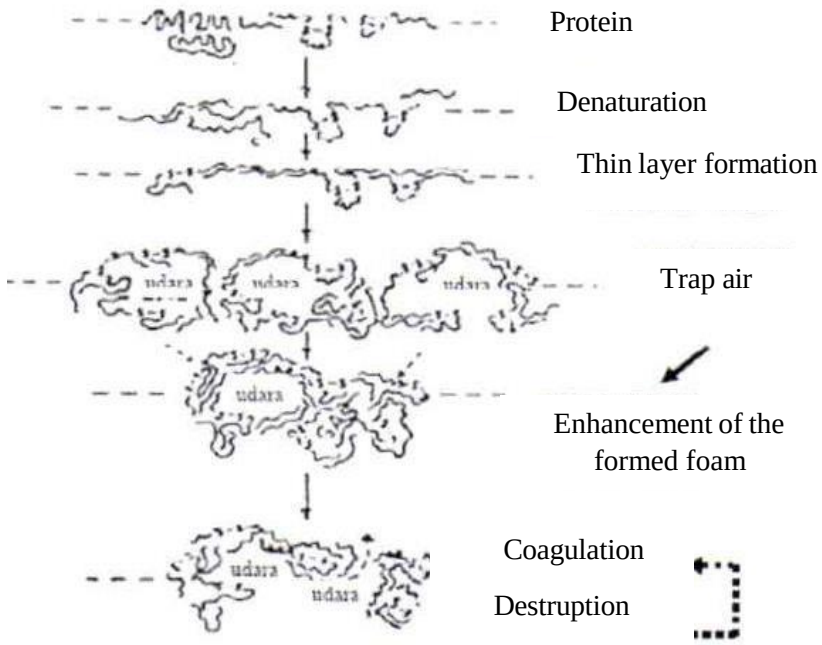


Figure 1. Foaming mechanism [2]

The more air that is trapped, the stronger the foam formed will be and the better it can retain water, making it less likely to collapse or become liquid.

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5. Conclusion

Based on the results of this study, it can be concluded that the drying method significantly affects the characteristics of albumin powder derived from duck egg white. Fresh duck egg white used as the raw material showed a pH value of 8.87 and a foaming capacity of 341.37%. Albumin powder produced using the pan drying method had a moisture content of 11.69% and a foaming capacity of 182.85%, while the foaming drying method resulted in a moisture content of 10.04% and a foaming capacity of 144.74%. The results indicate that pan drying provides better preservation of the foaming properties of albumin powder compared to foaming drying. Therefore, the pan drying method is more suitable for producing albumin powder that will be used as a foaming agent in the development of bio-based foam materials.

6. Declarations

6.1 Author Contributions

Conceptualization: Efrina; Methodology: Efrina; Software: Efrina; Validation: Efrina; Formal Analysis: Efrina; Investigation: Efrina; Resources: Efrina; Data Curation: Efrina; Writing – Original Draft Preparation: Efrina; Writing – Review and Editing: Efrina; Visualization: Efrina. The author has read and agreed to the published version of the manuscript.

6.2 Data Availability Statement

The data presented in this study are available on request from the author. The data are not publicly available due to research data management considerations.Funding

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6.3 Institutional Review Board Statement

Not applicable.

6.4 Informed Consent Statement

Not applicable.

6.5 Declaration of Competing Interest

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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