

## Preservation of Eggs Using Chitosan and Its Application in Angel Cake N.A.I.S. Bani<sup>1</sup>, W. Hatta<sup>1</sup>, and N. Nahariah<sup>1,2\*</sup>

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### ABSTRACT

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Eggs are easily damaged because of their high nutritional content, particularly their protein content. Therefore, preservation methods are necessary, with one such method involving the use of chitosan to prolong the freshness of the eggs while preserving their quality. This study aimed to assess and compare the efficacy of chitosan in maintaining the quality of purebred chicken eggs when stored at room temperature and its application in processed angel cake products. The experimental approach employed for egg preservation was a completely randomized design (CRD) with four treatments (P0 = no treatment, P1 = 1% chitosan solution, P2 = 2% chitosan solution, and P3 = 3% chitosan solution), replicated five times. The data underwent variance analysis, followed by Duncan's test to ascertain the impact of chitosan on egg preservation and product quality. The results revealed a significant effect ( $P < 0.05$ ) of chitosan solution on egg weight loss, Haugh unit, yolk index, and egg pH. Notably, 3% chitosan was more effective in maintaining egg quality than 1% and 2% chitosan coatings. In the 3% treatment, egg weight loss only experienced a shrinkage of 2.57% or 1.67 g from the initial egg weight. Haugh Unit of 65.57, yolk index of 0.41, and egg pH of 7.98. Additionally, angel cake products made from preserved eggs using chitosan exhibited significant differences ( $P < 0.05$ ) compared to those made from fresh eggs. The panelists preferred the texture and organoleptic attributes of the angel cake prepared with chitosan-preserved eggs.

**Keywords:** Chitosan, egg interior quality, angel cakes, texture profile

## INTROODUCTION

Eggs are vital ingredients in human nutrition and food processing. In human diets, eggs are a high-quality source of protein and are rich in vitamins and minerals, such as vitamin D, vitamin B12, and iron, along with essential amino acids that the body needs. Additionally, eggs are a versatile raw material used in various foods, acting as a binding agent and emulsifier while boosting nutritional content. Therefore, eggs are both nutritious and adaptable food ingredients. Eggs play a crucial role as the primary component in cake production, possessing diverse functional attributes that can be harnessed in the manufacturing of different food items. This constituent contains essential nutrients, such as proteins, fats, vitamins A and D, and minerals. Fresh eggs have a short shelf life, making it challenging to store them for an extended period because of their perishable nature.

Chitosan is a natural polymer derived from chitin, which is the main component of shellfish and other crustacean shells. Chitosan has unique functional properties, including the ability to form a protective layer that can prevent bacterial contamination and reduce moisture loss, making it a natural preservation solution for eggs. The antimicrobial properties of chitosan also help inhibit the growth of microorganisms on the surface of eggs, thereby extending their shelf life and maintaining their quality. Thus, chitosan is an effective and environmentally friendly natural egg preservation alternative. Chitosan forms a thin, impermeable film [1]. Chitosan can undergo biological degradation owing to its natural and non-toxic properties. Findings from a study by Bhale et al. [2] suggested that applying chitosan coating efficiently preserves the internal quality of eggs, extending their shelf life for a minimum of 3 weeks at 25°C. The raw materials for chitosan can be obtained from crustacean shell waste, such as shrimp and crab. In Indonesia, Chitosan is derived from marine fishery waste, particularly shrimp shells, which can serve as effective egg preservatives.

Chitosan is a natural polymer derived from chitin, the main component of shellfish and other crustacean shells. As a natural preservation solution for eggs, chitosan has unique functional properties, namely the ability to form a protective layer that can prevent bacterial contamination and reduce moisture loss. The antimicrobial properties of chitosan also help inhibit the growth of microorganisms on the surface of eggs, thereby extending the shelf life of eggs and maintaining their quality. Thus, chitosan becomes an effective and environmentally friendly natural preservation alternative for eggs. Chitosan exhibits the characteristic of forming a thin, impermeable film [1]. Due to its natural and non-toxic properties, Chitosan can undergo biological degradation. Findings from a study by Bhale et al. [2] suggest that applying chitosan coating efficiently preserves the internal quality of eggs, extending their shelf life for a minimum of 3 weeks at 25°C. The raw materials for Chitosan can be obtained from crustacean shell waste, such as shrimp and crab. In Indonesia, Chitosan is derived from marine fishery waste, particularly shrimp shells, which can serve as an effective egg preservative.

High-quality eggs can be identified based on their functional characteristics, such as foamability and stability. The key to making angel cake using the whisking technique is to create foam in the eggs. Angel cake elasticity serves as a measure of its physical quality. Additionally, the color, general appearance, aroma, and taste of the angel cake can be evaluated through organoleptic assessment.

Angel food cake is a dessert known for its sweetness and delicate texture. Angel cake is made using flour, sugar, eggs, vanilla, salt, cream of tartar, and fragrance ingredients, and is baked. It is essential to use high-quality ingredients, particularly fresh eggs, to prepare angel food cake for optimal results. Egg quality plays a crucial role in the success of the angel cake. Fresh, high-quality eggs have a good protein structure, which helps create a light and tender texture in angel cake. Additionally, good egg quality affects the ability of eggs to incorporate air and maintain their shape, allowing the angel cake to achieve maximum volume and a smooth texture. Therefore, selecting high-quality eggs is essential for making angel cakes to achieve optimal results.

Based on the description above, it is necessary to conduct a study to identify the level of chitosan required to maintain the quality of eggs and its application in advanced processed products, namely angel cake.

## MATERIALS AND METHODS

This study was conducted in the Tanete Riaja District, Barru Regency, from April to June. The eggs used in this study were less than a day old, weighing 60-65 grams from the 80-week-old Isa Brown strain taken directly from MN Farm in Barru Regency, South Sulawesi. The Chitosan used in this research was of grade A quality and was a chitosan powder, as indicated by the Certificate of Analysis/Result of Analysis.

The tools used in egg preservation were egg trays, SF-400 digital scales with a capacity of 7000 g and an accuracy of 1 g, 30 cm glass solution stirrer, Pyrex measuring tube with a capacity of 10 ml, beaker glass with a diameter of 105 mm and a capacity of 1000 ml, glass drip pipette with a pipette length of 14.4 cm and a capacity of 1 ml, and digital Vernier range 0–150 mm/0–6 "with a resolution of 0.1 mm/0.01". The tools used in making the angel cake were a mixing bowl with a diameter of 28 cm and a capacity of 5 liters, a Philips HR7922/90 mixer with a capacity of 5 liters, a egg beater/whisk G-435 made of stainless steel with a size of 30 cm, a 20 cm diameter flour sieve made of stainless diameter 20 cm, electric oven brand Joil capacity 32 L, a rectangular stainless steel mold with a size of 20 cm × 10 cm × 5 cm, a cake mixer spatula with a size of 28 cm made of silicon, and digital scales SF-400 with a capacity of 7000 g and an accuracy of 1 g.. The materials used in egg preservation were 100 eggs from MN Farm in Barru Regency, South Sulawesi, and chitosan powder from Bogor Regency with grade A quality based on Certificate of Analysis / Result of Analysis—the most concentrated acetic acid with a concentration of 98%, and sterile distilled water. The ingredients used to make the angel cake were egg whites, Bogasari brand wheat flour, Gulaku brand sugar, Koepoe brand vanilla, and salt.

The design used in this stage was a completely randomized design (CRD). The treatment at this stage was the level of Chitosan with four types of treatment and five replicates with the following form: P1: 0%; P2:1%; P3:2%; P4: 3%

Subsequently, the analysis of angel food cake continued to ascertain the distinction between the two treatments using the provided form:

T<sub>0</sub> = Angel Cake using fresh eggs

T<sub>1</sub> = Angel Cake using treated eggs

The first stage of the research procedure involved preparing a chitosan solution with 2% acetic acid, as much as 1000 ml, by mixing 20.40 ml of 98% acetic acid with 979.60 distilled water in a glass measuring cup. Chitosan (10, 20, and 30 g) was dissolved in 1000 ml of 2% acetic acid solution, which was introduced gradually while stirring using a solution stirrer to produce chitosan concentrations of 1%, 2%, and 3%. P0, the control group, was not treated.

The prepared chitosan solution at three concentration levels was poured into five small containers as replicates for each concentration. The immersion process included placing the eggs into a solution for 5 s, removing them, and allowing them to dry or aerate on an egg tray for 15 min. This sequence was repeated with a second immersion, after which the eggs were stored indoors at a room temperature of 25°C for 14 days. The optimal results obtained from this experiment will be implemented in subsequent steps of angel cake production.

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Angel cake preparation commenced with the initial step of separating the egg yolk from the egg white, as only the egg white was utilized in the preparation of angel cake. Subsequently, medium-protein flour, sugar, vanilla, orange flavoring, and salt were added to the mixture. Next, combine the separated egg whites, orange juice, vanilla, and salt in a mixing bowl. Gradually increase the mixer speed from medium to high while adding sugar until the mixture becomes stiff. Next, the wheat flour was slowly incorporated into the mixture, and the mixture was gently stirred using a spatula. Once the dough was ready, it was transferred into a pre-greased pan measuring 20 cm in length and 5 cm in height, and then baked in an oven set at 160°C for 60 min. The cake was allowed to cool for approximately 30 minutes after baking.

### Measurement Parameters

#### Egg Weight Loss

Monitoring the weight loss of eggs is essential to assess the extent of water evaporation and carbon dioxide loss from the egg white through the eggshell during storage. The measurement of egg weight loss involved using an electric scale to weigh the eggs, followed by the application of a specific calculation formula.

$$\text{Weight loss} = \frac{\text{Initial weigh} - \text{Final weigh}}{\text{Initial weigh}} \times 100\%$$

#### pH Value

The pH of the eggs was determined using a digital pH meter. This parameter needs to be observed because a higher pH value will cause the egg quality to decrease. The pH value was measured by calibrating the digital pH meter before measuring the sample using a pH seven buffer solution.

After the pH meter was calibrated, it was used to calculate the pH of the sample by first separating the egg white and yolk. The egg white was stirred to mix evenly for 1 min at 25°C. Then, the pH is measured and repeated three times to avoid errors, and the value is taken from the average of the measurements.

### Haugh Unit

The Haugh Unit of the eggs was calculated using the Modified Egg meter formula. This variable needs to be observed because it is a standard method for measuring egg quality; the lower the HU value, the lower the egg quality. The HU value was calculated by weighing the eggs using an electric scale, breaking the egg, placing it on a flat glass, and measuring the height of the thick egg white. HU was calculated using the following formula:

$$HU = 100 \log(H + 7,6 - \times W^{0,371,7})$$

Description:

H = Albumen height (mm)

W = Whole egg weight (g)

### Egg Yolk Index

The yolk index was measured using a digital caliper that could read autonomously. This parameter must be observed to determine yolk quality. The lower the yolk index, the lower is the egg quality. The yolk index was measured by comparing the yolk height with the center line measured after the yolk was separated from the egg white [3]. The Egg Yolk Index (EYI) was calculated as follows:

$$EYI = \frac{a}{b}$$

Description:

EYI = Egg Yolk Index

A = Yolk height (mm)

B = Average yolk width (mm)

### Frothing Power

The frothing power was determined by measuring the volume of the egg white before shaking. The egg white was shaken at the same weight unit using a hand mixer for 2 min at medium speed, then at maximum speed until foam was formed. The frothing power is calculated using the following formula [4]:

$$\text{Frothing power}(\%) = \frac{\text{Froth volume}}{\text{Egg white volume}} \times 100\%$$

## Froth Stability

Froth stability can be measured by the number of froth curls that occur after 1 h [5]. The higher the number of froth curls produced, the lower is the froth stability. The froth stability was calculated using the following formula:

$$\text{Frothing power}(\%) = \frac{\text{Drain volume}}{\text{Froth volume}} \times 100\%$$

$$\text{Froth Stability per hour}(\%) = 100 - \text{percentage of drain}$$

## Implementation of Egg Preservation in Making Angel Cake

### Taste

The taste evaluation technique involves chewing, tasting, and ingesting the angel food cake, which is then evaluated using a predetermined scale.



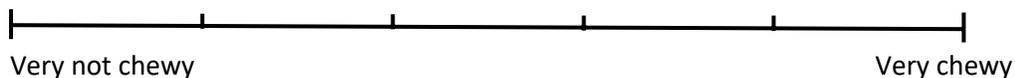
### Aroma

Product quality evaluation frequently involves assessing aroma, which can be perceived through the sense of smell of the consumer. In the case of the angel cake, the aroma was analyzed by smelling the cake sample.



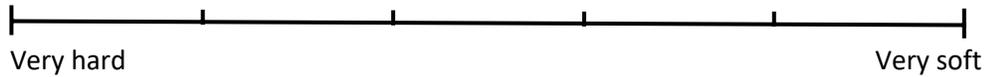
### Chewiness

Chewiness refers to the capacity of a compressed food substance to revert to its original form after pressure application. This characteristic is significant in sausage products, as it forms an integral component of the overall texture profile and serves as a crucial sensory attribute that consumers consider when evaluating products.



## Hardness

Hardness is an essential indicator in analyzing the texture of food. Hardness is also a property of food products that shows the power resistance to rupture due to the applied compressive force.



Hardness was measured using a Likert scale with the following conditions: very soft (the cake crumbles very quickly with little pressure), soft (the cake crumbles quickly but has little resistance), medium (the cake has moderate resistance, neither too soft nor hard), hard (the cake requires considerable pressure to crumble), and very hard (the cake is tough to crumble, requiring enormous pressure).

## Cake Volume

The volume of the cake was calculated using the formula:

$$Volume = Length \times Width \times Height$$

## Degree of Expansion

The Degree of Expansion can be determined by calculating the ratio of the volume increase of the angel cake to the volume of the original dough, which can be done using the specified formula.

$$Degree\ of\ expansion\ (\%) = \frac{V_2 - V_1}{V_1} \times 100\%$$

## Data Analysis

The mathematical model used in the first stage of egg preservation using chitosan is as follows:

$$Y_{ij} = \mu + \tau_i + \epsilon_{ij}$$

Description:

$i$  = 1,2,3,4 (chitosan solution)

$j$  = 1,2,3,4,5 (Replicates)

$Y_{ij}$  = Observed response in the chitosan solution treatment

$\mu$  = General mean value

$\tau_i$  = Effect of chitosan level on measured egg parameters

$\epsilon_{ij}$  = Effect of level treatment error on the chitosan solution replicate measured egg parameter

Then, proceed to the second stage by making an angel cake using the t-test with the following mathematical model:

$$t_{hit} = \frac{\bar{D}}{\frac{SD}{\sqrt{n}}}$$

$$SD = \sqrt{var}$$

$$var(s^2) = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2$$

Description:

t = Calculated t value

D = Average difference between measurements 1 and 2

SD = Standard deviation of the difference between measurements 1 and 2

n = Number of samples

## RESULTS AND DISCUSSIONS

### Egg Weight Loss

Analysis of variance showed that egg preservation with chitosan solution had a significant effect ( $P < 0.05$ ) on egg weight loss. The results of the analysis are presented in Table 1.

Table 1. Average Weight Loss of Eggs Preserved Using Chitosan Solution at Different Levels.

Level (%)	Egg Weight Loss (g)
0	2.23±0.01 <sup>a</sup>
1	1.85±0.01 <sup>b</sup>
2	1.80±0.01 <sup>c</sup>
3	1.67±0.01 <sup>d</sup>

Note: <sup>abcd</sup> Different superscripts in the same column indicate significant differences ( $P < 0.05$ )

Based on the Duncan test, the average weight loss of the eggs decreased with increasing chitosan solution concentration. The eggs treated with 0% chitosan solution had the highest weight loss, averaging  $2.23 \pm 0.01$ , while those treated with 3% had the lowest weight loss, averaging  $1.67 \pm 0.01$ . These findings suggest that a higher concentration of 3% chitosan effectively minimizes egg shrinkage.

The results of this study indicated a correlation between the treatment concentration and egg weight loss. The higher the treatment concentration, the lower the weight loss. This aligns with the opinion of Nongtaodum et al. [6], who stated that a relationship exists between the concentration of the treatment and the level of egg weight loss. The findings indicate that the rate of weight loss decreased as the treatment concentration increased. This treatment successfully minimizes egg weight loss, presumably by reducing water and gas evaporation through the eggshell.

Using Chitosan for preservation purposes is intended to extend the shelf life of eggs by reducing loss. Chitosan, a natural biopolymer with antimicrobial and coating-forming properties, helps maintain moisture and prevent microbial contamination. As a result, it effectively preserves

the internal quality of the egg, decreases weight loss during storage, and enhances its resistance to damage. This is consistent with Amaral and Fernandes [7], who emphasized the importance of proper management of egg weight loss in maintaining optimal egg quality during storage. The selection of an appropriate treatment can increase the shelf life and quality of eggs, thereby reducing losses due to quality deterioration during storage.

Egg preservation using chitosan involves complex chemical and physical mechanisms that maintain moisture and reduce weight loss in eggs. Chemically, chitosan contains amino groups that can interact with water molecules and form hydrogen bonds, thereby reducing the rate of water vapor diffusion from the inside of the egg to the surrounding environment. Additionally, chitosan has antimicrobial properties that can inhibit the growth of microorganisms on the egg surface, thereby reducing the risk of contamination and damage. Chitosan can physically form a thin, compact layer on the egg surface, acting as a semipermeable barrier. This layer can reduce the rate of water vapor and gas diffusion, thereby reducing moisture and egg weight loss. Furthermore, the chitosan layer can reduce the rate of oxidation and other chemical reactions that can damage eggs. Thus, egg preservation using chitosan can maintain moisture and reduce weight loss through complex chemical and physical processes. The amino groups on chitosan can interact with water molecules, while the chitosan layer acts as a semipermeable barrier to reduce the rate of water vapor and gas diffusion. This can improve egg quality and freshness and extend the shelf life of eggs.

The results of this study are similar to those of Falahuddin [8], with the lowest reduction in egg weight loss at 3% chitosan concentration, with an average of 1.66. Furthermore, the preservative has the characteristic of forming a thin layer that can close the egg's pores, thus effectively preventing water evaporation and loss of carbon dioxide and other gases, significantly affecting the retention of egg quality during storage.

### **Haugh Unit**

The analysis of variance showed that egg preservation with chitosan solution had a significant effect ( $P < 0.05$ ) on the average Haugh Unit of eggs. Based on Duncan's test, the average Haugh unit showed that the higher the level of chitosan solution, the higher the average Haugh unit of the eggs obtained. The highest Haugh Unit was observed in the 3% preservation using chitosan, with an average of  $65.57 \pm 0.02$ . The lowest weight loss was observed in the 0% preservation treatment using chitosan, averaging  $37.79 \pm 0.01$ , indicating that the high concentration of 3% chitosan in conservation is in the category of having good egg quality. Furthermore, the higher the HU value, the better the egg quality. It is further stated that good-quality eggs are 60-72, while damaged eggs have a HU value below 50. The results of the analysis are presented in Table 2.

Using Chitosan in egg preservation can help maintain egg quality, including higher Haugh Units. However, the effectiveness of chitosan as a preservative may vary depending on the preservation conditions. This is based on the opinion of Silva et al. [9], who stated that chitosan can affect the permeability of the egg membrane, which can affect the gas exchange and water retention. This affects the viscosity of egg white and ultimately affects the Haugh Unit of egg quality.

Table. 2 Average Haugh Unit of Eggs Preserved Using Chitosan Solution with Different Levels.

Level(%)	Haugh Unit
0	37.79±0.02 <sup>a</sup>
1	60.69±0.01 <sup>b</sup>
2	58.64±0.36 <sup>c</sup>
3	65.57±0.02 <sup>d</sup>

Note: <sup>abcd</sup> Different superscripts in the same column indicate significant differences (P<0.05)

The increase in Haugh Unit (HU) values in eggs preserved with chitosan indicates a positive impact on egg quality. The Haugh Unit is a measure used to determine the freshness and quality of eggs based on the height of the albumen (egg white) and egg weight. The higher the HU value, the better was the egg quality. In the context of storage, eggs with high HU values indicate the ability to maintain freshness and quality for a longer period. Chitosan, a natural preservative, can help maintain high HU values in eggs by reducing moisture loss and preventing microbial contamination. Thus, the use of chitosan as an egg preservative can help improve egg quality and extend its shelf life, making it highly beneficial in the food industry.

Chitosan can form a thin layer on the egg surface that acts as a semipermeable barrier, reducing the diffusion of gases and water vapor from the inside of the egg to the environment. This helps maintain the moisture and freshness of the eggs, thereby preserving their HU value. The HU value is a measure of egg quality related to the thickness and freshness of the egg white. Chemically, chitosan has antimicrobial properties that can inhibit the growth of microorganisms on the egg surface, thereby helping to maintain egg quality and reduce the risk of contamination that can affect HU values. Chitosan can also interact with water molecules and form hydrogen bonds, which helps maintain egg moisture and preserve the HU. Thus, the use of chitosan as an egg preservative can help maintain egg quality and preserve the Haugh unit value, allowing eggs to remain fresh and of high quality for a longer period. Therefore, chitosan can be an effective alternative for egg preservation and maintenance of egg quality.

The findings of this study are similar to those of Rahmawati et al. [10], who reported a peak Haugh Unit average of 68 in eggs without preservation. Additionally, as mentioned by Andi [11], the high unit value is affected by ovomucin in the egg white; a higher ovomucin content results in a higher unit value. Conversely, egg whites with a lower ovomucin content tend to deteriorate more rapidly.

### Egg Yolk Index (EYI)

The variance analysis outcomes indicated a significant impact (P<0.05) of the egg preservation treatment with chitosan solution on the mean yolk index. According to Duncan's test, as the chitosan solution level increased, the average yolk index also increased. The results of the analysis are presented in Table 3.

Table. 3. Mean of Egg Yolk Index Preserved Using Chitosan Solution with Different Levels.

Level(%)	Egg Yolk Index
0	0.29±0.00 <sup>a</sup>
1	0.37±0.00 <sup>b</sup>
2	0.38±0.01 <sup>c</sup>
3	0.41±0.00 <sup>d</sup>

Note: <sup>abcd</sup> Different superscripts in the same column indicate significant differences (P<0.05)

The highest yolk index was in the 3% preservation using chitosan, averaging  $0.41 \pm 0.00$ , and the lowest weight loss was in the 0% preservation using chitosan, averaging  $0.29 \pm 0.00$ . This indicates that a high concentration of 3% chitosan in conservation is in the category of excellent egg quality. This is the opinion of Cornelia et al. [12], which states that a good yolk index with an average of 0.40-0.42 using egg preservation using mangosteen peel helps slow down the decrease in EYI value of broiler eggs and extends the shelf life of eggs at room temperature.

The use of chitosan in egg preservation can affect the yolk index. Chitosan helps retain moisture and nutrient content in eggs during storage. This suggests that eggs preserved with chitosan could maintain a more stable or even lower yolk index than eggs stored without preservation treatment. According to Kerch et al. [13], using chitosan in egg preservation can affect the yolk index by maintaining moisture and nutrient content during storage. This condition results in eggs that maintain a stable or even lower yolk index than that of non-preserved eggs.

Physically, chitosan can form a thin layer on the egg surface that acts as a semipermeable barrier, reducing the diffusion of gases and water vapor from inside the egg to the surrounding environment. This helps maintain the moisture and freshness of the egg, thereby preserving its yolk index. Additionally, chitosan can reduce egg weight loss by reducing water vapor diffusion, which helps maintain egg quality. Chemically, chitosan has antimicrobial properties that can inhibit the growth of microorganisms on the egg surface, thereby helping maintain egg quality and reducing the risk of contamination. Chitosan can also interact with water molecules and form hydrogen bonds, which helps maintain egg moisture levels. Furthermore, chitosan can reduce oxidation, which can cause changes in the color and quality of the egg yolk, thereby preserving the yolk index.

### Egg pH Value

The variance analysis indicated that egg preservation treatment with chitosan solution had a notable impact (P<0.05) on the average pH value. According to Duncan's test, as the chitosan solution concentration increased, the average pH value decreased. Nevertheless, no significant differences were observed between the pH values obtained from 1% and 2% chitosan solutions. The results of the analysis are presented in Table 4.

Eggs treated with 0% chitosan had the highest pH value of  $8.80 \pm 0.00$ , while those treated with 3% chitosan had the lowest weight loss, with an average pH of  $7.98 \pm 0.00$ . The results suggest that a higher concentration of 3% chitosan in preservation leads to eggs falling within the normal pH range. This finding aligns with the observation that freshly released or fresh eggs typically have a pH value ranging from 7.6 to 7.9.

Table. 4 Average Egg pH was Preserved Using Chitosan Solution with Different Levels.

Level (%)	pH Value
0	8.80±0.00 <sup>a</sup>
1	8.10±0.00 <sup>b</sup>
2	8.11±0.01 <sup>b</sup>
3	7.98±0.00 <sup>c</sup>

Notes: <sup>abcd</sup>Different superscripts in the same column indicate significant differences (P<0.05)

The increase in pH causes the egg white to thin out as carbon dioxide escapes through the pores of the eggshell. This carbon dioxide plays a crucial role in producing bicarbonate ions, which are essential for regulating the buffer system in egg white. The buffering capacity of egg white weakens with decreasing bicarbonate ion concentration due to CO<sub>2</sub> loss. Consequently, the pH level of egg white increases, leading to alkaline properties [14].

The results of this study contrast significantly with those of Caner et al. [15], who found that the pH value of eggs treated with 8% chitosan averaged 8.77±0.03 after a 2-week immersion period. Additionally, Pires et al. [16] suggested that applying a chitosan coating contributes to the stability of egg pH by acting as a barrier against external factors that may impact the chemical composition of the albumen, such as CO<sub>2</sub>, which can lead to a decrease in pH.

#### Frothing Power

The analysis of variance results demonstrated a significant effect (P<0.05) of the treatment involving egg preservation with chitosan solution on the average frothing power. According to Duncan's test, an increase in the chitosan solution concentration resulted in a higher mean frothing power value. The results of the analysis are presented in Table 5.

Table 5. Average Frothing Power of Eggs Preserved Using Chitosan Solution with Different Levels.

Level (%)	Frothing Power (%)
0	195.54±2.64 <sup>a</sup>
1	249.45±11.43 <sup>b</sup>
2	336.95±4.06 <sup>c</sup>
3	403.91±3.94 <sup>d</sup>

Note: <sup>abcd</sup> different superscripts in the same column indicate significant differences (P<0.05).

The egg frothing power was the lowest in the 0% chitosan treatment for preservation, with an average of 195.54±2.64. In comparison, the highest frothing power was observed in the 3% chitosan treatment, with an average of 403.91±3.94. This indicates that a higher concentration of 3% chitosan in preservation resulted in average category egg froth values. Chitosan aids in forming a more robust and stable gel network, leading to increased and prolonged froth. Physically, chitosan can form a thin layer on the egg surface that acts as a semipermeable barrier, reducing the diffusion of gases and water vapor from inside the egg to

the surrounding environment. This helps maintain the moisture and freshness of the egg, thereby preserving the protein structure and affecting the egg's ability to form a stable foam. Chemically, chitosan has antimicrobial properties that can inhibit the growth of microorganisms on the egg surface, thereby helping to maintain egg quality and reduce the risk of contamination that can affect the egg's ability to form a foam. Additionally, chitosan interacts with egg proteins and helps maintain their structure and function, thereby preserving the egg's ability to form a stable foam. This observation is consistent with the assertion made by Pires et al. [16], who reported that chitosan serves as a natural stabilizer, enhancing the stability and emulsifying ability of egg white proteins. Furthermore, Falahudin [17] reported that high water content in the treatment posed challenges in the froth formation process.

### Froth Stability

The analysis of variance showed that egg preservation with chitosan solution had a significant effect ( $P < 0.05$ ) on the average value of froth stability. Based on Duncan's test, the mean value of frothing power showed that the higher the level of chitosan solution, the higher the average froth stability. The results of the analysis are presented in Table 6.

Table. 6 Mean Froth Stability of Eggs Preserved Using Chitosan Solution with Different Levels.

Level (%)	Frothing Power Stability (%)
0	51.35±0.95 <sup>a</sup>
1	59.83±0.60 <sup>b</sup>
2	79.70±0.91 <sup>c</sup>
3	90.07±0.55 <sup>d</sup>

Note:<sup>abcd</sup> different superscripts in the same column indicate significant differences ( $P < 0.05$ ).

The preservation treatment using 0% chitosan concentration yielded the lowest egg froth stability, averaging 51.35±0.95%. Conversely, treatment with 3% chitosan showed the highest froth stability, averaging 90.07±0.55%. This indicates that a higher concentration of chitosan, at 3%, falls within the average category value for egg froth stability. The interaction of chitosan with fat in the egg leads to the formation of a complex that enhances the foam structure. Physically, chitosan can form a thin layer on the egg surface that acts as a semipermeable barrier, reducing the diffusion of gases and water vapor from inside the egg to the surrounding environment. This helps maintain the moisture and freshness of the egg, thereby preserving the protein structure in the egg and affecting the egg's ability to form a stable foam. Chemically, chitosan has antimicrobial properties that can inhibit the growth of microorganisms on the egg surface, thereby helping to maintain egg quality and reduce the risk of contamination that can affect the stability of foams. Additionally, chitosan can also interact with egg proteins and help maintain the structure and function of proteins, thereby preserving the egg's ability to form a stable foam. This finding aligns with Wulandari and Arief [18], who asserted that chitosan serves as a natural stabilizer, strengthening the foam structure, improving stability, and enhancing the emulsifying ability of egg white proteins. In acidic solutions, chitosan, which is positively charged, can form favorable electrostatic interactions with negatively charged egg proteins such as albumin. These

interactions fortify the egg froth structure and extend its sustainability, resulting in a more resilient and long-lasting froth for various food applications.

### Implementation of Egg Preservation in Angel Cake Making

The implementation of preserved eggs in the preparation of angel cake products is presented in Table 7. The quality of angel cake products was measured in terms of hardness, chewiness, taste, and aroma.

Table 7. Angel Cake Parameter Test.

Parameters	Treatment	
	Without Chitosan	With Chitosan
Chewiness	2.15±0.37 <sup>a</sup>	3.75±0.55 <sup>b</sup>
Hardness	2.50±0.51 <sup>a</sup>	4.40±0.50 <sup>b</sup>
Taste	3.25±0.44 <sup>a</sup>	4.50±0.51 <sup>b</sup>
Aroma	4.4±0.50 <sup>a</sup>	4.1±0.41 <sup>a</sup>
Degree of Expansion (%)	22.80±4.38 <sup>a</sup>	42.00±8.37 <sup>b</sup>
Angel Cake Volume (cm) <sup>3</sup>	1248.00±50.20 <sup>a</sup>	1440.00±54.77 <sup>b</sup>

Notes: <sup>ab</sup> Different superscripts in the same column indicate significant differences P<0.05). **Chewiness:** 1. very not chewy, 2. not chewy, 3. moderately chewy, 4. Chewy, 5. Very Chewy **Hardness:** 1. very hard, 2. hard, 3. medium, 4. soft, 5. very soft. **Taste:** 1. Very bad, 2. Bad, 3. Neutral, 4. Good, 5. Very good.

#### Chewiness

The findings indicated that utilizing chitosan-treated eggs effectively preserved the eggs and resulted in angel cakes with a desirable texture, ranging from chewy to very chewy. Chitosan can retain water, improving the water retention of eggs treated with chitosan. This enhanced water retention may contribute to a more tender and chewier cake texture by ensuring adequate water content during the baking process. These results align with those of Elsabee and Abdou [19], who highlighted that the water-binding properties of chitosan play a crucial role in maintaining the desired texture of food products, such as the softness of bread or the chewiness of meat.

Chitosan can effectively retain water within the cake batter, thereby affecting the moisture levels of the baked cakes. The presence of optimal moisture content is a critical factor in determining the chewiness of cakes. By extending water retention in the dough, succinyl chitosan can improve the chewy texture of cakes [20].

#### Hardness

The data presented in Table 7 highlight a significant difference in the hardness of the angel cake as evaluated by the 20 panelists. Angel cake formulations using unpreserved eggs and those incorporating eggs preserved with chitosan were compared, with a statistical significance of P<0.05. Angel cake made from eggs without chitosan displayed an average hardness parameter value of 2.50±0.51 (challenging-Medium), while the counterpart prepared with chitosan-preserved eggs showed a mean value of 4.40±0.50 (soft-very soft).

Texture hardness refers to the tactile sensation of pressure experienced through touch, either with the mouth or fingers. In food preservation, chitosan has been found to impact the physical attributes, particularly texture. Acting as an antimicrobial agent and coating, chitosan plays a crucial role in prolonging the shelf life of food items by preserving their texture and hardness. Moradi et al. [21] supported this notion by suggesting that incorporating Chitosan can enhance bread's softness and tenderness, thereby preventing it from becoming too hard over time. By helping to maintain the cellular structure of bread, chitosan ensures that its texture remains pleasantly soft and chewy for an extended period. Additionally, Kerch et al. [13] highlighted that the presence of chitosan in eggs can enhance the stability and overall quality of the dough, resulting in cakes that are softer and more tender post-baking.

The quality of angel cake's hardness is influenced by various factors, including ingredients such as sugar, salt, and flour, as well as the baking process. Risa and Marsiti [21] emphasize the significance of considering other factors that impact cake quality, such as the type and quality of ingredients, including flour, fat, and eggs, and the dough-making and baking processes, including temperature and maturation time.

### **Taste**

The data presented in the table indicate a notable contrast in the measurement of angel cake taste attributes among the 20 panelists, with a statistically significant variance ( $P < 0.05$ ) observed between angel cakes produced from eggs lacking preservation and angel cakes from eggs preserved with chitosan. The average value of the taste attributes for angel cake made from eggs without chitosan was  $3.25 \pm 0.44$  (ranging from neutral to sound). In contrast, the angel cake from eggs preserved with chitosan exhibited an average score of  $4.50 \pm 0.51$  (ranging from good to very good).

The average results showed that angel cakes made using chitosan-treated eggs scored higher in taste than those made using untreated eggs. This indicates that using chitosan to preserve eggs can significantly improve the taste quality of angel cake, as reflected by the rating scale used (from neutral/tasty to very tasty). This is because the eggs preserved with chitosan made the angel cake more delicious because it had a soft or not hard texture; this is in accordance with the opinion of Ghoshal and Mehta [22], who stated that chitosan in eggs can improve dough stability and the quality of the resulting cake texture.

The taste of a food or product holds significant weight in the consumer decision-making process. Despite favorable characteristics in other areas, such as nutritional value or packaging, an unsatisfactory taste can result in the rejection of a product. Taste preferences are categorized into four main parameters: salty, sour, bitter, and sweet [23].

### **Aroma**

Table 7 illustrates no statistically significant difference ( $P < 0.05$ ) in the angel cake aroma parameters measured by 20 panelists between angel cake made from eggs without preservation and angel cake made from eggs preserved with Chitosan. The mean value of the aroma parameters for angel cake made with eggs without Chitosan was  $4.4 \pm 0.50$  (aromatic-very

aromatic), while for angel cake made with eggs preserved with Chitosan, it was  $4.1 \pm 0.41$  (aromatic).

Aroma development occurs during the Maillard reaction in baking, which partially evaporates volatile compounds from the ingredients. This finding aligns with the findings of Miftahul et al. [24], who suggested that volatile compounds contributing to the cake's aroma evaporate during baking. Interactions between amino acids from proteins and reducing sugars result in the formation of characteristic aromatic compounds. Additionally, the oxidation of fats during heating leads to the reaction of active substances with peptides and amino acids, contributing to the unique baking aroma. This observation is consistent with the research of Armila et al. [25], which indicates that protein denaturation into amino acids, reactions between amino acids and sugars, fat oxidation, and interactions between substances and amino acids and lipids are responsible for the distinct aroma during baking.

### **Degree of Expansion**

Table 7 illustrates no statistically significant difference ( $P < 0.05$ ) in the aroma parameters of angel cake measured by 20 panelists between angel cake made from eggs without preservation and angel cake made from eggs preserved with chitosan. The mean value of the aroma parameters for angel cake made with eggs without chitosan was  $4.4 \pm 0.50$  (aromatic-very aromatic), while that for angel cake made with eggs preserved with chitosan was  $4.1 \pm 0.41$  (aromatic).

Aroma development occurs during the Maillard reaction in baking, which partially evaporates volatile compounds from the ingredients used. This finding aligns with that of Miftahul et al. [24], who suggested that volatile compounds contributing to the aroma of the cake evaporate during baking. Interactions between amino acids from proteins and reducing sugars result in the formation of characteristic aromatic compounds. Additionally, fat oxidation during heating leads to the reaction of active substances with peptides and amino acids, contributing to the unique baking aroma. This observation is consistent with the study by Armila et al. [25], which indicates that protein denaturation into amino acids, reactions between amino acids and sugars, fat oxidation, and interactions between substances, amino acids, and lipids are responsible for the distinct aroma during baking.

### **Volume Angel Cake**

The table indicates a statistically significant difference ( $P < 0.05$ ) in the volume of angel cake after baking when comparing cakes with and without chitosan. The volume of angel cake made with egg ingredients but without chitosan was  $1248.00 \pm 50.20 \text{ cm}^3$ , whereas the volume of angel cake made with egg ingredients and preserved with chitosan was  $1440.00 \pm 54.77 \text{ cm}^3$ .

Eggs treated with chitosan exhibited a more significant size than untreated eggs due to the hydrophilic nature of chitosan, a polymer derived from chitin. By immersing eggs in a chitosan solution before incorporating them into an angel cake batter, chitosan enhances the water absorption or retention by the eggs. Consequently, this can lead to a more succulent and moist angel cake batter, ultimately producing a larger cake. Kerch et al. [13] asserted that chitosan, a chitin polymer with hydrophilic properties, attracts water. When eggs are immersed in a chitosan

solution before being incorporated into an angel cake batter, chitosan facilitates the absorption or retention of more water. This can lead to a moister and juicier angel cake batter, ultimately resulting in a cake with a larger volume. Additionally, Bravo-Núñez et al. [29] and Al-Dmoor [30] found a close correlation between the baking time of a cake and its volume.

Different research results in the study by Moradi et al. [21] state that the use of fermented egg whites reduces the height and volume of angel cake because the lactic acid in the eggs can limit cake expansion and moisture evaporation during the baking process.

## CONCLUSIONS

Preserving eggs using a chitosan solution effectively maintains the egg quality of fresh eggs. The 3% level of chitosan use showed the best results regarding the eggs' quality. Implementing angel cake in eggs treated using chitosan showed a better texture profile and more favorable organoleptic qualities.

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## AUTHORS' CONTRIBUTIONS

All authors designed the study and drafted and revised the manuscript, performed the experiments, and analyzed the data. All authors have read and approved the final manuscript.

## COMPETING INTERESTS

The authors declare that they have no conflict of interest with any party in writing this article.

## ETHICAL CLEARANCE

This research does not use animals as research objects, so it does not require ethical clearance.

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