

# Impact of Soy Protein Powder on The Physicochemical Properties of Light Mayonnaise

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**Abstract.** The high fat content in full fat mayonnaise has raised consumer health concerns, thereby increasing demand for light mayonnaise. Light mayonnaise often experiences instability due to low oil content. The addition of soy protein powder can improve emulsion stability by increasing viscosity. This study aimed to determine the optimal percentage of soy protein powder to improve the physicochemical qualities of light mayonnaise. The ingredients used were light mayonnaise made from rice bran oil, egg yolk, sugar, salt, mustard, pepper, and vinegar, with soy protein powder percentages of 0.5%, 1%, 1.5% and without addition as a control. The research method was an experimental laboratory using a Completely Randomized Design (CRD) with 4 treatments and 5 replications. The data were analyzed using ANOVA; if there were significant effects continued by Duncan's Multiple Range Test (DMRT). The results showed that the treatments had a highly significant effect, ( $P < 0.01$ ) on light mayonnaise based on moisture, pH, viscosity, acidity,  $L^*a^*b^*$  color. The results of this study indicated that soy protein powder reduced moisture content from 19.06 % to 16.47 % and acidity from 0.85 % to 0.81 %, but increased  $L^*a^*b^*$  color, viscosity from 2464 cP to 3060 cP, and pH from 4.22 to 4.48. The conclusion of the study showed that the addition of 1.5% soy protein powder gave the optimal light mayonnaise based on physicochemical quality

**Keywords:** emulsifier, light mayonnaise, soy protein powder.

## 1 Introduction

Mayonnaise is a processed food product in the form of an oil-in-water (O/W) emulsion, characterized by a semi-solid consistency. Mayonnaise has a thick and creamy texture and produces a distinctive sour aroma. Mayonnaise is widely used in the food industry as a sauce, a complement to dishes, and an additive in various processed products. Mayonnaise has a high fat content of around 70%. The paper should be written in 170 x 250 mm paper size (W x H mm) and the final printed area will be 130 x 210 mm. Do not add any page numbers.

In recent years, there has been a shift in people's food consumption preferences towards healthier products, including those with lower fat content. This change has been influenced by increased awareness of the health risks associated with excessive fat intake, such as

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cholesterol, obesity, cancer, and cardiovascular disease. As a healthier alternative, light mayonnaise is formulated with a lower vegetable oil content of around 50% [1].

The reduction in the proportion of vegetable oil in light mayonnaise has the potential to alter the physical and chemical properties of the product. Vegetable oil plays an important role in forming emulsion stability, viscosity, and contributes to the color of the product. Reducing oil without adding suitable substitutes can cause unstable emulsions, decreased viscosity, and separation between the oil and water phases. The formation of an emulsion system in mayonnaise occurs through a combination of several emulsifying and stabilizing components that play a role in maintaining the homogeneity, texture, and quality of the product.

Several studies have shown that the use of yeast protein in reduced-fat mayonnaise can improve emulsification properties and emulsion stability, resulting in a more uniform distribution of oil globules, better viscosity, and maintained texture quality and sensory acceptance [2]. In addition, the use of *dunaliella salina* microalgae protein in low-fat mayonnaise formulations was reported to increase emulsion stability and improve the system's ability to maintain the fat phase through the formation of a stronger protein interfacial layer [3]. One source of natural stabilizers that is abundant in Indonesia is soy protein. Soy protein is composed of an amphiphilic structure that contains hydrophilic groups, making it effective as an emulsifying agent in the development of low-fat food products.

Soy protein has a superior ability to form a three-dimensional gel matrix network, especially when formulated with additives such as salt, sugar, and polysaccharides such as mustard. Soy protein contains about 90% protein, which functions as an effective emulsifying and stabilizing agent and contributes to increased viscosity and emulsion stability in reduced-fat food systems [4]. Based on its composition and functional properties, soy protein has potential application in light mayonnaise. The addition of soy protein to light mayonnaise acts as a stabilizing agent to bind water, improve texture, viscosity, and emulsion stability.

This study aims to determine the optimal percentage of soy protein addition in light mayonnaise and its effect on water content, pH value, viscosity, acidity, and  $L^*a^*b^*$  color.

## **2 Materials and methods**

### **2.1 Materials**

The ingredients used in making mayonnaise were rice bran oil, egg yolks, sugar, salt, mustard, white pepper powder, vinegar obtained from a local supermarket, and soy protein powder (food grade) with an approximate protein content of 90% was used as the emulsifying agent in this study and was obtained from an e-commerce supplier in Indonesia. The equipment needed for the mayonnaise-making process was an egg separator, a bowl, a mixer, a spatula, a spoon, and an analytical scale.

The materials used in the study to test the variables were distilled water, pH buffer solutions (pH 4.0 and 7.0), sodium hydroxide (NaOH, 0.1 N), and phenolphthalein indicator. All chemicals were of analytical grade. The tools used as a means of testing variables in the study were an analytical scale, Petri dishes, an oven, a desiccator, a pH meter, a glass beaker, a magnetic stirrer, a viscometer, a spindle, a burette, a pipette, an Erlenmeyer flask, a measuring flask, and a colorimeter.

### 2.1.1 Formatting author names and author affiliations

The style for the names is First Names, typed in italic 10-point Times, then Last Name, typed in 10-point Times, with a comma after all except the last author, which is separated by comma + “and”. Do not use academic titles. Adjust the margins to those shown in the Table 1.

## 2.2 Method

This study was conducted as a laboratory experiment using a Completely Randomized Design (CRD). Four treatments were applied, namely light mayonnaise without soy protein addition (control) and light mayonnaise with soy protein addition at concentrations of 0.5%, 1.0%, and 1.5%. Each treatment was performed in five replications. The formulation of light mayonnaise used in this study is presented in Table 1. The reduction of oil content was achieved by decreasing the rice bran oil proportion from 70% in the control formulation to 50% in light mayonnaise formulations, with water added to maintain the total formulation at 100%.

**Table 1.** Light Mayonnaise Formulation.

<b>Ingredient (%)</b>	<b>T0</b>	<b>T1</b>	<b>T2</b>	<b>T3</b>
Rice bran oil	70	50	50	50
Egg Yolk	20	20	20	20
Sugar	2	2	2	2
Salt	1,5	1,5	1,5	1,5
Mustard	1	1	1	1
White pepper	0.5	0.5	0.5	0.5
Vinegar	5	5	5	5
Water	0	20	20	20
Soy protein	0	0.5	1	1.5

## 2.3 Mayonnaise Preparation

Mayonnaise was prepared by first separating the egg yolks from the egg whites using an egg separator. Mustard, sugar, salt, and white pepper were placed in a plastic container and mixed using a mixer at 1500 rpm for 1 minute until homogeneous. Egg yolks were then added to the mixture and mixed until a uniform pale color was obtained. Rice bran oil and vinegar were added gradually and alternately while mixing continuously to form an oil-in-water emulsion. Mixing was continued until a stable and homogeneous emulsion was formed. Soy

protein powder was then added according to the treatment concentration (0%, 0.5%, 1.0%, and 1.5%) and mixed until fully dispersed in the mayonnaise matrix. Mixing was continued for approximately 3 minutes until a stable and homogeneous oil-in-water emulsion was formed. All preparation processes were carried out at room temperature. The finished mayonnaise was stored in the refrigerator for 24 hours at 4°C to reach equilibrium.

## 2.4 Physicochemical Analysis

The physicochemical properties analyzed included moisture content, pH value, viscosity, acidity, and L\*a\*b\* color. Water content analysis was performed using the thermogravimetric method [5]. The pH of the sample was measured using a calibrated pH meter [5]. Viscosity as measured using a viscometer [5]. Acidity testing was performed using the acid-base titration method [5]. L\*a\*b\* color testing was performed using a colorimeter [5].

## 2.5 Data Analysis

The data obtained from the study were processed using Microsoft Excel and then analyzed statistically using analysis of variance (ANOVA). If the analysis results showed significant ( $P < 0.05$ ) or very significant differences ( $P < 0.01$ ), the testing was continued with Duncan's multiple range test (DMRT).

## 3 Results and discussion

### 3.1 Moisture Content

The ANOVA results showed that the addition of soy protein had a very significant effect ( $P < 0.01$ ) on the moisture content of light mayonnaise. The average moisture content values are presented in Table 2.

**Table 2.** Average moisture content of light mayonnaise

Treatment	Moisture content (%)
T0	19.06 <sup>d</sup> ± 0.03
T1	18.26 <sup>c</sup> ± 0.09
T2	17.19 <sup>b</sup> ± 0.06
T3	16.47 <sup>a</sup> ± 0.31

Note: Superscripts in columns (a,b,c,d) indicate significant differences ( $P < 0.01$ ) in the moisture content of light mayonnaise.

Moisture content is an important parameter in determining the quality of light mayonnaise, as it directly affects the stability of the emulsion, texture, and shelf life of the product. Most of the fat in light mayonnaise is replaced by water, so regulating the moisture

content is crucial to maintaining the balance between the water phase and the oil phase. The results showed that the moisture content of light mayonnaise decreased with increasing soy protein addition. It should be noted that the control formulation (T0) differed from the treated samples in terms of the proportion of oil and water, which may contribute to the observed differences in moisture content. The reduction of oil and the corresponding increase in water in the light mayonnaise formulations could influence moisture distribution within the emulsion system. Nevertheless, the consistent decrease in moisture content with increasing soy protein concentration indicates that soy protein played a significant role in reducing free water. Soy protein consists of 7S (*β-conglycinin*) and 11S (*glycinin*) globulin fractions, which have a high ability to form dense protein networks through hydrogen bonds. Functional groups, including carboxyl (–COOH), amine (–NH<sub>2</sub>), and hydroxyl (–OH) on the polypeptide chain, play a role in strongly binding water molecules, so that water becomes trapped in the protein structure and is not detected as free water. The moisture content of light mayonnaise in this study was lower than the results of previous studies which reported that the addition of whey protein concentrate to the formulation resulted in a mayonnaise moisture content of around 24.17 – 24.19%. [6]. An increase in protein concentration in emulsion systems can reduce free moisture content due to enhanced water-binding capacity and the formation of protein gel networks [7].

### 3.2 pH

The ANOVA results showed that the addition of soy protein had a very significant effect ( $P < 0.01$ ) on the pH value of light mayonnaise. The average pH values are presented in Table 3.

**Table 3.** Average pH of light mayonnaise

Treatment	pH
T0	4.22 <sup>a</sup> ± 0.04
T1	4.24 <sup>a</sup> ± 0.05
T2	4.32 <sup>a</sup> ± 0.04
T3	4.48 <sup>b</sup> ± 0.13

Note: Superscripts in columns (a,b,c,d) indicate significant differences ( $P < 0.01$ ) from the pH value of light mayonnaise

pH is an important parameter that reflects the acidity and chemical stability of light mayonnaise. The pH of mayonnaise is determined by the composition of the ingredients used, such as vegetable oil, egg yolk, vinegar, and mustard. The results of the study show that an increase in the percentage of soy protein added can increase the pH value of light mayonnaise. The increase in pH value is due to soy protein having a pH of around 7.20 [8]. This increase is related to the chemical properties of soy protein, which has amino groups (–NH<sub>2</sub>) and several other basic groups in its polypeptide chain. These groups can accept hydrogen ions (H<sup>+</sup>) from the aqueous phase, thereby acting as a buffer and increasing the pH value of the product [9]. Mayonnaise has a relatively low pH of around 3.5–4.5, which allows most of the acetic acid to remain undissociated, thus inhibiting microbial growth [10]. The increase in

the pH observed in this study remained within the acceptable range for mayonnaise products across all treatments, thus not posing a risk to microbiological stability and product safety.

### 3.3 Viscosity

The ANOVA results show that the addition of soy protein has a very significant effect ( $P < 0.01$ ) on the viscosity value of light mayonnaise. The average viscosity values are presented in Table 4.

**Table 4.** Average viscosity values of light mayonnaise

Treatment	Viscosity cP
T0	2464 <sup>a</sup> ± 20.74
T1	2642 <sup>b</sup> ± 26.83
T2	2848 <sup>c</sup> ± 17.89
T3	3060 <sup>d</sup> ± 55.23

Note: Superscripts in columns (a,b,c,d) indicate significant differences ( $P < 0.01$ ) from the viscosity values of light mayonnaise

Soy protein has the potential to act as a thickening agent that affects the viscosity of light mayonnaise. Increasing the amount of soy protein added to the formulation causes the viscosity value to increase, resulting in a thicker texture and strengthening the emulsion structure. This occurs because soy protein contains protein fractions that reduce the surface tension between the oil phase and the water phase. During the emulsification process, these proteins are adsorbed onto the surface of oil droplets and form a thick and stable protein film layer, thereby strengthening the stability of the emulsion in light mayonnaise. In addition, the addition of soy protein also increases the total solids in the emulsion system. The increase in solids causes the interaction between particles to become tighter and inhibits the movement of the liquid phase, which contributes to an increase in viscosity. The addition of 1.5% soy protein produces a thicker mayonnaise compared to other treatments. The higher the viscosity value, the lower the water content tends to be. The results of the study show that the viscosity value is still within the normal range. According to previous research, mayonnaise with the addition of modified rice starch granules showed an apparent viscosity value ranging from 3000–8000 cP [11].

### 3.4 Acidity

The ANOVA results show that the addition of soy protein has a very significant effect ( $P < 0.01$ ) on the acidity value of light mayonnaise. It should be emphasized that titratable acidity and pH are two conceptually distinct parameters. Titratable acidity measures the total amount of acidic substances that can be neutralized by a base during titration, thereby reflecting the overall acid content of a sample. In contrast, pH indicates the concentration of free hydrogen ions ( $H^+$ ) in the system at the time of measurement. Therefore, although both parameters are used to describe acidity, titratable acidity and pH represent different chemical

properties and should not be used interchangeably when interpreting the acidity of food products [12]. The average acidity values are presented in Table 5.

**Table 5.** Average acidity values of light mayonnaise

Treatment	Viscosity cP
T0	2464 <sup>a</sup> ± 20.74
T1	2642 <sup>b</sup> ± 26.83
T2	2848 <sup>c</sup> ± 17.89
T3	3060 <sup>d</sup> ± 55.23

Note: Superscripts in columns (a,b) indicate significant difference ( $P < 0.01$ ) from the acidity value of light mayonnaise

Table 5 shows that the more soy protein added to light mayonnaise, the more its acidity tends to decrease. The highest acidity level was found in the control mayonnaise (T0), and the lowest acidity level was found in the mayonnaise with 1.5% soy protein added (T3). This decrease is due to the ability of soy protein as a buffering agent that can bind  $H^+$  ions in the emulsion system, thereby reducing the concentration of free hydrogen ions in the water phase. The results of this study indicate a decrease in the measured titratable acidity, accompanied by a slight increase in pH. This phenomenon suggests the presence of a buffering effect exerted by soy protein, in which the acidic and basic groups on the side chains of amino acids interact with hydrogen ions ( $H^+$ ). These interactions reduce the total amount of titratable acids as well as the concentration of free hydrogen ions, leading to a modest increase in pH. Nevertheless, the observed changes remain relatively small due to the high buffering capacity of the emulsion system. The decrease in acidity plays a role in maintaining the physical stability of mayonnaise, preventing protein denaturation and phase separation, thereby maintaining the physicochemical quality of light mayonnaise. Previous research showed that low fat mayonnaise formulated with flaxseed oil-based Sunflower and whale wax oleogels produced an acidity value of around 3.63 - 4.91 [13]. Other studies have reported that the addition of clover sprout protein hydrolysate to mayonnaise results in an acidity value of around 0.80 - 0.90 [6].

### 3.5 L a\*b\* Color

The ANOVA results showed that the addition of soy protein had a very significant effect ( $P < 0.01$ ) on the L\*a\*b\* color of light mayonnaise. The average L\*a\*b\* color values are presented in Table 6.

**Table 6.** Average L a\*b\* color values of light mayonnaise

Treatment	L a*b*		
	Lightness	Redness	Yellowness
T0	90.42 <sup>a</sup> ± 0.18	-6.43 <sup>a</sup> ± 0.31	42.52 <sup>a</sup> ± 0.23
T1	91.64 <sup>b</sup> ± 0.33	-5.43 <sup>b</sup> ± 0.35	43.58 <sup>b</sup> ± 0.22
T2	92.51 <sup>c</sup> ± 0.42	-4.39 <sup>c</sup> ± 0.22	44.41 <sup>c</sup> ± 0.15
T3	93.53 <sup>d</sup> ± 0.34	-3.62 <sup>d</sup> ± 0.33	45.47 <sup>d</sup> ± 0.36

Note: Superscripts in columns (a,b) indicate significant difference (P<0.01) from the acidity value of light mayonnaise

The addition of dry ingredients to processed food products is one of the factors that influence changes in L\*a\*b\* color values [14] Table 6 shows that brightness values (L) tends to increase as the percentage of soy protein added increases. This is due to the light color of soy protein, which can increase the brightness level of light mayonnaise. The increase in brightness value indicates that the product has a higher brightness in line with the characteristics of light mayonnaise, which is expected to have a brighter appearance. The redness value (a\*) in all treatments tended to be low or close to zero, indicating that the product maintained a neutral color balance without significant red or green tendencies. This shows that soy protein does not cause red color changes in light mayonnaise, thus remaining in line with the desired visual characteristics. Meanwhile, the yellowness value (b\*) increased with increasing soy protein concentration. This increase in yellow intensity can be explained by the natural pigment content in soy protein, such as carotenoids, and the protein-lipid interaction that occurs in the emulsion system. Fat-soluble carotenoids can add a soft yellow color to mayonnaise, making the product more appealing [15].

## 4 Conclusion

The addition of 1.5% soy protein was effective in improving the stability and physicochemical quality of *light mayonnaise*.

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## References

1. Evanuarini, H., & Susilo, A. (2024). Effect of apple peel flour addition on physicochemical characteristics and fatty acid profile of reduced-fat mayonnaise. *Malaysian Journal of Nutrition*, 30(2), 193-202.
2. Kong, Y., Guo, R., Xiong, J., Li, P., Ma, C., He, Y., & Huang, Q. (2025). Yeast protein as a sustainable fat replacer in reduced-fat mayonnaise: Impact on rheological properties, emulsion stability, and microstructure. *Food Chemistry*, 493,145729.

3. Hasanzadeh, M. H., Mahdian, E., Salehi, E. A., & Hakimzadeh, V. (2025). Production of low-fat mayonnaise with *dunaliella salina* protein: a sustainable alternative for improved sensory and functional properties. *Food Science & Nutrition*, 13(11), 1-17.
4. Farid, E., Mounir, S., Siliha, H., El-Nemr, S., & Talaat, E. (2023). Effect of soy protein isolate concentration and whipping time on physicochemical and functional properties of strawberry powder. *Journal of food measurement and characterization*, 17(4), 3815-3826.
5. Association of Official Analytical Chemists. (2005). *Official methods of analysis of the Association of Official Analytical Chemists* (18th ed.). AOAC International.
6. Darabi, D. M., Ariaii, P., Safari, R., & Ahmadi, M. (2022). Effect of clover sprouts protein hydrolysates as an egg substitute on physicochemical and sensory properties of mayonnaise. *Food Science & Nutrition*, 10(1), 253-263.
7. Wang, S., Wu, Z., Jia, L., Wang, X., He, T., Wang, L., Yao, G., & Xie, F. (2024). Soybean protein isolate-sodium alginate double network emulsion gels: Mechanism of formation and improved freeze-thaw stability. *International Journal of Biological Macromolecules*, 274, 133296.
8. Zhang, X., Pan, H., Jiang, X., & Shi, W. (2023). Study on the mechanism of soy protein isolate to improve quality of reduced-salt Hypophthalmichthys molitrix surimi gel: Focus on gel quality, protein structure, and in vitro digestibility. *Food Chemistry: X*, 20, 100878.
9. van den Berg, L. A., Mes, J. J., Mensink, M., & Wanders, A. J. (2022). Protein quality of soy and the effect of processing: A quantitative review. *Frontiers in Nutrition*, 9, 1004754.
10. Arshad, M. T., Ikram, A., Ahmad, M., Maqsood, S., Hossain, M. S., & Gnedeka, K. T. (2025). Sensory characteristics, quality attributes, and storage stability of mayonnaise: a review. *International Journal of Food Science and Technology*, 60(2), 148.
11. Taghavi, E., Andriani, C., Nordin, N., Awang Seruji, A. Z. R., Wan Rasdi, N., & Abdul Hadi, N. (2024). Rheological and stability of mayonnaise-based Pickering emulsions stabilised by modified rice starch granules as a plant-based emulsifier. *International Journal of Food Science and Technology*, 59(8), 5651-5663.
12. Santanatoglia, A., Angeloni, S., Caprioli, G., Fioretti, L., Ricciutelli, M., Vittori, S., & Alessandrini, L. (2024). Comprehensive investigation of coffee acidity on eight different brewing methods through chemical analyses, sensory evaluation and statistical elaboration. *Food Chemistry*, 454, 139717.
13. Yılmaz, E., & Keskin Uslu, E. (2025). Physicochemical, rheological, and sensory properties of low-fat mayonnaises formulated with flaxseed oil-based sunflower and whale wax oleogels. *Journal of the American Oil Chemists' Society*, 102(10), 1563-1575.
14. Chen, C., Espinal-Ruiz, M., Francavilla, A., Joye, I. J., & Corradini, M. G. (2024). Morphological changes and color development during cookie baking—Kinetic, heat, and mass transfer considerations. *Journal of Food Science*, 89(7), 4331-4344.
15. Li, Y., Wang, S., Liu, X., Zhao, G., Yang, L., Zhu, L., & Liu, H. (2023). Improvement in texture and color of soy protein isolate gel containing capsorubin and carotenoid emulsions following microwave heating. *Food Chemistry*, 428, 136743