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Organoleptic and Durability of Frozen Whole Broiler Chicken Thawed with Chitosan Edible Coating for Different Shelf Life

Yusni Khairani Tampubolon, Winda Fransisca Saragih* 6904310

[1]*Animal Science Study Program, Faculty of Agriculture, Universitas Sumatera Utara, Medan, 20155, Indonesia*
*Corresponding Author: windafransisca@usu.ac.id

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ABSTRACT

The increase in broiler production led to an oversupply of chicken in the market while the increase in chicken consumption was not proportional to the increase in production. Therefore frozen storage is one of the alternatives to overcome this excess chicken production. This study aimed to determine the effect of chitosan edible coating concentration and storage time on the shelf life and organoleptic properties of frozen broiler chicken carcasses during the thawing process. This study used a Factorial Completely Randomized Design (RALF) consisting of two factors, namely Factor 1: differences in shelf life (1, 2, and 3 months) and factor 2: concentration of edible chitosan coating (0, 1%, 1.5%) with five replications. The parameters observed were shelf life and organoleptic properties (aroma, texture, color, and total acceptance). Data were analyzed using Two-way Analysis of Variance and further testing of the Duncan Multiple Range Test (DMRT). The results showed that chitosan concentration had a significant effect ($P < 0.05$) on shelf life and organoleptic quality, whereas shelf life did not have a significant effect. The use of 1% chitosan gave the best results in organoleptic quality and 1.5% in slowing down broiler carcass decay. In conclusion, edible chitosan coatings can be effectively applied during thawing to extend the shelf life and maintain the quality of frozen broiler chicken meat.

Keyword: Broiler, Chitosan, Edible Coating, Durability, Organoleptic

1. Introduction

Broiler chicken production in Indonesia has increased significantly to reach a surplus. Based on data from the [1], the chicken meat surplus is estimated to reach 214.79 million tons in 2025. This number is projected to continue to increase annually. This increase in production has caused an oversupply of chicken in the domestic market, while the volume of broiler meat exports is still relatively small compared to total domestic production [1]. On the other hand, the increase in broiler chicken consumption is not comparable to the rate of increase in production [2].

Frozen storage is an alternative to the excessive production of broiler chicken. In Indonesia, this method has been widely applied by various companies to maintain product quality over a long period. It is estimated that the use of frozen storage methods increases by around 10-20% each year [3]. In frozen storage conditions, chicken meat is stored at 20°C to inhibit the growth of microorganisms that cause food spoilage [4]. Chicken meat is classified as easily damaged by the activity of spoilage microorganisms that produce metabolites, which trigger color changes, unpleasant tastes, slimy textures, and the appearance of exudates. These conditions have a negative impact on the organoleptic and sensory properties of a product, thereby reducing consumer acceptance [5].

The final stage of handling frozen products is the thawing process. The most commonly used thawing methods are water and room temperature [6]. The thawing process must be performed optimally because at this stage, pathogenic microorganisms that were previously dormant during the freezing process can become active again [7]. The activation of these microorganisms can cause contamination of meat, which can then trigger a decrease in product quality to the point of spoilage. [8] also stated that thawing process that are not carried out properly can have a negative impact on the texture, taste, color, and nutritional content of a product.

Chitosan is often used in the process of preventing food product spoilage because it has broad-spectrum antimicrobial properties that can inhibit the growth and reproduction of harmful microorganisms [9], thus extending the shelf life. Chitosan is a polysaccharide obtained from shrimp and crab shell waste, which is a fishery waste that is safe for consumption. Several studies have shown that the use of chitosan can prevent spoilage, thereby extending the shelf life and maintaining the quality of food products [10], [11], [12].

One of the most common applications of chitosan in food products is its use as an edible coating or food surface coating. This coating prevents meat from being contaminated by pathogenic bacteria so that product quality is maintained [13]. Previous studies have examined the effects of edible chitosan coatings on the thawing process. [14] reported that the application of 1% chitosan in the thawing process of frozen broiler chicken carcasses was effective as an antimicrobial agent that can inhibit the growth of pathogenic microorganisms, thereby slowing down the meat rotting process and improving sensory quality. However, to date, no research has discussed the effect of storage time on the effectiveness of the chitosan concentration used. Therefore, this study was conducted to determine the effect of shelf life and edible chitosan coating concentration during thawing on the durability and organoleptic properties of frozen broiler carcasses.

2. Method

The research used broiler carcasses weighing 0.9 - 1 kg obtained from a poultry slaughterhouse with as many as 45 heads (5 heads per treatment). Commercial edible chitosan coatings obtained from local producers. The tools used include freezer storage, knives, basins, pans, stoves, distilled water, labels, aluminum foil, and ziplock plastic. This study used a completely randomized design (CRD) consisting of two factors, namely differences in the shelf life (1, 2, and 3 months) and the concentration of edible chitosan coating (0%, 1%, 1.5%) with 9 treatments and 5 replications. The treatments in the study can be seen in Table 1.

2.1 Procedure

The research procedure consists of freezing, preparation of edible chitosan coating, thawing, and sample analysis.

1. Freezing. Cleaned broiler chicken carcasses are placed into a PP plastic ziplock model, and then stored in freezer storage at -20°C until the internal temperature of the chicken is at least 12°C. There are four chicken shelf life groups, namely 1, 2, and 3 months.
2. Preparation of a Chitosan Edible Coating. Chitosan powder was obtained from local shrimp waste. The edible coating solution was prepared by dissolving chitosan in 0.5% acetic acid. The chitosan edible coating used in this study was 0, 1%, and 1.5% of the weight of the chicken carcass.
3. Thawing. After reaching the specified storage time, the frozen chicken is removed from the freezer and placed from the plastic. Then it is thawed by soaking the chicken in a chitosan edible coating solution for 90 min at room temperature. After that, the chicken is allowed to dry for 15 minutes.
4. Sample Analysis. Analysis was conducted on frozen chicken meat coated with edible chitosan. The analysis conducted was organoleptic analysis and durability analysis.

2.2 Research Variables

1. Organoleptic Analysis

   Organoleptic analysis was conducted on frozen broiler chicken samples thawed with edible chitosan coating. Organoleptic test with a hedonic scale of 1-5. The assessment includes four parameters: aroma, texture, color, and total acceptance. Descriptions of the assessment scale are presented in Table 1. The samples were analyzed by a panel of 25 people, consisting of housewives, young people and male workers with an age range of 20-50 years.

Table 1. Organoleptic Assessment Scale for Frozen Broiler Chicken Meat Thawing Using Edible Chitosan Coating

Indicator	Scale	Information
Aroma	1	Fishy
	2	A bit fishy
	3	Typical meat aroma, there is a strange aroma
	4	Distinctive meat aroma, no off-flavors
	5	The distinctive aroma of delicious meat
Texture	1	Very soft and very slimy
	2	Soft and a little slimy
	3	Normal
	4	Dense and slimy
	5	Very dense and not slimy
Color	1	Pale, unattractive
	2	Pale, less attractive
	3	White (normal)
	4	White, attractive
	5	White, very attractive
Total Receipts	1	Very disliked
	2	Disliked
	3	Neutral
	4	Liked
	5	Very much liked

2.3 Meat Preservation Power

The durability of meat was analyzed using Pb acetate to detect early signs of decay. The test method was performed based on [15] by cutting the meat into 10 g pieces and placing it in a Petri dish. Furthermore, filter paper that had been dripped with 1-2 drops of 10% Pb acetate solution was placed in the center of the dish, and then the Petri dish was closed. The time from the time of dripping until the appearance of brownish spots was used as an indicator of early decay. The duration was recorded and noted for analysis.

2.4 Data Analysis

The research data were analyzed using the Two Way ANOVA (Analysis of Variance) method. To determine whether there were differences between treatments, the Duncan Multiple Range Test (DMRT) was conducted at a significance level of $\alpha = 0.05$. The data were analyzed using SPSS version 21.

3. Result and Discussion

3.1. Aroma

The results of the assessment of aroma, texture, color, and total acceptance of broiler meat with different chitosan concentration dipping treatments and the shelf life of broiler chickens are presented in the Table 2. This study showed no significant interaction ($P>0.05$) between the concentration of chitosan given and the shelf life on the aroma value of broiler chicken meat. The chitosan layer is a type of polysaccharide in the form of deacetylation of chitin, which has good permeability and mechanical properties that can withstand the exchange of water and gas. Dipping broiler chickens with chitosan solution suppresses respiration, thereby reducing metabolic activity, which inhibits the decay process [16].

The tendency for decreasing aroma values along with increasing chitosan concentration is thought to be due to an increase in the concentration of volatile compounds.Increasing the concentration of chitosan produces a thicker layer, which can inhibit the release of volatile compounds that make up the aroma, thereby reducing the intensity of the meat aroma [17]. [18] in his research concluded that chicken carcass samples coated with 1% and 1.5% chitosan edible coating could only last up to 14 days. Chicken carcasses stored for up to 15 days at 4°C exhibited a slimy appearance and an unpleasant odor due to the growth of pathogenic bacteria up to > 7 log CFU/g. Based on SNI 3924:2023 concerning broiler chicken carcasses and meat, the maximum total plate count (TPC) threshold is 1×10^6 CFU/g. Proteolytic enzymes are produced by pathogenic microorganisms that degrade the chitosan coating. Proteolytic reactions are catalyzed by exopeptidase (dipeptidase, aminopeptidase, and carboxypeptidase) and lipolysis (lipase and phospholipase), which produce large amounts of peptides, free amino acids, and fatty acids, which contribute to the taste, aroma, texture, and final quality of processed meat products [19].

The results of the panelist assessment of the aroma of broiler chicken meat showed a significant decrease in value (P<0.05) with the use of various concentrations of chitosan as the base material for edible coating. Chitosan acts as a chelator of metal ions that trigger lipid peroxidation and cause a decrease in aroma in meat [20]. [21] added that total volatiles can be used to interpret meat freshness because of their role as biomarkers of protein degradation. The degradation of proteins and other nitrogen-containing compounds because of the above-mentioned spoilage mechanisms increases the accumulation of organic amines or total volatile basic nitrogen. These compounds are toxic and cause significant changes in meat aroma, color, and texture.

Table 2. Organoleptic Properties and Durability of Frozen Chicken Carcasses Thawed with Edible Chitosan Coating for Different Shelf Lives

Parameter	Concentration of Edible Chitosan Coating (%)	Shelf Life (Months)		
		1	**2**	**3**
Aroma				
	0	3.92 ± 0.28^{a}	3.96 ± 0.20^{a}	3.88 ± 0.33^{a}
	1	3.44 ± 0.51^{b}	3.40 ± 0.50^{b}	3.36 ± 0.49^{b}
	1.5	3.36 ± 0.49^{b}	3.32 ± 0.48^{b}	3.27 ± 0.50^{b}
Texture				
	0	3.12 ± 0.33^{ax}	3.16 ± 0.37^{ax}	3.08 ± 0.28^{ay}
	1	3.92 ± 0.27^{bx}	3.88 ± 0.33^{bx}	3.72 ± 0.46^{by}
	1.5	4.04 ± 0.20^{bx}	3.96 ± 0.20^{bx}	3.76 ± 0.44^{by}
Color				
	0	2.92 ± 0.49^{ax}	3.00 ± 0.41^{ay}	2.96 ± 0.20^{az}
	1	2.88 ± 0.60^{bx}	2.84 ± 0.62^{by}	2.76 ± 0.52^{bz}
	1.5	2.88 ± 0.53^{cx}	2.84 ± 0.48^{cy}	2.68 ± 0.48^{cz}
Total Acceptance				
	0	3.08 ± 0.28^{a}	3.12 ± 0.33^{a}	3.08 ± 0.28^{a}
	1	2.80 ± 0.41^{b}	2.76 ± 0.44^{b}	2.68 ± 0.48^{b}
	1.5	2.68 ± 0.48^{b}	2.64 ± 0.49^{b}	2.52 ± 0.51^{b}
Durability (minutes)				
	0	707.00 ± 19.87^{a}	712.00 ± 20.80^{a}	726.80 ± 13.03^{a}
	1	852.00 ± 19.74^{b}	848.80 ± 23.44^{b}	853.40 ± 30.11^{b}
	1.5	884.00 ± 35.60^{c}	893.60 ± 31.21^{c}	891.60 ± 38.12^{c}

abc: mean values with different superscripts in the same column indicate significant differences (P<0.05), xyz mean values with different superscripts in the same row indicate significant differences (P<0.05).

3.2 Texture

Texture assessment is a parameter used to determine the level of panelist acceptance. Statistical analysis indicated a significant interaction (P<0.05) between different chitosan concentrations and shelf life on the texture value of broiler chicken. As the chitosan concentration increased the texture of the broiler chicken meat became denser and slightly slimier. This is because chitosan is hydrophilic. The hydrophilic polymer network that binds and retains water produces a hydrogel. [22] stated that chitosan is a hydrogel based on natural cross-linked biopolymers. Chemical molecules that interact with each other determine the hydrogel integrity. The stronger the interaction between the chemical molecules, the stiffer the resulting hydrogel, and vice versa.

The results of the study showed a significant decrease in the texture of broiler chicken meat at shelf life of 1, 2, and 3 months with the use of chitosan as the basic ingredient edible coating. One of the functional properties of chitosan is its ability to bind water well. The presence of hydroxyl groups (-OH) and amine groups (-NH2) allows chitosan to play a role in holding water molecules through hydrogen bonds [23]. However, chitosan has a limited number of active groups that can bind water. Hydrogen bonds that fully bind water molecules, cannot bind additional water. The longer the storage of broiler chicken meat coated with edible chitosan, the lower its water binding ability, which had an impact on the decrease in the texture value of the broiler chicken meat [24]

During 3 months of storage, broiler chicken meat was coated edible coating chitosan with concentrations of 0.1 and 1.5% has a sensory texture value on the hedonic scale of 3.08-4.04 which is interpreted as having a normal and dense texture. In accordance with the research conducted by [25] that by coating edible coating made from 2% chitosan dissolved in 0.5% oleic acid is able to maintain the normal texture of pork for 21 days of storage by inhibiting the growth of E. Coli bacteria. [26] in his research concluded that the use of 1% chitosan and 0.5% tomato plant extract was able to maintain the shelf life of meat for up to 13 days with an average meat texture acceptance value of 6.3 on a hedonic scale of 9. In addition, the storage temperature in the refrigerator will extend the shelf life of meat for up to 21 days.

3.3 Color

The results of the panel's assessment of the color of broiler chicken meat showed a significant decrease in value ($P<0.05$) with the use of chitosan as the base material for edible coating at shelf life of 1, 2, and 3 months. The characteristic color of chitosan is clear. The color change is caused by the natural color of broiler chicken meat, which comes from myoglobin. During storage, myoglobin interacts with oxygen to produce metmyoglobin. Metmyoglobin is formed after protein denaturation, which changes the color of meat to brown. The maillard reaction occurs in the aldehyde component of the carbonyl class with the amino group of chitosan [27].

The lowest color value was found in broiler chicken meat stored for 3 months with a layer concentration of edible coating chitosan 1.5%, while the highest value was obtained from broiler chicken meat stored for 2 months without chitosan coating. The chitosan solution was prepared by dissolving chitosan in 0.5% acetic acid. The chitosan solution is acidic, as indicated by a low pH value. The application of chitosan solution as an edible coating on broiler chicken meat results in its decrease in pH, which can change myoglobin to metmyoglobin so that the color of the meat changes to dark brown. In accordance with the research conducted [12], reported that the pH value of frozen chicken carcasses with edible chitosan coating during thawing was lower than that without chitosan. Chitosan is also semipermeable to gas, thus slowing down the oxygenation process that triggers color changes due to the formation of deoxyhemoglobin [16].

3.4 Total Acceptance

The total acceptance value is the average overall preference of the panelists, which includes the aroma, texture, and taste. There was no significant interaction ($P>0.05$) between the concentration of chitosan given and the shelf life on the total acceptance of broiler chickens. This means that edible coating made from chitosan is neutral so that it does not increase or decrease the panelists' preference for broiler chicken meat. Research [28][28] comparing various types of edible coating materials and their applications as packaging, states that chitosan is a polysaccharide that can form a semipermeable membrane with the ability to retain oxygen and carbon dioxide so that it plays a good role in increasing the sensory power of food products.

Significant decrease revenue ($P<0.05$) on broiler chicken meat coated with 1%, and 1.5% chitosan produced average values of 2.80, and 2.68. The results are similar to the research conducted by [14], a significant decrease in the total overall acceptance of raw chicken meat that was thawed and coated with 1% chitosan decreased the total acceptance compared to raw chicken that was thawed without chitosan coating and with 0.5% chitosan. [29][29] reported the effect of applying edible coating with 1% chitosan and 0.1% tomato plant extract resulting in the highest antioxidant activity, phenolic content, and total overall acceptance. [30][25]. [26] concluded that overall, there was no significant effect on the total acceptance and sensory characteristics of chicken carcasses coated with chitosan.

The total acceptance value obtained from the sample indicates that chitosan can be used as an edible coating with the aim of maintaining the sensory characteristics of chicken meat. The basic ingredients of edible coatings must be sourced from materials that are safe for consumption and comply with food product packaging regulations with good hygienic standards and practices. The existence of an optimal limit for the use of chitosan as an edible coating shows that increasing the concentration can cause changes in the sensory characteristics of the product (aroma, texture, color) which ultimately reduces the total acceptance of the panelists toward the product. Chitosan has a large molecular weight of 10-1000 kDa and a high viscosity of 1220 cPs [31], [32]. The high molecular weight and viscosity of chitosan solution affect the sensory value of chicken meat, especially the texture and appearance of the meat, which ultimately contributes to a decrease in the total acceptance value by panelists [33], [34].

3.5 Durability

Based on research results, the shelf life of chicken carcasses did not have a significant effect (P>0.05) on the resulting durability. The durability in this study was influenced by the chitosan concentration used. The thawing process using edible coating. Chitosan showed a significant effect (P<0.05) on the durability of frozen broiler carcasses. Chicken carcasses thawed with chitosan were longer durable than those without chitosan. This is due to the antimicrobial properties of chitosan, which can inhibit the growth of microorganisms that cause decay [35]. These microorganisms produce various metabolite compounds that accelerate the process of meat quality degradation [5]. The use of chitosan as an edible coating has been proven effective in inhibiting the growth of gram-positive and gram-negative bacteria [36]. Therefore, the use of chitosan in this study showed effective antimicrobial properties in suppressing the activity of spoilage microorganisms, as shown through the results of the Pb-acetate test, resulting in longer broiler carcass durability.

Treatment with 1.5% chitosan resulted in a longer shelf life (P <0.05) than treatment with 1%. This is because the higher the concentration of chitosan used, the more effective it is at suppressing the growth of microorganisms, thereby slowing the rate of decay [37]. [12] added that the use of a chitosan concentration of 1.5% showed a lower total number of microbes than the use of 1% chitosan in the thawing process.

The durability of this study is lower than the results of the study by [10], which reported that broiler carcasses with edible chitosan coating at 1% had a durability of 892.00 ± 65.16 minutes. However, the durability of this study was higher than that of broiler carcasses prepared using bay leaf extract solution. [38] reported that broiler chickens dissolved in bay leaf extract at a concentration of 25% had a durability of 718.75 min.

4. Conclusion

The use of 1% chitosan gave the best results in maintaining organoleptic quality, and 1.5% in slowing down broiler carcass decay up to a shelf life of 3 months with an aroma score of 3.44 (typical meat aroma), texture 3.92 (solid), color 2.88 (white) and total acceptance 2.80 (neutral).

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