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Effects of Egg White Addition on Moisture, Protein Content, Solubility and Hedonic Quality of Foam-mat Dried Soybean Powder

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Abstract

Soymilk is a widely popular beverage and often regarded as a dairy alternative. One option to increase the shelf life of soymilk is by converting it into soy milk powder. Foam mat drying technique offers faster drying process due to larger surface area and better rehydration due to more porous agglomerates. This research aims to determine the effects of egg white addition as a foaming agent in the foam-mat drying process of powdered soymilk on the water content, protein, solubility and hedonic quality. The research employed a completely randomized design with 4 treatments and 5 replications, i.e., addition of egg white as a foaming agent at different concentrations: 25%, 30%, 35%, and 40% (w/v). The results showed that the increasing egg white concentration significantly increases protein content and reduces both solubility and hedonic quality of the powdered soymilk product. However, egg white addition has no significant effect on water content. The best powdered soymilk product was observed at 25% egg white addition, which gave a water content of 3.88%, protein content of 23.61%, and solubility of 61.06%.

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Introduction

Soybean (*Glycine max* L.) is one of the major food crops widely consumed in Indonesia. The largest soybean-producing region in the country is East Java Province, accounting for 31.29% of national production, or an average of 215.04 thousand tons per year, followed by Central Java Province with a contribution of 15.44% or 106.09 thousand tons per year (Triyanti, 2020). Soybeans contain high protein levels, making them an excellent source of plant-based protein. Dried soybeans contain up to 35–40% protein, 20% fat, 9% dietary fiber, and 8.5% water (Qin et al., 2022).

Soybeans can be processed into various food products, one of which is soymilk. According to the Indonesian National Standard (SNI) 01-3830-1995, soymilk is a beverage obtained from the extraction process of soybeans with water. Soymilk can serve as an alternative for individuals with lactose intolerance, which is the inability to digest lactose found in cow's milk due to a deficiency of lactase enzyme in the digestive tract. The complete amino acid profile in soymilk makes it an alternative to animal-based milk (Qin et al., 2022). However, soymilk is a perishable food product due to its high water content, ranging from 87–90% (Ciptasari and Nurrahman, 2020). Its relatively short shelf life poses a challenge for conventional soymilk production, as it begins to lose freshness after 6 hours at room temperature and after 24 hours under refrigeration (Setyani et al., 2022). To extend the shelf life of soymilk, it can be processed into powdered form through drying.

One drying method suitable for producing soymilk powder is foam-mat drying. The principle of foam-mat drying involves adding stabilizers and foaming agents to the product, which accelerates the drying process (Kurniasari et al., 2019). This process is conducted at relatively low temperatures to minimize nutrient loss in the ingredients. The temperatures used in foam-mat drying range between 50–80°C (Melianti et al., 2021). Compared to other methods, such as spray drying and freeze drying, foam-mat drying offers a low-energy consumption alternative and requires relatively affordable equipment (Hardy and Jideani, 2017).

In foam-mat drying, stabilizers play a role in binding or stabilizing the foam formed. One commonly used stabilizer in powder beverage production is maltodextrin. Adding maltodextrin can enhance the drying rate and increase the volume of the material (Kurniasari et al., 2019). The foaming agent creates air bubbles, further accelerating the drying process. Egg white can be used as a foaming agent due to its globulin, ovomucin, and ovalbumin content, which produces foam when whipped (Kusumaningrum and Hartati, 2018). Egg white contains 10.26 g of protein per 100 g, which can enhance the nutritional value of the product (Wulandari and Arief, 2022). Egg white is a relatively affordable, natural, and easily accessible foaming agent. Research conducted by Kusumaningrum and Hartati (2018) demonstrated that higher concentrations of egg white in foam-mat drying can accelerate the drying process, as egg white forms a porous structure and expands the material's surface area, resulting in faster and more even drying. Research by Ansori *et al.* (2022) showed that adding egg white and maltodextrin in foam-mat drying of cream soup reduces the moisture content of the final product. Using optimal concentrations of egg white and stabilizers yields more effective drying results.

This study aims to evaluate the use of egg white as a foaming agent in foam-mat drying of soymilk powder. It is expected to provide an alternative method for producing powdered beverages with natural ingredients that retain nutritional value. Instant soy powder beverages offer a convenient, ready-to-serve product innovation, requiring minimal preparation time. Powdered beverages have the advantage of being durable, lightweight, and compact, making them easier to package and distribute (Purbasari, 2019). Powdered soymilk products can serve as a convenient and long-lasting alternative to traditional plant-based milk.

Materials and Methods

Materials

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Methods

The research was conducted over the period of December 2023 to January 2024. The study included the production process of soymilk powder, as well as analysis of moisture content, protein content, solubility, and hedonic quality of the soymilk powder.

Soymilk Powder Production

The production of soymilk was adapted from Ciptasari and Nurrahman (2020) with modifications. Soybeans were washed and soaked in water for 6–7 hours, then separated from their skins. The soybeans were boiled for 5 minutes and then blended with a soybean-to-water ratio of 1:3 (kg/L). The blended soybeans were filtered, and sugar was added at 7.5% of the dry weight. The soymilk was then boiled until the sugar was completely dissolved.

The production of soymilk powder was based on the method by Ciptasari and Nurrahman (2020) with modifications. A total of 200 ml of soymilk was mixed with the foaming agent (egg white) according to the treatment levels: 25%, 30%, 35%, and 40% (v/v). The minimum concentration of 25% was based on preliminary research for minimum egg whites' concentration needed to produce satisfactory foam. The mixture was homogenized using a mixer for 3 minutes until foam formed. Next, the filler material, maltodextrin at 15% (w/v), was added and homogenized again with a mixer for 5 minutes. The mixture was then poured onto a tray lined with aluminum foil. Drying was performed in an oven at 70°C for 8 hours. The dried soymilk was ground using a grinder and then sieved with an 80-mesh sieve.

Moisture Content Analysis Procedure (AOAC, 2005a)

The principle of moisture content analysis is to determine the water content in the material by calculating the weight loss during heating in an oven. The porcelain crucible to be used in the test is dried in an oven for 1 hour at 105°C, then cooled in a desiccator for 15 minutes and weighed (a). A 2-gram test sample is weighed in the dried porcelain crucible (b). The crucible is placed in an oven for 6 hours at 105°C. It is then cooled in a desiccator for 30 minutes and weighed until a constant weight is achieved (c).

Moisture content is calculated as follows:

$$\text{Moisture Content} = \frac{b - (c - a)}{b} \times 100\%$$

a = weight of the empty crucible (g)
b = weight of the sample before drying (g)
c = weight of the crucible and sample after drying (g)

Protein Content Analysis Procedure (AOAC, 2005b)

The sample is weighed and placed into a 100 ml Kjeldahl flask. Concentrated H_2SO_4 and a selenium catalyst are added to the sample. The sample is digested until the solution becomes clear. The digested sample solution is cooled, then distilled water and 40% NaOH are added. The sample solution is distilled, and the distillate is collected in an Erlenmeyer flask containing a mixture of H_3BO_3, bromcresol green indicator, and methyl red. Distillation is carried out until the distillate volume reaches 25 ml and turns bluish-green. The distillate is then titrated with 0.02 N HCl until it turns pink. The same procedure is performed for the blank sample.

Protein content is calculated as follows:

$$\text{Protein Content} = \frac{(V_1 - V_2) \times N \times 14.007 \times 6.25 \times 100\%}{W}$$

V_1 = volume of HCl for sample titration (ml)
V_2 = volume of HCl for blank titration (ml)
N = normality of the HCl solution
W = weight of the sample (mg)
14.007 = atomic weight of nitrogen
6.25 = protein conversion factor for soy

Solubility Analysis Procedure (AOAC, 1995)

Whatman filter paper no. 42 is dried in an oven at 105°C for 30 minutes and weighed. A 1 g sample is weighed and dissolved in 20 ml of distilled water. The test sample is filtered using the pre-dried filter paper. After filtration, the filter paper is dried again in an oven at 105°C for 1 hour. The filter paper is then cooled in a desiccator and weighed until a constant weight is obtained.

Solubility in water is calculated as follows:

$$\text{Solubility} \;=\; 1-\frac{(c-b)}{a}\times 100\%$$

a = weight of the test sample (g)
b = weight of the empty filter paper (g)
c = weight of the filter paper and sample after drying (g)

Hedonic Quality Testing Procedure (Meilgaard et al., 1999)

The assessment attributes for the powdered soymilk drink include color, aroma, taste, texture, and overall preference. Each powdered soymilk sample with different treatments was brewed using a ratio of powdered soymilk to warm water of 1:6 (g/ml). Testing was conducted by presenting each brewed sample in cups labeled with different three-digit codes. The hedonic test was performed by 25 untrained panelists, aged 19–24 years, based on their level of preference using a rating scale of 1 (dislike), 2 (somewhat like), 3 (like), and 4 (strongly like).

Statistical Analysis

The data obtained from the tests, including moisture content, protein content, and solubility, were analyzed using Analysis of Variance (ANOVA) with a significance level of 5%. If there was an effect between treatments, further testing was conducted using Duncan's Multiple Range Test (DMRT). The data from the hedonic quality assessment were statistically analyzed using the non-parametric Kruskal-Wallis test at a 5% significance level, and if an effect was observed, further testing was conducted with the Mann-Whitney test. Data analysis was performed using SPSS 26.0 for Windows.

Results and Discussion

Moisture Content of Powdered Soymilk

Based on the data in Table 1, it can be seen that the addition of egg white did not significantly affect (p>0.05) the moisture content of powdered soymilk. The moisture content of the produced powder ranged from 3.44% to 3.88%, meeting the SNI 7612:2011 (2011) standard for powdered soymilk, which stipulates a maximum moisture content of 10%. The moisture content test results for powdered soymilk showed no significant reduction. According to research conducted by Purbasari (2019) on the production of powdered soymilk using foam-mat drying, the water reduction curve of the material indicated that over time, the mass of the material decreased and eventually stabilized, with no further mass changes occurring. Drying with the addition of 10% dextrin and 1% tween 80 at 70°C yielded the fastest drying time of 8 hours, resulting in a moisture content of 3.05%. The drying process is considered complete when the material's mass no longer changes, suggesting that the moisture content achieved represents the maximum amount of water that can be evaporated. The obtained moisture content reflects the bound water in the material. Bound water is difficult to evaporate even with the drying process (Widyanti et al., 2021).

Increasing the concentration of egg white enhances foam formation, thereby increasing foam volume (Abidin et al., 2020). According to Harfika et al. (2023) the moisture content decreases as the concentration of egg white increases because egg white enlarges the material's surface area, which accelerates the drying process. Higher concentrations of egg white also create a porous structure, making it easier for water in the material to evaporate during drying (Ansori et al., 2022). The larger surface area and porous structure enable heating to occur throughout the material, resulting in a faster drying process (Hariyadi, 2019). Maltodextrin helps to stabilize the foam formed by egg whites, preserving the surface area and porous structure throughout the drying process (Widyasanti et al., 2018). The addition of maltodextrin increases water absorption and the amount of reducing sugars in the material. Hydroxyl groups in reducing sugars can bind free water in the material, and the water absorbed by maltodextrin forms hydrogen bonds, making it easier to evaporate during heating (Kusuma et al., 2023).

Table 1. Moisture Content of Powdered Soymilk

Treatment	Moisture Content^{ns} (%)
25% (T1)	3.88±0.48
30% (T2)	3.60±0.28
35% (T3)	3.52±0.24
40% (T4)	3.44±0.26

Note: ^{ns} superscripts indicates non-significant differences (p>0.05).

Protein Content of Powdered Soymilk

Based on the data in Table 2, it can be observed that the addition of egg white significantly affected (p<0.05) the protein content of powdered soymilk. The test results indicated that increasing the concentration of egg white led to a rise in the protein content of powdered soymilk. The protein content of the product ranged from 23.61% to 26.68%, which does not meet the SNI 7612:2011 (2011) standard for powdered soymilk, where the minimum protein content should be 30%. Egg white contains 10.26 g of protein per 100 g (Wulandari and Arief, 2022), so higher concentrations of egg white increase the protein content of the product. However, the data suggest that fresh egg whites contain almost 90% of water. This results in the low protein concentration in the final product due to the significant addition of maltodextrin. Maltodextrin is a polysaccharide that does not contain protein (Kania et al., 2015), thus its addition will 'dilute' the total protein concentration in the final product. Maltodextrin functions as a filler and coating material during the powder drying process, helping to protect compounds in the material from degradation during heating (Amini et al., 2023). An improvement in protein concentration can be achieved by reducing the amount of filler in the product.

The local soybean variety, Anjasmoro has 41.25% of protein content (Handayani et al., 2023). The protein content in powdered soymilk was lower than that in soybeans used as raw materials due to heating during the production process. Higher heating temperatures and longer heating times reduce the protein content, as proteins denature and form simpler structures. Proteins begin to undergo structural changes at temperatures above 50°C, leading to denaturation. During denaturation, some amino and carboxyl bonds in proteins break (Henggu et al., 2021). High-temperature boiling causes protein denaturation, resulting in reduced protein levels in soybeans (Putri et al., 2021). Additionally, the amount of water used in the extraction process affects the protein content of the product. Soymilk extraction involves separating soy essence from its pulp by filtering the ground soybeans mixed with water. The more water used in extraction, the lower the protein content in the product, resulting in a lower protein level than in the raw material (Picauly et al., 2015).

Table 2. Protein Content of Powdered Soymilk

Treatment	Protein Content (%)
25% (T1)	23.61±0.22^{a}
30% (T2)	25.09±0.77^{b}
35% (T3)	25.58±0.50^{b}
40% (T4)	26.68±0.17^{c}

Note: Different superscripts indicate significant differences (p<0.05).

Solubility of Powdered Soymilk

Based on the data in Table 3, it can be observed that the addition of egg white significantly affected (p<0.05) the solubility of powdered soymilk in water. The solubility of the resulting product ranged from 54.41% to 61.06%. The test results indicated that increasing the concentration of egg white decreased the solubility of the product. This is in line with the statement by (Amini et al., 2023) who reported that high egg white concentrations reduce product solubility because egg white contains components that are insoluble in water and form precipitates. Heating during the drying process causes proteins to precipitate due to denaturation. Denatured proteins undergo structural changes, altered viscosity, and reduced solubility, making them more prone to precipitation. Proteins begin to denature at temperatures ranging from 50°C to 80°C, which makes them less soluble in water (Rizqiati et al., 2020). The decrease in solubility will affect the consumers' liking to the soymilk powder product. Therefore, an optimum egg white concentration must be evaluated in terms of its foaming ability and the resulting product' solubility.

Table 3. Solubility of Powdered Soymilk

Treatment	Solubility (%)
25% (T1)	61.06±0.96^{a}
30% (T2)	58.95±0.98^{b}
35% (T3)	56.07±0.96^{c}
40% (T4)	54.41±0.87^{d}

Note: Different superscripts indicate significant differences (p<0.05).

The use of high temperatures can reduce product solubility. An increase in temperature from 65°C to 80°C will cause the foam to collapse more quickly, reducing the product's porosity and solubility (Abbasi and Azizpour, 2016). Solubility is also affected by the starch content in soymilk. Dilute starch solutions will precipitate if left for a certain period (Ciptasari and Nurrahman, 2020). The less stable emulsion properties of soymilk cause soybeans to precipitate more quickly (Ayu et al., 2020). The precipitate formed will be retained on the filter paper during testing, thereby reducing the solubility test results of the product.

Hedonic Quality of Powdered Soymilk

a. Color

The powdered soymilk product produced has a light yellow color. This color resembles that of the soymilk before it is processed into powder. The addition of egg white can reduce browning reactions in the product. The foam formed by whipping egg whites can reduce browning because its opacity covers the color of the material (Abidin et al., 2020). The addition of maltodextrin in the product formulation can result in a brighter color. Maltodextrin, which is white in color, will cause the product to appear lighter (Amini et al., 2023). Table 4 shows that addition of egg whites in soymilk powder did not affect the preference of the consumers (P>0.05), with average rating of score 3 (like). This shows panelists' likeness towards four different samples in this study.

b. Aroma

The addition of egg white as foaming agents did not affect (P>0.05) the panelists' likeness towards aroma of powdered soymilk (Table 4). Potential reasoning is because the aroma of egg white is not as dominant as the aroma of soybeans. The powdered soymilk product has a characteristic soybean aroma because soymilk typically have a beany flavor. The activity of the enzyme lipoxygenase leads to the oxidation of unsaturated fatty acids in soybeans, particularly linoleic acid, forming carbonyl compounds responsible for the beany aroma (Mandang et al., 2016). The addition of maltodextrin also did not affect the aroma of the powdered soymilk product. Maltodextrin serves as a filler that helps preserve the flavor during the heating process without interfering with the aroma of the ingredients (Nazaryan et al., 2023). The beany aroma in soymilk can be minimized by performing extraction with water at temperatures between 80°C and 100°C during production to inactivate the lipoxygenase enzyme (Margareta and Maryani, 2021). Nevertheless, the panellists gave relatively high hedonic score (3, like) which shows the preference in the resulting aroma (Table 4)

c. Taste

Hedonic evaluation shows that the panellists rating is in between 'somewhat like and 'like' with the range of 2.44-2.88 score. There was no significant difference among treatments (P>0.05). The powdered soymilk product has a bland taste due to the relatively low addition of sweetener (7.5% w/w of the soybean). According to Picauly et al. (2015), the simple sugar sucrose can provide a sweet taste and is widely used as a sweetener in food products. Maltodextrin has a mildly sweet taste but is generally neutral, so it does not alter the flavor or make the product sweeter (Wulansari et al., 2022).The low sugar addition and the use of the neutral taste maltodextrin might be the reason of the slight lower score in the hedonic rating in taste, as compared to color and aroma. It is expected that higher addition of sweetener will increase the preference of panellists in future study.

Table 4. Hedonic Quality of Powdered Soymilk

Treatment	Hedonic Quality Scale of Soymilk Powder				
	Color^{ns}	Aroma^{ns}	Taste^{ns}	Texture^{ns}	Overall^{ns}
25% (T1)	3.04±0.61	3.08±0.75	2.84±0.80	2.96±0.84	3.04±0.73
30% (T2)	3.00±0.57	3.20±0.81	2.88±0.66	2.92±0.81	3.16±0.62
35% (T3)	3.12±0.52	2.96±0.84	2.44±0.78	2.52±0.87	2.76±0.77
40% (T4)	3.08±0.64	2.96±0.73	2.64±0.70	2.44±0.86	2.84±0.74

Note: ^{ns} superscripts indicate non-significant differences (p>0.05).

d. Texture

As can be seen in Table 4, the panelists' liking to reconstituted soymilk powder was not affected by the concentration of egg whites (p>0.05). The rating score is lower than 3, indicating a lower panelists' preference. Potential reasoning to this is due to undiluted lumps in the reconstituted powdered soymilk, resulting in somewhat grainy texture. The presence of lumps is highly related to the solubility of the product. Solubility can be defined as the maximum amount of a substance that can dissolve in a solvent, and the solubility of a product is affected by drying conditions, solvent temperature, and dissolution methods (Husnani and Zulfitri, 2022). Low solubility in the product means that not all of the powder dissolves in water, resulting in 'grainy' solution. Improvements to this problem might be achieved by the use of boiling water for reconstitution. According to Astuti *et al.,* (2022), the use of a higher-temperature solvent accelerates dissolution because more molecules are in motion, making it easier to break molecular bonds.

e. Overall

The powdered soymilk product can be classified as an instant beverage, which is a powdered drink that dissolves easily in water, rehydrates quickly, is practical, and has a relatively long shelf life (Yolandari and Batubara, 2019). The overall hedonic evaluation of the powdered soymilk product with varying concentrations of egg white, after reconstitution, was found to closely resemble the original form of the product. The addition of egg whites as foaming agent did not affect the overall liking of the products (Table 4).

Conclusion

Based on the results of the study, it can be concluded that the addition of 25-40% egg white in the production of powdered soymilk using the foam-mat drying method does not affect the moisture content of the product but does influence the protein content and solubility of the product. Higher concentrations of egg white increase the protein content in the product but decrease its solubility in water. The addition of 25-40% egg white did not significantly affect the color, aroma, taste, texture, or overall hedonic attributes of the product. The addition of 25% egg white yielded the best results, this concentration was able to produce a high-quality powder through foam-mat drying, with the highest solubility and similar hedonic results with higher concentration of egg white.

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