

# EVALUATION OF DRYING METHODS AND STORAGE STABILITY OF PROTEIN POWDER FROM SALTED EGG WHITES

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## GENERAL INFORMATION

Received date: 19/03/2024

Revised date: 11/05/2024

Accepted date: 09/07/2024

## KEYWORD

*Drying Methods;*

*Protein Powder Quality;*

*Salted Egg Whites;*

*Storage Stability.*

## ABSTRACT

This study compared the effects of convective hot air drying and freeze-drying on the quality and storage durability of protein powders made from salted egg whites. The results showed that freeze-drying produced higher protein concentrations (56.43%) and powder recovery efficiency (18.43%) than convection drying, which produced a 50.58% protein yield and a 15.57% recovery rate. Nonetheless, convection drying outperformed freeze-drying in terms of solubility (11.13% versus 3.10%) and water absorption capability (2.91% versus 2.62%), all while requiring a significantly shorter processing time of 2.5 hours compared to 15 hours for freeze-drying. Over a 20 days storage period, powders treated to convection drying showed a greater increase in moisture content (0.72% increase) and water activity than their freeze-dried counterparts. Furthermore, while both drying processes resulted in lower whiteness levels, freeze-dried powders had better color stability. After a thorough study of quality features, processing efficiency, and storage longevity, convection hot air drying emerged as the preferred method for producing high-grade protein powder from salted egg whites. This strategy finds the right mix between ensuring product excellence and remaining cost-effective, making it ideal for large-scale industrial procedures.

## 1. INTRODUCTION

Egg white proteins are well-known for their exceptional functional qualities, such as foaming, gelling, emulsifying, and water-binding capacities, making them essential in the creation of a variety of food items (Razi et al., 2023). Despite this, salted egg whites, a

byproduct of salted egg processing, are an underappreciated protein source in Asian culinary traditions (He et al., 2021; Xiao et al., 2021). The conversion of these residual salted egg white solids into high-value protein powder not only reduces waste but also provides economic benefits and serves as a

sustainable alternative to traditional protein sources (Grossmann & Weiss, 2021; Razi et al., 2023).

The drying process is crucial for producing high-quality protein powders with a longer shelf life (Selomulya et al., 2024; Zhang & Zhou, 2022). Convection hot air drying and freeze-drying are common drying methods used for processing protein powders (Shen et al., 2021; Ma et al., 2021; Zhang et al., 2020). While the former is known for its low cost, the high temperatures involved can cause protein denaturation and degradation (Goula and Adamopoulos, 2005). In contrast, freeze-drying, also known as lyophilization, uses ice sublimation to retain protein integrity and functionality, albeit at a higher operational cost (Ratti, 2024). There has been a lot of research on how different drying methods change the properties of egg white protein powders (Ma et al., 2021; Wang et al., 2022), but we still don't fully understand how these changes happen in protein powders made from salted egg whites. Furthermore, the subject of how these powders perform under different storage circumstances after drying has yet to be completely addressed.

As a result, the purpose of this study is to determine how convective hot air and freeze-drying procedures affect the key properties of protein powder made from salted egg whites. This study will also look at how these properties change during a 20-day storage period, which will provide insights into the storage stability of protein powders prepared using these two drying processes. This investigation aims not only to close the identified knowledge gap but also to inform future practices in the sustainable manufacturing and storage of protein powders derived from salted egg whites.

## 2. METHODOLOGY

### 2.1. Materials

#### Materials Collection and Preparation

Salted duck egg whites were acquired from Wind Chimes Bakery Company's processing line, and polypropylene packaging was used to ensure compliance with food safety regulations and appropriate frozen storage conditions (Pal et al., 2019). The egg whites were kept at  $-18^{\circ}\text{C}$  after collection to preserve quality and prevent bacterial development (Dawson, 2019). Thawing was done judiciously to retain functional qualities for further processing.

#### Protein Precipitation

Add water at a 3.5:1 ratio to salted egg white (Yao et al., 2023) and heat to  $80^{\circ}\text{C}$  for 60 minutes (Chaiyasit et al., 2019). Then, the precipitate protein is collected and dried.

#### Drying Procedure

Convection drying was carried out at  $75^{\circ}\text{C}$ , a temperature chosen for its capacity to remove moisture while also preserving protein structure, ensuring the powdered product's integrity (Zhang et al., 2023).

In the freeze-drying process, precipitated salted egg white protein was first pre-frozen at  $-40^{\circ}\text{C}$  for 24 hours, then freeze-dried under a vacuum at  $-50^{\circ}\text{C}$  followed by a secondary drying at  $25^{\circ}\text{C}$  to ensure moisture removal while preserving protein integrity (Du et al., 2022).

### 2.2. Research method

To determine the effect of the drying method on the qualities of the protein powder generated from salted egg whites, precipitated salted egg whites were dried using two different methods: convective hot air drying and freeze-drying. The experiment was set up with one factor and three replications for each treatment.

Protein powder made from salted egg whites will be kept in dark-colored zip bags with a desiccant inside that have been vacuum-sealed and sealed. This will be done so that different signs can be used to compare the differences in quality between two different drying processes. After one day, five days, ten days, fifteen days, and twenty days of storage, samples of salted egg white protein powder dried using the two methods will be collected for indicator analysis to examine changes in the powder over time. The experiment is set up with one factor, five levels, and three replications per treatment.

### 2.2.1 Analytical methods

**Moisture Analysis:** Utilized a KERN moisture analyzer, heating samples to a specific temperature to ascertain moisture content as a percentage of initial weight.

**Protein Determination:** Employed the Kjeldahl method (AOAC, 2000) to assess nitrogen content, converting this measurement to protein content.

**Whiteness and Color Measurement:** Color parameters ( $L^*$ ,  $a^*$ ,  $b^*$ ) were quantified in the Lab color space while whiteness was evaluated according to Thao and Noomhorm, 2011:  $Whiteness = 100 - ((100 - L^*)^2 + a^{*2} + b^{*2})^{1/2}$

**NaCl and Water Activity Measurement:** Sodium chloride content was determined following ISO standards 1841-1981 (NEQ) and ISO 3634-1979, and water activity measured with an Ez-200 water activity meter, ensuring sample equilibration within the device for precise readings (ISO 1841-1981; ISO 3634-1979).

**Water Absorption and Solubility:** Assessed water absorption capacity to gauge hydration properties and measured solubility according to the methodology of Roy & Flynn

(1988), analyzing the soluble fraction under standardized conditions.

### 2.2.2 Analyzing data

Experimental data analyzed and graphed on Microsoft Excel 2013. Analysis of variance (ANOVA) to compare treatments.

The experimental data was analyzed and graphed using Microsoft Excel 2013. ANOVA (Analysis of variance) was performed to compare the different treatments.

## 3. FINDINGS AND DISCUSSION

### 3.1 Effect of Drying Method

Table 1 shows that the drying process significantly ( $p < 0.05$ ) affected the characteristics of salted egg white protein powder (SEWP powder) produced from protein precipitate. Freeze-drying produced a greater protein content of 56.43% compared to 50.58% via convection drying. Similarly, freeze-drying achieved a higher powder recovery efficiency (18.43%) than convection drying (15.57%). These results are in line with earlier studies that showed freeze-drying could improve protein quality and yield by slowly removing water through sublimation, which reduced protein denaturation, aggregation, and degradation (Oetjen and Haseley, 2004; Shen et al., 2021).

In comparison, convection drying outperformed freeze-drying in terms of solubility (11.13% vs. 3.10%) and water absorption capacity (2.91% vs. 2.62%). The higher temperatures used in convection drying (usually 70–80 °C) likely caused partial protein unfolding and denaturation, revealing hidden hydrophobic groups and boosting solubility (Pan et al., 2021). This finding is similar to prior research on egg white protein powders, which found that spray drying or convection drying at higher input temperatures

enhanced solubility more than freeze drying (Ma et al., 2021; Wang et al., 2022).

Convection drying was substantially more time-efficient, taking only 2.5 hours to dry compared to 15 hours for freeze drying. This shortened processing time results in significant energy and manufacturing cost savings, which is critical for industrial-scale applications (Ratti, 2024). However, the longer drying times associated with freeze-drying are frequently required to protect heat-sensitive chemicals and maintain maximum product quality (Ratti, 2024).

**Table 1.** Table of SEWP powder properties by drying methods

Criteria	Convection drying	Freeze drying
Humidity (%)	7.70 <sup>a</sup> ±0.01	7.69 <sup>a</sup> ±0.01
Water activity	0.35 <sup>a</sup> ±0.01	0.34 <sup>a</sup> ±0.01
Water absorption	2.91 <sup>b</sup> ±0.00	2.62 <sup>a</sup> ±0.00
Solubility	11.13 <sup>b</sup> ±0.02	3.10 <sup>a</sup> ±0.12
L*	95.34 <sup>a</sup> ±0.32	95.33 <sup>b</sup> ±0.13
a*	-0.53 <sup>c</sup> ±0.08	-0.56 <sup>d</sup> ±0.02
b*	8.69 <sup>e</sup> ±0.41	5.24 <sup>f</sup> ±0.02
Whiteness (%)	90.11 <sup>g</sup> ±0.32	92.95 <sup>h</sup> ±0.09
Protein content after drying (%)	50,58 <sup>a</sup> ±0,2	56,43 <sup>b</sup> ±0,03
Powder recovery efficiency (%)	15,57 <sup>a</sup> ±0,01	18,43 <sup>b</sup> ±0.05
Salt content (%)	3,39 <sup>a</sup> ±0,07	3,41 <sup>a</sup> ±0,05
Time of drying (hours)	2.5	15

In terms of color, freeze-dried powder had a higher whiteness (92.95%) than convection-dried powder (90.11%), making it more visually appealing for specific food applications. This finding is consistent with other research indicating improved color

retention in freeze-dried food powders due to reduced exposure to heat and oxidation (Ramly et al., 2021; Samborska, 2019). On the other hand, convection drying made a brighter powder (L\* 95.34) than freeze-drying (L\* 95.33). This might be because higher drying temperatures led to non-enzymatic browning events like Maillard browning (Walters et al., 2014).

After a thorough study of quality attributes, processing efficiency, and economic considerations, convection hot air drying was determined to be the best method for manufacturing SEWP powder from salted egg white. This conclusion is consistent with previous research on egg protein powders, which has identified spray or convection drying as a more cost-effective and time-efficient approach for industrial production, as long as quality standards are met (Lyu et al., 2021; Wang et al., 2023). While freeze-drying may better maintain certain functional qualities, the accompanying processing time and energy needs may be insufficient for some applications.

### 3.2 Storage Stability of SEWP Powders

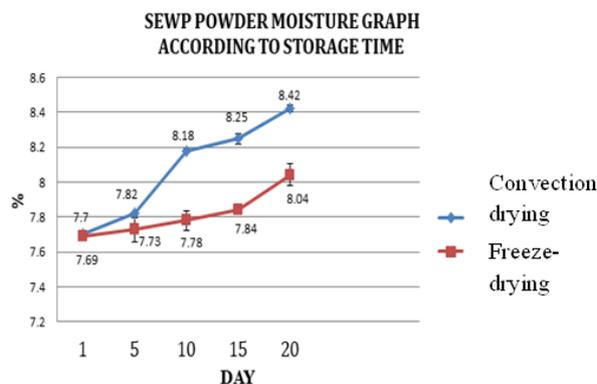
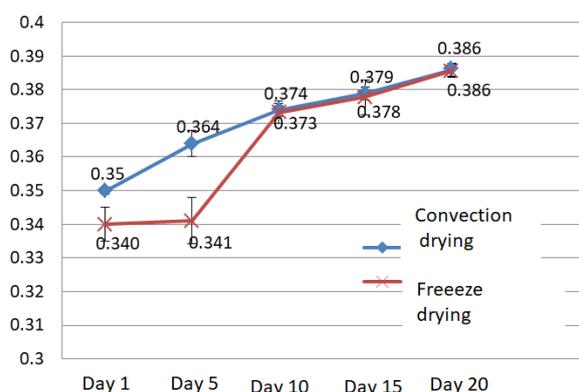


Figure 1. The moisture content of SEWP powder over storage time.

The moisture content and water activity of the SEWP powders gradually rose over the 20-day storage period for both drying processes (Figures 1 and 2). However, the rate of

increase was greater for the convection-dried powder than for the freeze-dried powder. By day 20, the moisture content of convection drying had grown by 0.72%, while freeze-drying had increased by only 0.34%. The water activity followed a similar pattern, reaching 0.39 for both drying methods by day 20, but with a faster increase in convection-dried powder.

**Water activity of SEWP powder over storage time**



**Figure 2.** Water activity of SEWP powder over storage time

**Table 2.** SEWP powder L\* over storage time

Day	L*	
	Convection drying	Freeze drying
1	95.34 <sup>a</sup> ±0.38	95.33 <sup>a</sup> ±0.13
5	95.09 <sup>b</sup> ±0.03	93.88 <sup>a</sup> ±0.16
10	94.16 <sup>b</sup> ±0.03	93.77 <sup>a</sup> ±0.16
15	94.08 <sup>b</sup> ±0.16	92.92 <sup>a</sup> ±0.08
20	93.80 <sup>b</sup> ±0.52	91.90 <sup>a</sup> ±0.05

In terms of color changes, both drying methods decreased whiteness after storage, but freeze-dried powder kept more whiteness than convection-dried powder (Table 2, 3, 4, 5). This finding is consistent with previous studies demonstrating that freeze-dried food powders have improved color stability during storage

due to less exposure to heat and oxidation (Ratti, 2024; Lee et al., 2024). It's likely that the higher temperatures used in convection drying sped up non-enzymatic browning processes like Maillard browning, pigment oxidation, and protein cross-linking, which made the color fade faster (Udomkun et al., 2015)

**Table 3.** SEWP powder a\* over storage time

Day	a*	
	Convection drying	Freeze drying
1	-0.53 <sup>a</sup> ±0.1	-0.56 <sup>a</sup> ±0.01
5	-0.60 <sup>b</sup> ±0.01	-0.70 <sup>a</sup> ±0.03
10	-0.64 <sup>b</sup> ±0.02	-0.74 <sup>a</sup> ±0.01
15	-0.63 <sup>a</sup> ±0.04	-0.71 <sup>a</sup> ±0.01
20	-0.60 <sup>b</sup> ±0.02	-0.72 <sup>a</sup> ±0.01

**Table 4.** SEWP powder b\* over storage time

Day	b*	
	Convection drying	Freeze drying
1	8.69 <sup>b</sup> ±0.48	5.24 <sup>a</sup> ±0.02
5	9.07 <sup>b</sup> ±0.02	6.26 <sup>a</sup> ±0.19
10	9.52 <sup>b</sup> ±0.02	6.42 <sup>a</sup> ±0.07
15	9.23 <sup>b</sup> ±0.03	5.95 <sup>a</sup> ±0.13
20	9.29 <sup>b</sup> ±0.28	5.80 <sup>a</sup> ±0.01

**Table 5.** SEWP powder Whiteness over storage time

Day	Whiteness	
	Convection drying	Freeze drying
1	90.11 <sup>a</sup> ±0.37	92.96 <sup>b</sup> ±0.09
5	89.67 <sup>a</sup> ±0.03	91.21 <sup>b</sup> ±0.14
10	88.80 <sup>a</sup> ±0.01	91.02 <sup>b</sup> ±0.16
15	89.01 <sup>a</sup> ±0.05	90.72 <sup>b</sup> ±0.05
20	88.81 <sup>a</sup> ±0.52	90.01 <sup>b</sup> ±0.03

The results of this storage research emphasize the trade-offs between the two drying procedures. While convection drying saves processing time and money, the resulting powder may have a lower shelf life due to rapid moisture uptake, greater water activity, and color degradation during storage. These modifications may have an impact on the powder's functional qualities and applications, including solubility, water absorption, and visual appeal. Freeze-drying provides a more stable powder in terms of moisture retention and color, but it takes longer to manufacture and requires more energy. So, to choose the best drying method, you should think about the qualities you want the product to have, how it will be stored, your budget, and what you want to use it for (Suo et al., 2021; Shen et al., 2021).

#### 4. CONCLUSION

This research looks into how freeze-drying and convection hot air drying change the quality of protein powders made from salted egg whites, which is a waste product that isn't used enough. The comparative investigation shows that freeze-drying protects protein content and improves powder recovery, whereas convection hot air drying maintains solubility and water absorption capability while requiring significantly less processing time. Notably, convection-dried powder showed a quick increase in moisture content and water activity during storage, as opposed to freeze-dried powder, which had better color retention and consequently preserved whiteness more effectively throughout the storage period. Convection hot air drying is recognized as the best technology for producing protein powder from salted egg whites, based on overall assessments of quality attributes, processing efficiency, and storage resilience. This technology represents a synergistic mix of quality and economic

viability, making it ideal for large-scale production initiatives.

The findings of this study not only highlight the potential for valorizing underutilized protein sources but also pave the way for the introduction of novel, sustainable, and commercially viable components. Future research objectives could include improving storing and packaging techniques to increase the durability and stability of such protein powders. Furthermore, investigating the functional properties and usability of these powders in various food matrices could greatly increase their industrial utility.

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