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The Effect of Carboxymethyl Cellulose (CMC) Use on The Physical Quality of Rejected Chicken Egg White Powder

Karin Saragi[1*], Metha Monica[2], Heru Handoko[3]

[1]Undergraduate Student in Animal Science, University of Jambi, Jambi 36361, Indonesia

[2,3]Faculty of Animal Science, University of Jambi, Jambi 36361, Indonesia

ABSTRACT

Rejected chicken egg white powder is a powdered product made from rejected chicken egg whites that are considered unfit for consumption due to physical damage such as breakage, cracks, or shell defects. The purpose of this study was to determine the effect of Carboxymethyl Cellulose (CMC) on the physical quality of rejected chicken egg white powder. The material used in this study was rejected chicken egg whites with the addition of CMC. The method used in this study was foam mat drying technology using a Completely Randomized Design (CRD) with 5 treatments and 4 replicates consisting of the use of CMC at different concentrations, namely P0 (0%), P1 (0.25%), P2 (0.5%), P3 (0.75%), and P4 (1%). The data obtained were then analyzed statistically using analysis of variance (ANOVA). If there was a significant or very significant effect, it was followed by Duncan's Multiple Range Test (DMRT). The results showed that the treatment had a significant effect ($P<0.05$) on the pH value and a very significant effect ($P<0.01$) on the yield, moisture content, and foaming power. The conclusion of the study was that the use of 0.75-1% CMC increased the yield to 14.43-14.68%, the use of 1% CMC decreased the pH value to 8.9, the use of 0.5-1% CMC decreased the moisture content of the product to 8.85-9.85%, and the use of up to 0.5% CMC produced a foaming power that was almost the same as the control, namely 440%, because the use of 0.75-1% CMC decreased the foaming power of the product to 365-391.25%. The use of 0.5% CMC is the best in terms of economy and quality because it successfully reduces the water content and increases the foaming power of rejected chicken egg white flour.

KEYWORDS: physical quality of egg white, carboxymethyl cellulose, rejected eggs, egg white powder

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1 INTRODUCTION

Chicken eggs are an important source of animal protein for human nutritional needs. Eggs are a source of animal protein that is highly nutritious. In one egg, the egg white has a higher percentage of protein than the egg yolk. The protein content in egg whites is 10.5 grams/100 grams [1]. The majority of the protein content in egg whites is ovoalbumin (54%), with other major proteins being ovotransferrin (12%), ovomucoid (11%), lysozyme (3.5%), and ovomucin (3.5%). Minor proteins include avidin, cystatin, ovomacroglobulin, ovoflavoprotein, ovoglycoprotein, and ovoinhibitor, which together account for less than 3% [2]. Egg whites or albumin contain most of the liquid in eggs, approximately 67%. Albumin contains more than 50% of egg protein and also contains niacin, riboflavin, chlorine, magnesium, potassium, sodium, and sulfur [3]. The high protein content in egg white makes it a valuable component, not only in terms of nutrition but also for its functional capabilities, such as foam and gel formation, which are required in various food industries.

In the process of egg production and distribution by producers, damage to eggs often occurs, especially in the form of broken eggs, cracked eggs, or shell defects (rejected eggs). Damaged or low-quality chicken eggs have the following criteria: white eggs, cracked eggs, and broken eggs [4]. Eggs that have suffered this damage are usually unfit for consumption and are immediately separated to maintain the overall quality of the product. However, the egg whites from these rejected eggs still have a high protein content and can be reused. One effective way to increase added value is to process these egg whites into egg white powder. The foam mat drying method is one alternative that can be used to produce powder by first turning the food ingredient into foam [5]. This flour product has the advantage of being easy to store and flexible in its use in processed food products [6]. The quality requirements for egg white flour according to SNI 01-4323-1996 are a pH value of 6.5-7.5 and a maximum moisture content of 8% [7].

The drying process carried out to obtain flour often causes various physical quality declines such as reduced foaming ability, decreased foam stability, color changes, and increased moisture content, which implications on the decline in the quality of the final product and its shelf life. Therefore, an additive is needed that can maintain or even improve the physical quality of the processed egg white flour, namely a stabilizer. Some stabilizers are in the form of polysaccharides or hydrocolloids [8]. Carboxymethyl Cellulose (CMC) is a cellulose derivative commonly used in the food industry as a stabilizer and gel former. CMC also has an important function in minimizing the Maillard reaction during the drying process of protein products. The Maillard reaction, characterized by the condensation of carbonyl groups from reducing sugars with amino groups from proteins, is also known as the glycosylation reaction or protein-polysaccharide conjugation reaction, which causes a dark brown color change and a decrease in nutritional quality and product quality [9]. The use of CMC forms a protective gel layer that limits the interaction between proteins and sugars, thereby inhibiting this reaction. The polysaccharide bonds in CMC break down hydrogen and proteins more easily, minimizing nutritional damage caused by the Maillard reaction that occurs during drying [10]. In addition, CMC has hydrophilic properties, so when added to food, it can absorb and bind water, which is another important factor affecting the Maillard reaction [11].

The processing of rejected egg white flour using CMC is expected to improve and enhance the physical quality of rejected egg white flour. In a previous study on the effect of CMC use on salted egg white powder, it was found that CMC improved the physicochemical quality. At a CMC concentration of 6%, the moisture content was reduced to 4.86% with a pH value of 7.05 [12]. Furthermore, in a study of failed egg white flour with the use of yeast reaching 1%, it did not affect the yield, pH value, moisture content, and foaming power of the flour [13]. This study aims to determine the effect of CMC use on the physical quality of rejected chicken egg white flour in terms of yield, pH value, moisture content, and foaming power, as well as to determine the optimal use of CMC to produce egg white flour with the best physical quality.

2 METHOD

2.1 Time and Place

The research was conducted from November 10 to November 18, 2025, at the Laboratory Building C, Faculty of Animal Husbandry, University of Jambi, for the production of rejected chicken egg white flour and the testing of the physical quality of rejected chicken egg white flour.

2.2 Research Materials

The research materials consisted of 120 rejected chicken eggs obtained from Alek Farm located in Sungai Bertam, Jambi Luar Kota District, Muaro Jambi Regency, Jambi, Carboxymethyl Cellulose (CMC) obtained from Tropi Mart, and distilled water. The equipment used in this study included an egg tray, egg separator, containers, beaker glass, hand mixer, digital scale, measuring cup, plastic cup, pH meter, gloves, stopwatch, spatula, flat baking pan, aluminum foil, large drying oven, spoon, blender, ziplock plastic bag, measuring cup, porcelain dish, dish clamp, desiccator, oven, stationery, and labels.

2.3 Research Method

The method used in this study was foam mat drying technology at a temperature of 60ºC for 8 hours, using a Completely Randomized Design (CRD) with 5 treatments and 4 replicates. The treatments consisted of:

P0: Rejected egg white flour with 0% Carboxymethyl Cellulose
P1: Rejected egg white flour with 0.25% Carboxymethyl Cellulose
P2: Rejected egg white flour with 0.5% Carboxymethyl Cellulose
P3: Rejected egg white flour with 0.75% Carboxymethyl Cellulose
P4: Rejected egg white flour with 1% Carboxymethyl Cellulose

2.4 Research Variables

2.4.1 Yield (%)

The percentage yield was obtained by weighing the egg white and CMC before drying and after becoming flour. The yield was calculated by comparing the weight of the flour (grams) with the weight of the egg white and CMC mixture (grams) multiplied by 100% [14].

2.4.2 pH Value

pH measurements were performed using a pH meter. For calibration, pH 4 and 7 buffer solutions were used. Measurements were performed by preparing 2 grams of sample mixed with 20 ml of distilled water and homogenized. The pH value was measured by dipping the pH meter electrode and the measurement results were read on a stable pH meter screen [14].

2.4.3 Moisture Content (%)

The porcelain dish to be used is first dried in an oven at 105°C for 60 minutes or until the weight remains constant, then cooled in a desiccator for 30 minutes and weighed. A sample weighing 5 grams (initial weight) is weighed and placed in the dish, then oven-dried for 20 hours at 105°C. The dish is then cooled in a desiccator for 30 minutes and weighed again after cooling (final weight). The moisture content is determined by comparing the difference between the initial weight (grams) and the final weight (grams) with the initial weight (grams) multiplied by 100% [14].

2.4.4 Foaming Power (%)

Add 10 grams of egg white powder to a measuring cup, then add 100 ml of distilled water. Mix using a hand mixer for 120 seconds at 8,000 rpm. Calculate the foam power by comparing the volume of foam (ml) with the volume of egg white solution (ml) multiplied by 100% [15].

2.5 Data Analysis

Data were statistically analyzed using analysis of variance (ANOVA). If the results obtained in this study were significantly different ($P<0.05$) or highly significantly different ($P<0.01$), they were further analyzed using Duncan’s Multiple Range Test (DMRT).

3 RESULTS AND DISCUSSION

The average value of the effect of carboxymethyl cellulose use on the physical quality of rejected chicken egg white powder in terms of yield, pH value, moisture content, and foaming power can be seen in Table 1.

Table 1. Average yield, pH value, moisture content, and foaming ability

Treatment	Yield (%)	pH value	Moisture Content (%)	Foaming Power (%)
P0	13.68±0.03^{c}	9.03±0.02^{a}	11.30±0.42^{a}	440±43.97^{a}
P1	14.05±0.18^{bc}	9.04±0.05^{a}	10.40±0.59^{ab}	427.50±9.57^{a}
P2	14.20±0.41^{abc}	9.00±0.07^{ab}	9.85±0.75^{bc}	408.75±6.29^{ab}
P3	14.43±0.47^{ab}	9.05±0.11^{a}	9.35±0.55 ^{bc}	391.25±8.54^{bc}
P4	14.68±0.38^{a}	8.9±0.02^{b}	8.85±1.09^{c}	365±9.13^{c}

$^{a\text{-}c}$Different superscripts within the same column indicate significant differences ($P<0.05$)

3.1 Yield (%)

Based on the analysis of variance, it shows that the treatment has a very significant effect ($P<0.01$) on yield. Based on Duncan's follow-up test, the use of 0%, 0.25%, and 0.5% CMC does not significantly affect yield, while the use of 0.75% and 1% CMC significantly increases yield, with 1% CMC as the treatment with the highest yield. Based on these data, it can be seen that increasing the CMC concentration can increase the yield produced. The average yield of rejected egg white powder in various treatments ranged from 13.68% to 14.68%. The lowest average yield was shown by the treatment without the use of CMC with a yield of 13.68%, while the highest average yield was shown by the treatment using 1% CMC, which produced a yield of 14.68%.

The increase in yield observed with the use of 0.75-1% CMC is thought to be related to CMC's ability to bind water and form a more compact colloidal matrix during the drying process. Hydrocolloids such as CMC are known to increase the viscosity of the liquid phase and reduce the movement and evaporation of free water, thereby reducing mass loss during drying and increasing the yield of the dried product. CMC has a greater water absorption capacity than other stabilizers because it has a high stabilizing agent content and is hygroscopic, allowing hydrocolloid particles to bind large amounts of water [16]. In addition, CMC can interact with egg white protein through hydrogen bonds and electrostatic forces, producing a gel network that is more stable against heat. This structure can minimize denaturation and excessive protein damage, so that the fraction of non-water solids retained in the system is greater and contributes to an increase in yield at a CMC concentration of 1%. The increase in yield when using 1% CMC is thought to be related to CMC's ability as a hydrophilic hydrocolloid to form a thick colloidal matrix with egg white protein. This matrix is able to retain solids (protein, minerals, and other dissolved components) during the drying process, resulting in less loss of solids carried away with the water and an increase in the mass of dry matter retained.

The increase in yield with the use of CMC concentration can also be attributed to the Maillard reaction during the drying process, especially in protein-rich products such as egg whites. In treatments with low CMC concentrations, the stability of the dough foam is relatively poor, so that during drying, foam collapse and loss of solids carried along with the liquid flowing at the bottom of the drying container can easily occur. This condition causes some of the protein and other dissolved components to not be effectively trapped in the dry matrix, resulting in a lower yield compared to treatment with higher CMC concentrations, which produces a more stable foam and a more compact dry structure. This is in line with the fact that stabilizers have the function of maintaining the stability of the dough foam so that the drying process is fast and the material is not damaged by heating [17]. The average yield graph can be seen in Figure 1.

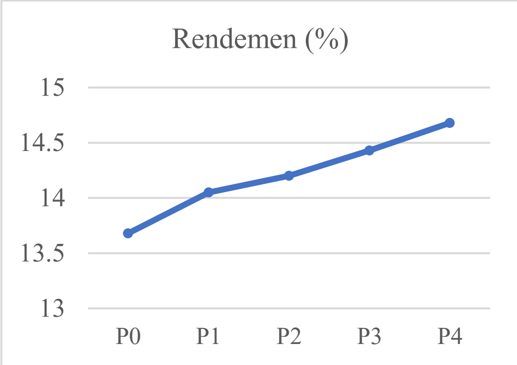

Figure 1. Average yield graph

3.2 pH value

Based on the analysis of variance, it shows that the treatment has a significant effect ($P<0.05$) on the pH value. Based on Duncan's multiple range test, the use of CMC 0%, 0.25%, 0.5%, and 0.75% did not differ significantly from each other, while the use of CMC 1% was significantly lower than the use of CMC 0%, 0.25%, and 0.75%. Based on these data, it can be seen that an increase in CMC concentration can lower the pH value but not significantly. The average pH value of rejected egg white powder in various treatments ranged from 8.9 to 9.05. The lowest average pH value was shown by the use of 1% CMC with a pH value of 8.9, while the highest average value was shown by the use of 0.75% CMC, which produced a pH value of 9.05. The difference in pH that appears at higher CMC concentrations indicates that the use of this hydrocolloid begins to affect the ionic balance and charge distribution in the egg white protein system. However, the changes that occur are still within a small range so that they do not shift the basic properties of egg white as a system with a weak alkaline pH. The pH value of the CMC used in this study was 7.28. The recommended pH value for Na-CMC is between 6 and 8.5 [18].

Electrostatic interactions between CMC and egg white protein can also cause changes in the microenvironment around charged amino acid residues, for example by forming protein-polysaccharide complexes. This complexation can shift the charge equilibrium on the protein surface and cause different local buffering effects, so that the pH value measured in samples with high CMC (P4) becomes slightly lower than the control. In addition, during the heating and drying process, side reactions such as the formation of carbohydrate degradation compounds or initial Maillard reactions between reducing sugars and proteins may occur. In products containing more CMC, these changes can be mediated by a thicker colloidal matrix, so that some weakly charged compounds (e.g., light organic acids) are more trapped and contribute to a decrease in pH, albeit to a relatively small degree. The higher the drying temperature and the longer the drying process, the greater the increase in pH [19]. The average pH value graph can be seen in Figure 2.

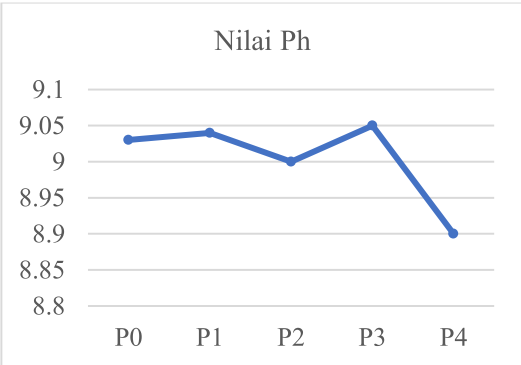

Figure 2. Graph of average pH values

3.3 Water Content (%)

Based on the analysis of variance, it shows that the treatment has a very significant effect ($P<0.01$) on the moisture content. Based on Duncan's multiple range test, the treatment without CMC use was not significantly different from the use of 0.25% CMC, but it significantly reduced the moisture content in the use of 0.5%, 0.75%, and 1% CMC. This means that the use of CMC at different concentrations can reduce the moisture content of the resulting flour. The average moisture content in various treatments ranged from 8.85 to 11.30%. The highest average moisture content was shown by the treatment without CMC use, with a moisture content of 11.30%, while the lowest average moisture content was found in the treatment with 1% CMC use, which produced a moisture content of 8.85%. Higher CMC use tended to reduce the moisture content of the flour. CMC is a hydrophilic hydrocolloid that can bind water and increase the viscosity of the liquid phase. During drying, increased viscosity and the formation of CMC-protein colloidal networks cause water to move more easily in the form of controlled vapor and reduce the chance of trapped water pockets forming in the matrix. As a result, the final moisture content of the product in the 0.5%–1% CMC treatments was lower than the control, indicating better drying efficiency. On the other hand, at too low CMC concentrations, the structure of the colloidal network formed is not strong enough to regulate water distribution and release optimally. This is because CMC has the ability to absorb water in the material, so that during the drying process, water evaporates more easily, resulting in a decrease in the water content of the product [17]. CMC acts as a stabilizer, water binder, and is capable of binding other compounds [20].

In the treatment using 1% CMC, the moisture content was actually lower at 8.85% compared to the control, which had a moisture content of 11.30%. This shows that the higher yield in 1% CMC was not caused by a wetter product, but rather by greater dry solid retention. The more stable CMC-protein gel structure facilitated water release but retained the solid components within the matrix. Thus, the use of 0.5-1% CMC can be said to increase the efficiency of the drying process because it can reduce the final moisture content while increasing the yield of egg white powder, whereas at lower CMC concentrations, the solid retention and matrix formation effects are not yet strong enough, so the yield is still comparable to the control. The average moisture content graph can be seen in Figure 3.

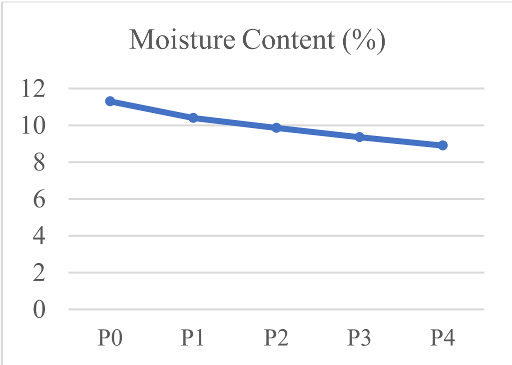

Figure 3. Average moisture content graph

3.4 Foam Strength (%)

Based on the analysis of variance, it shows that the treatment has a very significant effect ($P<0.01$) on foaming power. The total average foaming power value is between 365% and 440%, indicating a decrease as the CMC concentration increases. Based on Duncan's test, the treatment without the use of CMC 0% was not significantly different from the use of CMC 0.25% and 0.5%, but decreased significantly with the use of CMC 0.75% and 1%. This shows that the use of CMC with different concentrations has a significant effect on the foaming power of the flour produced. The highest average foaming power was shown by the use of 0% CMC with a foaming power of 440%, while the lowest average foaming power was found in the use of 1% CMC, which produced a foaming power of 365%. Foaming power is influenced by pH, among other factors, because pH regulates the charge and degree of protein denaturation during the whisking process. At weak alkaline pH, proteins are negatively charged so they can spread and form a stable interface layer around air bubbles, which ultimately increases the foam volume. CMC 1% can also interact with proteins (through hydrogen bonds and electrostatic forces) to form a more rigid complex. These complexes do make the foam more stable and the bubbles smaller and more uniform, but they inhibit the formation of new bubbles during agitation, so that the total foam power decreases compared to without CMC. This is consistent with the fact that the pH value causes the egg-forming proteins to capture air more easily, resulting in higher foam power [21].

In general, the foaming power of egg whites is determined by the ability of proteins to partially denature and rapidly adsorb between air and water. At high concentrations, CMC can interact with oppositely charged proteins and form soluble complexes and aggregates, which further alter the structure and flexibility of the protein film on the surface of the bubble. This results in a denser foam with smaller and more uniform bubble sizes, stable against collapse, but with lower total foaming capacity as seen in the decrease in foaming capacity from 440% to 365%. Research on food foam systems shows that the use of hydrocolloids such as CMC generally increases foam stability but often reduces foaming capacity, especially when the hydrocolloid concentration is high enough to alter the viscosity and microstructure of the liquid phase. In a previous study using CMC, it was found that the average bubble size in the control group was the largest, at 987 µm [22]. The average bubble size in the 0.4% CMC group was the smallest, at 223 µm, a reduction of 77.4% [22]. The reduction in average bubble size was due to the use of CMC in the foaming solution, which increased the viscosity of the solution [23], thereby increasing the strength of the liquid layer [24], further inhibiting the coalescence and rupture of bubbles, effectively reducing the rate of large bubble formation, and providing specific stability to the foam. The average foaming power graph can be seen in Figure 4.

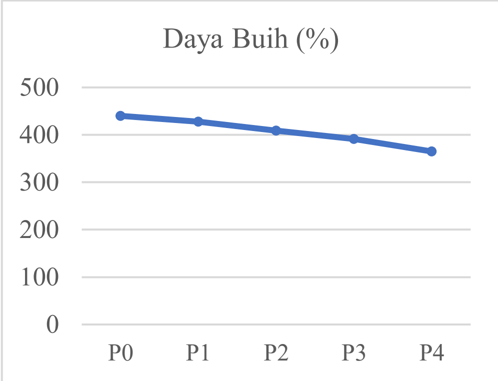

Figure 4. Average foam power graph

4 CONCLUSION

The use of CMC 0% to 1% in the production of rejected chicken egg white flour had a significant effect ($P<0.05$) on pH value, and a very significant effect ($P<0.01$) on yield, moisture content, and foaming ability. The use of CMC 0.75-1% increased the yield to 14.43-14.68%. the use of 1% CMC decreased the pH value to 8.9, the use of 0.5-1% CMC decreased the moisture content of the product to 8.85-9.85%, and the use of up to 0.5% CMC produced a foaming power that was almost the same as the control, namely 440%, because the use of 0.75-1% CMC decreased the foaming power of the product to 365-391.25%. The use of CMC at 0.5% is the best in terms of economy and quality because it successfully reduces the water content and increases the foaming capacity of rejected chicken egg white flour.

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