MASTER THESIS

JETA MUHAXHERI

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Hungarian University of Agriculture and Life Sciences
Budai Campus
Institute of Food Science and Technology

Effect of oil treatment on chicken egg quality during shelf life

Insider consultant: Dr. Nguyen Le Phuong Lien
Institute/department: Department of Livestock Product and Food Preservation
Created by: Jeta Muhaxheri

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1. Introduction

My graduate studies in Food Safety and Quality Engineering made me realize how much I really want to learn about the different methods that can be used to assess and regulate the quality of food and about the different processes of food quality preservation and maintenance. I am excited to use the knowledge I have received about creative approaches during my studies in the sector of egg preservation, where the most important parameter is quality.

Eggs are a highly nutritious and adaptable food, consumed worldwide, offering a rich protein content, essential vitamins, and functional properties in various gastronomic applications (Shurmasti et al., 2023). They are a vital ingredient in numerous diets, not only because of their nutritional benefits, but also because they are affordable and versatile in both the home and the food industry. Despite their benefits, eggs are highly perishable, making their preservation a key concern in food safety and quality management. Their quality is especially affected at ambient temperature. Carbon dioxide (CO_2) and moisture loss escape through eggshell pores, causing quality degradation (Gabriela Da Silva Pires et al., 2020).

Besides the fact of being very delicate, eggs are also very sensitive to germs and environmental factors, which makes it even more necessary to come up with effective strategies to extend their shelf life. Consumers are not the only ones who would benefit from a longer shelf life of eggs; but it would also lead to less food waste and more efficient supply chains. These factors can be divided into internal and external factors.

Internal factors are the eventual breakdown of proteins and lipids and their consequent effects on texture, flavor, and appearance. External factors, however, are environmental like temperature changes, moisture and environment, and handling and hence, the spoilage is hastened.

Microbial contamination is a serious issue which can cause health risks, especially from bacteria like *Salmonella and Enterobacteriaceae*. For this reason, preservation methods are very important. Managing these challenges requires a thorough understanding of the mechanisms of egg degradation as well as the use of improved storage strategies.

Over the years, there have been several methods used to maintain the freshness and safety of eggs. For example, refrigeration is a traditional technique that slows down microbial growth and biochemical reactions, extending shelf life. Moreover, the functionality of edible coatings made from natural polymers such as chitosan and alginate has proven to create a barrier that is protective of the eggs and lessens the loss of moisture and the chance of contamination. As well as these methods, there are more traditional methods, which their goal is the same, to extend the shelf life of products.

This thesis provides a thorough exploration of the effect of oil treatment on chicken egg quality during storage. It focuses on analyzing parameters such as Haugh Unit, weight loss, albumen index, and yolk index. It aims to provide a comprehensive understanding of egg shells through a review of preservation techniques, their effectiveness, and their impact on egg quality, as well as the explanation of egg size and shape effects on egg firmness.

1.1 The goal of the study

The study aimed to evaluate the effect of oil treatment on chicken egg quality during storage and how different sizes of egg affect the effectiveness of oil treatment. Various egg sizes were used for the experiment. Quality parameters of egg, such as Haugh unit, weight loss, yolk index, albumen index, and air cell size, were determined.

The experiment results provide information about the potential benefits of oil treatment for maintaining egg quality and extending shelf life. This research offers practical implications for the food industry and suggests potential for further exploration in this field.

2. Literature overview

2.1 Overview of eggs

Eggs, from a historical perspective, have been one of the most adaptable food items in the human diet. They are valued for both their flavor and the variety of nutrients they offer.
According to the studies of Miranda et al. (2015), eggs are a source of high-quality proteins, containing all essential amino acids, along with lipids, vitamins, and minerals that are important for human nutrition.
Due to the fact that they are affordable and accessible, eggs play a vital role in sustainable diets and help to ensure proper nutrition for various populations.

Eggs are rich in phospholipids, carotenoids, and proteins, which are known as bioactive components. These components take part in providing health benefits besides widely accepted disease prevention. Certain proteins found in egg yolk like vitellogenin, lipovitellin, and phosvitin, and those from egg whites such as ovotransferrin, have been known to possess antioxidant and antimicrobial properties (Fernandez, 2016). These properties explain why eggs are not only valued for their nutritional contribution but also for their functional roles in human health.

Eggs regardless their benefits, are highly perishable. When stored, their internal quality changes as albumen pH increases and the yolk membrane weakens, which contributes to reducing firmness and freshness (Rho & Cho, 2024).

For evaluating these changes, we use the Haugh Unit (HU), which is often used as a standard indicator of freshness. Haugh Unit is based on albumen height and egg weight, but it decreases significantly with longer storage time and higher temperatures (Rho & Cho, 2024)

Microbial safety is another important concern that influences the quality and safety of eggs. Eggs and egg products have been linked with food-borne illnesses, which are mainly caused by *Salmonella*, which continue to pose a major public health problem (Miranda et al., 2015).

In summary, eggs offer a combination of nutritional richness and health-promoting compounds, but they are also vulnerable to quality loss and microbial contamination during storage. For this reason, proper preservation and handling are crucial to maintaining both their freshness and safety.

2.2. Structure and composition of eggs

Eggs are biologically complex structures optimized for storing nutrients and providing protection. Chicken eggs are the most widely consumed, and they comprise three main components: the shell, albumen (also known as egg white), and the yolk**.** Each of these components contains unique physicochemical and functional properties (Belitz et al., 2009).

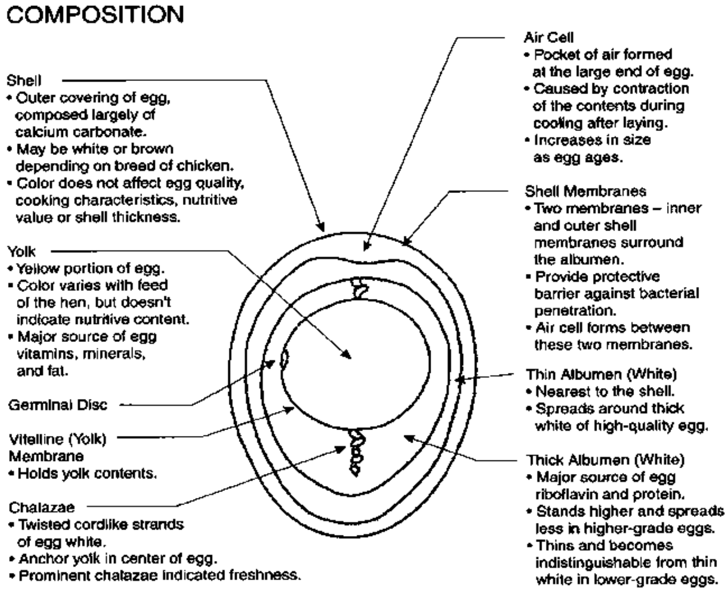

Figure 1: Egg composition

2.2.1. Shell

The shell of the egg provides protection and is mainly composed of calcium carbonate ($CaCO_3$), which is present in the form of calcite crystals. These crystals are arranged within a protein-rich organic matrix. This combination plays an essential role by providing the shell with mechanical strength and elasticity, protecting the egg from physical damage, but at the same time allowing control of gas exchange. (Belitz et al., 2009; Hincke, 2012)

The shell is closely linked with other protective structures. Beneath it lie the inner and outer shell membranes, and its external surface is sealed by the cuticle. Together, these components help to ensure the egg's quality and safety (Hincke, 2012).

2.2.2. Shell membranes and air cell

The shell membrane is made from two layers: the inner and outer layers. Together they form a fiber barrier with a thickness of around 70 µm (Belitz et al., 2009). They are located beneath the calcified shell and are mainly composed of protein (90%) and smaller amounts of lipids, sugars also calcium, and magnesium. (Han et al., 2023)

According to, eggshell membranes play an important role in both the strength and formation of the shell. This study explains the impact that the changes in the fibres of these membranes have on shell forms and on their mechanical properties.

The two membranes separate to create the air cell. During the storage, this aircell expands as CO_2 and water vapor slowly get out through the shell pores. The enlargement of the air cell over time is widely used as a practical sign of freshness in research and commercial quality control (Nys & Gautron, 2007). While the membranes strengthen the egg from within, the outside protection is provided by the cuticle, a specialized layer that covers the shell surface.

2.2.3 Cuticle

The cuticle is a very thin layer of protein that is formed during the final stage of shell formation. Even though it is only a few micrometers thick, it plays an important role in egg defense. By sealing the shell's opening, the cuticle plays a role in reducing microbial entry and helps to minimize moisture loss. It also contributes to maintaining freshness during storage and is now recognized as a big factor in food safety (Kulshreshtha et al., 2022). Because of these properties, the cuticle can be recognized as the primary barrier against microbial contamination.

2.2.4. Albumen

The albumen contains 57% of the egg's weight and is a viscous, aqueous gel divided into thick and thin layers. Fresh egg white is known to have a pH of around 7.6–7.9, rising to 9.7 during storage as CO_2 diffuses through the shell (Belitz et al., 2009). This alkaline shift destabilizes proteins like ovomucin, leading to reduced viscosity. Albumen is mostly made of 88% water and the other part of 10–12% protein, with trace carbohydrates such as glucose and minerals. Functional properties such as foaming, gelation, and antimicrobial activity stem from specialized proteins:

2.2.5. Ovalbumin (54%):

Ovalbumin is a glycophosphoprotein that is composed of three isoforms (A_1, A_2, A_3) differing in serine-bound phosphate content. It denatures at 84.5°C, from which are formed heat-stable S-ovalbumin (92.5°C) during storage via thiol-disulfide exchanges (Belitz et al., 2009).

2.2.6. Conalbumin (Ovotransferrin, 12%):

Conalbumin, kwnon as ovotransferrrin too, makes up about 12% of egg white proteins and plays an important antimicrobial role by binding metals such as iron, copper, and zinc, limiting their availability for bacterial growth (Abeyrathne et al., 2013). Also, it has antioxidant activity when bound to copper or manganese (Ibrahim et al., 2007).

However, sometimes it can cause reddish or pink discoloration in processed eggs due to its strong affinity for iron (Abeyrathne et al., 2013).

2.2.7. Lysozyme (3.4%):

Lysozyme makes up about 3–4% of egg white proteins. It plays a role as an antimicrobial agent and it works by breaking down the cell walls of bacteria, mainly Gram-positive bacteria, limiting their survival and growth (Abeyrathne, 2013).

Because of this property, lysozyme plays a key role in keeping eggs safe from microbial contamination during storage.

2.2.8 Ovomucoid (11%):

Ovomucoid comprises 11% of egg white proteins and is a heat-stable inhibitor with three disulfide-rich domains (Dhanapala et al., 2015).

2.2.9. Ovomucin (3.5%):

Ovomucin makes up about 3–4% of egg white proteins, and it is responsible for the gel-like structure of thick albumen. It is known to contribute to egg defense, too, when combined with lysozyme. It forms a pH-dependent antimicrobial barrier that helps restrict microbial growth (Abeyrathne et al., 2013).

There are minor proteins like avidin (biotin-binding) and flavoprotein (riboflavin carrier) that enhance nutritional and preservative roles.

2.3. Egg yolk

Egg yolk is a highly nutritious component of the egg, which constitutes 33% of the egg's weight and it is a lipid-protein emulsion stabilized by lipoproteins (Belitz et al., 2009).

The lipid fraction consists of triglycerides and phospholipids. The protein components are composed of ovalbumen, livetin, and conalbumin.

These lipids are attached to proteins in lipoprotein complexes such as low-density lipoproteins (LDL) and high-density lipoproteins (HDL). LDL, which is the main type, is rich in lipids and plays a key role in stabilizing emulsions. This is why the egg yolk is widely used in products like mayonnaise and sauces. In contrast, HDL contains a higher percentage of proteins, including phosvitin, a highly phosphorylated protein with the ability to bind iron. Although it lowers iron availability, this property limits lipid oxidation and offers antioxidant advantages. Together, these components make egg yolk an important nutritional source of essential lipids and proteins, and at the same time a key functional ingredient in food processing, especially recognized for its emulsifying and textural properties (Oladimeji & Gebhardt, 2023) The composition of fresh hen eggs is presented in Table 1. While values can vary slightly depending on the source, they consistently show that water makes up the majority of egg mass, followed by proteins and lipids (Tomczak et al., 2024) ; (Usturoi et al., 2025).

Table 1: Composition of hen egg yolk

Source: Tomczak et al. (2024), (Usturoi et al. (2025)

Components	Content %
Water	75-76%
Lipids	12-13%
Proteins	9-12%
Carbohydrates	~0.7%
Minerals	~1.1%

2.3.1. Other Constituents

Carotenoids: give the yolk its yellow to orange color, and their levels mainly reflect the hen's diet. Egg yolk consists of carotenoids such as anthaxanthin, β-apo-8′-carotenal, capsanthin, and β-apo-8′-carotenoic acid ethyl ester (Nimalaratne & Wu, 2015).

Vitamins: Yolk is rich with two groups of vitamins: Fat-soluble vitamins (A, D, E, K) and B-complex vitamins (B_{12}, biotin) (Belitz et al., 2009).

Cholesterol: Egg yolk contains 250 mg cholesterol, which contributes to debates over dietary intake (Belitz et al., 2009).

2.3.2. Functional properties

Yolk's pseudoplastic behavior (shear-thinning viscosity) is a result of lipoprotein interactions. This pseudoplastic property is considered important because it affects how yolk contributes to the texture and stability of emulsified food products, although it can change during freeze–thaw treatments. These rheological properties can be altered by freeze-thaw treatments, which contribute to increasing viscosity, storage, and loss moduli (G′ and G″), and can reduce tan δ, indicating stronger gel formation (Yuan et al., 2025). Several approaches aim to prevent or mitigate these undesirable effects. According to Ma et al. (2024), one of these approaches is the addition of saccharides such as L-arabinose and xylitol, which can help to reduce gel strength, resulting in lower consistency indices, leading to fewer rheological units compared with untreated yolk. Their findings also indicated that saccharides were able to reduce the protein aggregates, and the structural transitions were less pronounced, as they delayed the transition from α-helices to β-sheets and decreased the exposure of tryptophan residues, thus slowing down the unfolding process.

In summary, these studies altogether affirm that the functional properties of egg yolk, including its flow behavior, viscosity, and emulsifying ability, are highly sensitive to storage and processing conditions. Therefore, the use of stabilizing additives is essential to maintain quality in food systems.

2.4. Egg size

The study by Wang et al. (2021) states that the shell of larger eggs does not get thicker in proportion to their weight. In practical terms, this means that larger eggs very often end up with thinner shells, which makes them more sensitive and vulnerable to physical damage and microbial contamination.

Similarly, studies of Motselisi & Molapo (2020) explained the relationship between the size and quality. According to this study, bigger is not always better when it comes to balancing shell protection with internal content. Their study was focused on Koekoek chicken eggs, where they grouped them and concluded that medium-sized eggs had the thickest shells and the highest hatchability. By contrast, very large eggs, even though they contained heavier yolks, showed thinner shells and reduced hatchability.

There have been similar studies in broiler breeder eggs. Based on Sabah & Şahan (2018), heavier eggs tend to have thinner shells and higher pore density. It is important to check these differences in structure because pore density influences how quickly eggs lose moisture, which affects air cell size and overall quality during storage. Heavier eggs, on first sight may look appealing, but they can lose freshness more quickly under standard storage conditions.

Taken together, both studies, Motselisi & Molapo (2020); Sabah & Şahan (2018), indicate that medium-sized eggs offer the best balance between shell protection and internal quality.

Motselisi & Molapo (2020), for the Koekoek chicken, eggs were grouped by size and measured for shell thickness and hatchability. The results showed that medium-sized eggs had thicker shells and higher hatchability compared to large ones. On the other hand, in broiler breeder eggs, Sabah & Şahan (2018) counted shell pores and checked quality during storage, and heavier eggs were found to lose moisture faster and stay fresh for a shorter time.

Both of these results explain why medium-sized eggs are often more reliable when testing preservation methods, since the outcome can depend on egg size.

2.4.1 Effect of egg size on firmness

Egg size significantly affects the firmness of the egg, affecting both the outside, shell strength, and inside, albumen and yolk quality.

Hahn et al. (2017) have shown that ostrich eggs, which are larger than chicken eggs, can resist fracture strengths above 5000 N. However, their relative strength is actually lower because the thickness of the shell does not increase in proportion to egg size. This helps to explain why larger eggs, such as those of ostriches, are more likely to develop microstructural defects compared to smaller eggs.

Other researches confirm this tendency, for example, Zhang et al. (2023) found that in laying hens, as egg weight increased with age, shell thickness, breaking strength, and Haugh Unit declined. This indicates that larger eggs are more fragile and less firm compared with smaller eggs.

Ketta & Tůmová (2018), discussed the importance of shell thickness in firmness, explaining that shell thickness has a direct impact on shell strength. Eggs with thicker shells were more resistant to breakage in both litter ($r = 0.64$) and cage ($r = 0.48$) systems. This shows the impact of shell thickness on firmness and that firmness can be attributed to shell thickness and size, not just to the egg size. Furthermore, Yan et al. (2014) have pointed out that thickness is not the only consideration, but also the exact manner in which the shell is formed. The experiment revealed that eggs with the most uniform shells were the strongest; they had the highest breaking strength, stiffness, and toughness, even though the shells were not the thickest. This leads us to conclude that the qualities of eggshells are determined by a combination of uniformity and thickness.

2.5. Egg Shape

Texture, color, cleanliness, and shape of the egg are the main factors that have the most important impact on the quality of the egg. The criteria that the shell of each egg should have to contain quality are to be smooth, clean, and free of cracks, and what is also important is that the egg should be uniform in color, size, and shape (Moula et al., 2010).

Egg shape is known as a crucial characteristic that influences the preservation, mechanical strength, and biological function of the egg. There can be various egg shapes in nature. They range from spherical to elliptical, conical, and asymmetric forms. Each of the shapes serves specific adaptive and functional roles (Stoddard et al., 2017).

The determination of egg shape happens during its formation in the oviduct, especially in the isthmus, where the shell membranes are deposited. Stoddard et al. (2017), suggest that variations in egg shape arise due to differences in pressure distribution, membrane thickness, and material properties during development. As an example, we can mention spherical eggs, which provide structural uniformity, making them less prone to breakage and reducing material use.

2.5.1. Egg shape index and its impact on quality

As outlined in Section Egg size, the form Index (SI) is used to measure egg shape, which is calculated as the ratio of egg width to length. Egg shapes are categorized as sharp (SI<72), standard (SI=72-76), and round (SI > 76) (Duman et al., 2016).

According to Duman et al. (2016), the shape of the egg has an impact not only on the appearance of the egg but also plays a role in several quality traits. The studies based on Duman et al. (2016), explain that egg shape has an interaction with albumen index and Haugh unit (HU). Rounder eggs tend to have higher Haugh unit values, indicating better internal quality, while, on the other hand, sharp eggs may be more vulnerable to breakage due to differences in specific gravity.

Furthermore, the differences in egg shape impact packaging efficiency, consumer preference, and mechanical resistance during transport.

2.5.2 Egg shape and its role in preservation and quality

For the quality, which is a crucial parameter for eggs, egg shape plays a vital role in it, as it also has an impact on egg preservation. According to Duman et al. (2016), the shape index (SI) is correlated with albumen index and Haugh Unit (HU), indicating that rounder eggs tend to have better internal quality. However, no significant correlation was found with breaking strength.

On the other hand, Altuntaş & Şekeroğlu (2008), reported that SI affects rupture force, deformation, and rupture energy. They further explained that properties such as egg shape index and shell thickness are critical factors in determining the proportion of damaged eggs during handling and transport. They noted that the packaging coefficient values were greater in rounded than in sharp eggs.

This relationship highlights that egg shape contributes not only to internal quality but also to preservation, by reducing susceptibility to breakage, improving packaging efficiency, and ultimately helping to maintain freshness and minimize microbial contamination risks.

2.5.3 Egg shape and quality correlations

Several studies demonstrated that egg shape is strongly associated with albumen quality and internal freshness**.** Based on Duman et al. (2016) egg shape index (SI) significantly influences the albumen index and Haugh unit (HU**)**, with rounder eggs exhibiting higher Haugh unit values, which are indicators of better internal quality and freshness. Additionally, eggs with a higher Shape Index have been found to have a better yolk index and albumen viscosity, both of which contribute to the overall quality of the egg (Altuntaş & Şekeroğlu, 2008).

2.5.4 Impact of egg shape on egg safety

Egg shape also impacts the egg's resistance to microbial contamination**.** Round eggs have stronger shells, which makes them even more resistant to microbial invasion through the shell, especially during transport and storage. As Sharaf Eddin et al. (2019) explained, stronger-shell eggs offer more security against the coming of bacteria like *Salmonella*, which might cause illness through eggs. Furthermore, eggs that contain a smoother surface, typically one that poses a rounder shape, would not allow microbial entry through the eggshell pores.

2.5.5 Packaging efficiency and transport

The shape of the egg influences packaging efficiency and the possibility of damage during transport. Eggs of standard shape find a better fit into packaging. This allows the packaging to be done more efficiently and thus reduces mechanical damage. However, round or unusually shaped eggs are more difficult to pack in an efficient way, and this leads to an increased risk of breakage and higher waste (Altuntaş & Şekeroğlu, 2008).

This has an immediate effect on the commercial value and the satisfaction of the consumers because eggs with uniform shapes are the ones that are preferred for their ease of handling and storage.

2.5.6. The effect of egg shape on firmness

The indicated Shape Index (SI), is the element that is used to quantify the egg shape, and it has been shown to influence both shell strength and egg firmness.

The way external forces act on an egg's shell depends on its shape. The curved structure of rounder eggs helps spread pressure more evenly, and it is said that the round eggs exhibit higher mechanical resistance. In contrast, the sharp or elongated eggs are more easily broken due to the reason that the stress is concentrated in their pointed ends (Altuntaş & Şekeroğlu, 2008).

The shape index also interacts with internal quality metrics. Eggs with a higher shape index or rounder eggs tend to have firmer albumen, and the reason is their structure, who retain moisture and protein stability (Alkan et al., 2016).

In conclusion, egg shape plays a critical role in determining both the shell egg and internal firmness. Rounder eggs show a greater mechanical resistance, while the elongated eggs are more easily to get broken, due to stress distribution (Duman et al., 2016).

2.6. Egg firmness

As a quality parameter, egg firmness directly affects the egg's resistance to mechanical forces, microbial safety, and consumer preference. It can be assessed through two major factors:

Eggshell firmness – Known as the mechanical strength of the shell, it plays a role in protecting the internal contents from damage and microbial contamination (Ahmed et al., 2005).

It is important to understand egg firmness, which is crucial for commercial egg production**,** storage optimization, and food safety, as firmer eggs are less likely to crack or spoil**.**

2.6.1. Eggshell firmness and its determinants

Features that are used to determine eggshell firmness primarily are: shell thickness, crystal structure, and mineral composition. The ability to resist external force without breaking is what characterizes the strength of an eggshell**,** which is influenced by calcium carbonate deposition and the organization of calcite crystals (Ahmed et al., 2005).

2.6.2. Eggshell composition and mechanical strength

The major constituent of eggshells is calcium carbonate ($CaCO_3$), which is present in the form of calcite crystals**,** along with an organic matrix of proteins and glycoproteins (Ahmed et al., 2005). These two constituents are the main contributors to the strong yet slightly flexible structure**.**

Calcite Crystal Arrangement – The strength of the shell is dependent on the size and orientation of calcite crystals. Smaller, more uniform crystals help to make a shell stronger. Meanwhile, larger, irregular crystals result in brittle shells prone to cracking (Ahmed et al., 2005)

Organic Matrix Influence – The organic matrix plays a role in modifying shell elasticity, allowing eggs to withstand pressure without breaking immediately. (Ahmed et al., 2005) explains how the studies have shown that proteins such as ovocleidins and ovotransferrin are involved in shell mineralization, and have a direct impact on firmness.

2.6.3. Eggshell thickness and breaking strength

Shell thickness is known to be one of the main and strongest indicators of firmness. However, thickness alone does not determine shell strength; also, the microstructure and mineral composition are important parameters (Ahmed et al., 2005).

Thicker shells generally provide greater firmness and mechanical resistance**.**

However, if the calcite crystals aren't put in order**,** even a thick shell may still break easily (Ahmed et al., 2005)**.**

The application of compression testing has exposed the natural strength of the eggs at the poles (ends) rather than at the equator. This is a result of the curved structure of the shell, which allows stress to be distributed evenly across the surface (Ahmed et al., 2005).

2.6.4. Albumen consistency and egg quality

Albumen (egg white) consistency is another important measure of egg quality, especially for consumer preference and nutritional properties. The viscosity and gel-like consistency of the albumen are affected by protein structure, pH balance, and storage conditions (Singh et al., 2014).

2.6.5. Haugh Unit (HU) as a freshness indicator

As mentioned previously, Haugh Unit (HU) is a very important standard that plays an important role in determining parameters that are essential for our understanding. In the industry, it is known as a standard for measuring albumen quality and assessing the height of the thick albumen relative to the weight of the egg (Singh et al., 2014)

It is widely used in the poultry industry to evaluate egg quality, protein content, and freshness. As we previously discussed, the Haugh Unit measures the height of the thick albumen relative to egg weight, with higher values indicating fresher eggs.

The pH of fresh eggs varies around 7.6, but during storage, temperature changes and time increase the Ph, which leads to the albumen thickening, thinner. Higher HU values are generally associated with higher internal quality, where it specify firmer albumen and better freshness**.** In contrast, lower HU values indicate a decline in albumen quality due to protein degradation, making the albumen more watery and less firm (Jin et al., 2010).

Research shows that rounder eggs tend to have higher HU values, meaning they maintain albumen firmness longer compared to elongated eggs, which may experience faster moisture loss and protein breakdown (Duman et al., 2016).

2.6.6. Changes in pH and protein breakdown over time

The pH of eggs can increase as eggs age, due to carbon dioxide escaping through the shell, leading to a higher pH. This alkalization process causes protein denaturation, making the albumen less firm (Jin et al., 2010)

The pH of fresh eggs is around 7.6, with firm, gel-like albumen**.**

The pH of stored eggs (especially those kept at room temperature) can be evaluated around a pH of 9.5, causing albumen to become more liquid and less viscous (Jin et al., 2010).

2.6.7. Storage effects on albumen consistency

What can have a direct impact on albumen consistency are storage conditions. According to Da S. Oliveira et al. (2020), these conditions influence the internal quality of eggs, mainly by increasing or slowing down their loss, as reflected in albumen height and Haugh Unit values.

Based on the research, ambient temperature storage speeds up deterioration, leading to a decline in albumen height and Haugh Unit values, together with an increase in pH. On the other hand, these changes can happen slowly through refrigerated storage**,** maintaining albumen firmness for longer periods. For example, Da S. Oliveira et al. (2020) found that eggs stored at 26.5 °C had an albumen height of only 3.76 mm, while refrigerated eggs at 7.3 °C maintained 6.75 mm, clearly demonstrating the protective effect of cooling.

In conclusion, eggs that are stored in cooler environments retain firmness for a longer period**,** while on the other hand, eggs kept in hotter conditions lose firmness more quickly**.**

2.7. Shelf-life of eggs and the role of eggshell quality

Eggs are known to be the only animal products that are naturally protected by a shell, which is also considered an essential factor in determining the quality of the eggshell itself (Yamak et

al., 2021). The shelf-life of eggs term, refers to the period in which eggs retain freshness, nutritional value, sensory attributes, and microbiological safety when stored under defined conditions (Kim et al., 2024). Although eggs are naturally protected by the shell and cuticle, they still remain perishable due to the porous structure that they contain. The porous structure of the egg shell allows the exchange of gases to happen, known as carbon dioxide, and moisture between the inside of the egg and its surrounding environment (Tanpure et al., 2024).
Based on the studies of (Tanpure et al., 2024), these exchanges gradually alter the albumen and yolk, reducing overall quality. The quality of the eggshell is evaluated by some parameters, such as: shell thickness, strength, weight, and density, which indicate the egg's structural integrity.

Thickness and breaking strength are particularly critical. The force required to break the shell is known as the breaking strength and is usually expressed in Newtons (N). On average, eggshells generally have a breaking strength of approximately 4.2 N, while the lowest acceptable range is between 3.0 and 3.5 N. These values can range depending on several factors, such as hen age, egg size, and breed, between 1 and 7.5 N (Tanpure et al., 2024).

Another important factor is shell thickness, typically ranging from 0.2 to 0.57 mm, with an average of 0.4 mm. For high-quality eggs, the minimum acceptable thickness is about 0.3 mm. Based on studies, there is a positive correlation between shell thickness and breaking strength, which confirms that thicker and more uniform shells provide greater resistance against cracking and microbial penetration (Tanpure et al., 2024).

Therefore, shell quality not only influences the mechanical protection of eggs but also has a significant role in preserving freshness, consumer preference, and food safety. Eggs with thinner shells are more prone to cracks, which encourages microbial contamination during transport and storage. For this reason, maintaining good shell quality is a fundamental component of ensuring longer shelf-life and minimizing risks to food safety (Tanpure et al., 2024).

2.8. Physicochemical changes during storage

During storage, eggs undergo characteristic physicochemical changes that gradually reduce their quality. One of the most important processes is the loss of carbon dioxide (CO_2) through the pores of the shell. This diffusion raises the pH of the albumen from an initial value of about 7.6 to above 9.0 as storage time increases (Shurmasti et al., 2023).

The alkalization of the albumen affects its protein structure. In particular, ovomucin, which is responsible for maintaining the gel-like consistency of the egg white, becomes destabilized. As a result, the albumen loses viscosity and becomes thinner, which is a clear sign of quality deterioration (Pham et al., 2023).

At the same time, water migrates from the albumen into the yolk. This process weakens the vitelline membrane, which normally ensures the round and firm shape of the yolk. When the membrane loses strength, the yolk becomes flatter and less spherical, a visual indicator of reduced freshness (Kim et al., 2024). Another key alteration during storage is lipid oxidation in the yolk. This reaction increases over time, producing undesirable off-flavors and odors. In addition, lipid oxidation compromises the nutritional value of eggs, since essential components of the yolk are degraded (Liu et al., 2023).

Together, these physicochemical changes weaken the egg's internal structure, which not only reduces sensory quality but also makes eggs more vulnerable to microbiological contamination, as will be discussed in the following section.

2.9. Eggshell porosity and its role in microbiological and sensory deterioration

The eggshell contains around 7,000 to 17,000 pores, which means that it is not a completely solid barrier (Tanpure et al., 2024).

These pores allow gases like oxygen and carbon dioxide to enter and exit. This design helps the egg remain viable for embryo development. However, microorganisms can also enter through these pores more easily when the cuticle is damaged or when humidity levels are high (Tanpure et al., 2024). The shell's surface has a variety of microflora, including both Gram-positive and Gram-negative bacteria. It is noted that Gram-positive bacteria, such as *Staphylococcus*, *Streptococcus*, *Aerococcus*, and *Micrococcus*, are dominant (Techer et al., 2013).

However, Gram-negative species like *Salmonella*, *Escherichia*, and *Alcaligenes* are also present and concerning. These bacteria pose significant risks to food safety because they can move into the egg contents and are more resistant to the antimicrobial properties of the albumen than Gram-positive bacteria (Techer et al., 2013).

When a microorganism breaks through the shell barrier, spoilage becomes clear through sensory and microbial signs. A strong off-odor often appears along with discolorations like black, blue, pink, red, and green "rots." Species commonly linked to these spoilage types include *Pseudomonas, Proteus, Serratia,* and *Enterobacter.* Some bacteria, like *Proteus,* are frequently found in rotten eggs, indicating their ability to invade even though they are not commonly present (Techer et al., 2013).

2.10. Egg preservation methods

Ensuring effective egg preservation is very important because it plays a key role in reducing economic losses, extending shelf life, and providing freshness and quality of the eggs. Several methods have been developed, starting from traditional physical methods such as refrigeration and washing, to modern technologies such as edible coatings. Among these, surface oiling stands out for its practicality, cost-effectiveness, and simplicity. This method is going to be discussed in detail in the following section, followed by a comparative overview of other preservation techniques, which also contribute to extending the shelf life of eggs.

To prevent the spoilage and to extend the shelf life of the eggs, a wide range of cleaning and preservation methods has been developed. Each of the methods is going to be explained in detail below.

2.10.1 Surface oil coating (Oiling)

Among food preservation methods, coating plays a vital role in maintaining the quality and safety of perishable foods, including eggs. The application of oil as a protective material has been continuously observed since the early years of 1807 (Waimaleongora-Ek et al., 2009), and several studies have demonstrated and discussed its effectiveness. As we discussed, eggshells contain a porous nature that allows for the exchange of gases and water vapor. Due to this permeability, carbon dioxide and moisture is accelerated, leading to increased albumen pH, thinning of the egg white, and a decreased yolk index during storage. All of these changes affect the freshness of the eggs and shorten the shelf life of eggs, especially under ambient conditions.

2.10.2 Experimental evidence on oiling

Oiling as a method addresses this issue by spreading a thin layer of oil over the shell, which contributes to reducing pore permeability and at the same time, limits gas and moisture exchange. It has been demonstrated by several authors that this method helps to maintain albumen quality, to delay pH changes, and to reduce weight loss. When it comes to preserving internal qualities effectively lipid-based coatings (oils and waxes), are generally considered to be more effective barriers than polysaccharide or protein-based coatings because of their ability to reduce gas and water vapor transmission (Gabriela Da Silva Pires et al., 2020).

Recent research continues to confirm the effectiveness of this method in extending egg quality during storage. Revanda & Puspitarini (2024), evaluated several oils, such as coconut, palm, and maize oils, by dipping table eggs and storing them for forty-five days at room temperature. This study was focused on measuring weight loss and shell thickness, and the results showed that storage duration influences both parameters ($p < 0.05$, while the oil type did not significantly influence weight loss. From the results, the eggs that performed best were the eggs coated with coconut oil, maintaining shell thickness and limiting weight loss, preserving acceptable internal quality for around 40 days.

In contrast, other studies, such as Narmhikaa K (2022), compared both coated and uncoated eggs under tropical conditions (32°C, 78% RH). A total of 300 eggs were divided into five groups: sesame oil, coconut oil, olive oil, mustard oil, and an uncoated control. Over four weeks, parameters such as weight loss, Haugh Unit (HU), yolk index (YI), and pH values were monitored. The findings showed that uncoated eggs deteriorated the fastest, with weight loss approaching 13% and HU values declining to around 23 after 28 days. By comparison, eggs coated with olive oil exhibited only 7% weight loss and maintained HU values above 59. In the same way, YI remained significantly higher in coated eggs, with olive oil again providing the strongest protection (28.9% compared to only 11% in uncoated controls). The study concluded that olive oil was the most effective coating, significantly extending egg shelf life under ambient storage conditions and slowing internal quality degradation compared to untreated controls.
The effectiveness of oiling as a method was discussed in earlier studies, too.

Waimaleongora-Ek et al. (2009) researched the effect of mineral oils with six different viscosities on the preservation of egg quality. During five weeks of storage at 25 °C, eggs coated with high-viscosity mineral oils showed minimal weight loss of only 0.85%, while uncoated eggs lost about 8.78%**.** Furthermore, albumen quality measured through Haugh Unit declined quickly in untreated eggs, dropping from grade AA to grade C within three weeks. In contrast, oil-coated eggs retained values corresponding to grade A or B for the same period. This study explained that not only the presence of oil but also its physical properties, such as viscosity, can significantly influence its effectiveness in limiting gas and moisture exchange.

In a similar line, Okiki & Ahmed (2017) did research on the effect of soybean oil, shea butter, and groundnut oil on the quality of eggs stored under ambient conditions in Nigeria. Dividing 300 eggs into groups treated with different oils and compared with uncoated controls, they reported that soybean oil preserved quality the longest, up to 50 days, while shea butter and groundnut oil were moderately effective. Throughout storage, Haugh Unit values and protein concentrations remained consistently higher in the oil-treated eggs, confirming that coating significantly delays albumen thinning and yolk flattening compared to untreated controls.

M. Wahba (2014), extended the comparison by evaluating different preservation methods, including refrigeration, pasteurization, and oiling with mineral oil at 25 °C. Within these treatments, oil-coated eggs deteriorated more slowly than uncoated controls. After five weeks of storage, untreated eggs showed nearly 9% weight loss, whereas mineral oil–coated eggs exhibited less than 1% weight loss. Albumen quality, measured by Haugh Unit, also declined faster in uncoated eggs, dropping to grade C within three weeks, while oil-treated eggs retained values consistent with grade A–B. Although refrigeration remained the most effective method, the results of this study supported that oiling can be considered effective and contribute to extending the shelf life of eggs by providing quality.

Oiling was evaluated as a method by Jisna K. S. (2023) too, under ambient storage conditions. In this study, lime coating, edible oil coating, and a combination of both were compared against uncoated controls. The results expressed that edible oil coating alone contributed to reducing weight loss and delaying quality deterioration compared to untreated eggs. However, when the lime and oil were combined, the protection was even stronger, maintaining better internal quality and extending shelf life the longest. This confirms that while oiling itself is effective, its efficiency can be further enhanced when it is combined with other preservation agents.

2.10.3 Advantages and limitations of oiling

Taken together, the evidence across all of these studies that we mentioned confirms that oiling consistently slows down albumen thinning and yolk flattening. This process extends the shelf life of eggs. Despite the fact that the level of effectiveness can vary depending on the type of oil, its physical properties, or its combination with other treatments, all studies support the conclusion that surface oil coating remains a practical and efficient method for preserving egg quality. When considering advantages and limitations of this method**,** oiling is valued for being simple, low-cost, and widely accessible. Due to these benefits, oiling can be suitable for small-scale farmers and regions where refrigeration is limited or unavailable.

On the other hand, oiling does not provide antimicrobial protection, and its efficiency can be reduced by mechanical damage during handling or when the application is not done correctly.

These limitations explain why many researchers are exploring combinations of oils with other coating agents to enhance both barrier properties and microbial safety, ensuring a stronger preservation strategy.

2.10.4 Washing

All of the processes of protection begin as early as the start of egg production, since the egg shell normally contains a considerable number of microorganisms on its surface (Jisna K. S., 2023). Egg washing is known as one of the first and most essential steps to ensure hygienic quality and extend the shelf life of the eggs. Over the past years, different approaches have been developed to treat the eggshell surface in order to maintain quality while minimizing bacterial penetration. This method refers to the use of water and sanitizers to remove dirt, and microorganisms from the eggshell surface. Based on Gole et al. (2014), egg washing can reduce *Salmonella* enetrica, and other egg shell contamination by bacteria.

Egg washing includes two methods: dry cleaning and wet cleaning.

2.10.5. Dry cleaning

The dry cleaning method involves removing visible dirt from the eggshell surface by using brushes or paper towels, loofa, or a sanding sponge, and is one of the earliest methods recommended for table eggs (Jisna K. S., 2023).

This method, however, contains certain disadvantages. A major limitation of dry cleaning is that the friction and pressure applied during the process can cause micro-cracks or weaken the structural integrity of the shell, which in turn reduces its ability to act as a natural protective barrier (Jisna K. S., 2023).

For this reason, only the eggs that contain dirt should be subjected to dry cleaning.

2.10.6. Wet cleaning (Egg washing)

Wet cleaning or egg washing method is used to remove dirt and contributes to reducing microbial contamination on the eggshell under both commercial conditions and laboratory conditions (Gole et al., 2014).

The temperature of the wash water must be maintained at least 11 °C above the egg temperature (typically 41-44 °C) to avoid creating a vacuum that makes bacterial penetration possible (EFSA, 2005). There are sanitizers that are used in the egg washing method, including chlorine-based compounds, alkaline detergents, ammonium compounds, and their efficacy depends on pH and concentration (Moats, 1978).

Despite its effectiveness, wet cleaning also has disadvantages, as the process can partially or completely remove the natural cuticle layer of the shell, which normally serves as a barrier to microbial penetration and moisture loss (Jisna K. S., 2023). Because the cuticle may be damaged during washing, eggs that undergo this treatment must be placed under strict cold-chain storage immediately afterward to maintain safety and prevent rapid deterioration of interior quality (Jisna K. S., 2023).

2.10.7. Refrigeration

Refrigeration is the most recommended method because of its effectiveness. It is one of the methods that helps to extend the shelf life of shell eggs. Low temperatures prevent bacterial growth and slow the natural chemical changes that occur during storage (M. Wahba, 2014). Eggs have the best internal quality when they are at the time of lay. However, if they sit at room temperature for too long, the albumen gets thinner, carbon dioxide escapes through the shell, and the pH increases. These changes all decrease freshness, which is the key feature that represents egg quality. Refrigeration greatly slows these processes (Abebe et al., 2023).

According to the studies of M. Wahba (2014), eggs stored at 4–5 °C keep their internal quality for up to three weeks longer than eggs kept at room temperature. This method not only slows the thinning of the albumen but also maintains Haugh unit values, yolk index, and yolk firmness. These factors are widely recognized as signs of freshness (Abebe et al.,2023). In conclusion, cold storage lowers the risk of microbes entering the egg from the shell, which is crucial for controlling pathogens like *Salmonella* (Jisna K. S., 2023). Despite its benefits, refrigeration has its limitations as it requires a steady power supply and proper handling. If the condensation on the shell happens due to changes in temperature, it can increase the risk of microbial growth (Abebe et al., 2023).

Despite these limitations, refrigeration is still an important preservation method and can be used alongside other techniques (M. Wahba, 2014).

2.10.8. Pausterization

Pasteurization is a gentle heat treatment that significantly lowers microbial contamination, especially *Salmonella*, while trying to keep the egg’s functional and sensory qualities (Abebe et al., 2023). The main idea behind this technique is to heat the egg using a controlled method, like a water bath, for a period of time. This duration is enough to kill pathogens but not so long that it denatures the proteins in the albumen and yolk (M. Wahba, 2014). Heating shell eggs at around 57 °C for several minutes, followed by refrigeration, effectively reduces microbial risks without changing the egg's internal quality (M. Wahba, 2014). This method is especially important for liquid egg products, such as whole egg blends, yolk, or albumen. These products are often used in the food industry and cannot be cooked further before eating (M. Wahba, 2014). When its performance is optimized correctly, pasteurization adjusts a balance between food safety and preserving functional properties, such as foaming, emulsifying, and gelling, which are crucial for industrial use (Abebe et al., 2023).

However, one limitation of this method is that if time or temperature is not carefully managed, too much heat can cause permanent changes in egg proteins. This can result in lower consumer acceptance and poor functionality (M. Wahba, 2014).

3. Materials and methods

3.1. Materials

For this study, fresh chicken eggs were obtained from Capriovus Ltd (Szigetcs´ep, Hungary). The eggs were fresh, unwashed, with a brown shell color, and free from cracks or any physical damage.

A total of 256 eggs were used in the experiment. The eggs were classified into four size categories according to their weight: small (S), medium (M), large (L), and extra-large (XL).

Table 2: Categories of eggs based on size and weight range

Source: (own work)

Categories	Weight
Small	48-55 g
Medium	57-67 g
Large	61-70
Extra Large	74-81

Cold-pressed corn germ oil was used for the experiment. This oil is produced by Bagolyia (Hungary), and it was purchased from a local supermarket.

Figure 2: Corn-pressed oil (Kukorica-csira olaj)

The equipment used for the experiment included:

- a digital balance (KERN EMB 2000-2, Germany; precision ± 0.01 g) for measuring egg weight,
- a digital caliper (INSIZE, ± precision 0.01 mm) for measuring air cell depth, yolk height and diameter, and albumen height and diameter.

⇒ **Experimental Design : Effect of oil treatment on quality of four different sizes of chicken egg during shelf life**

The experiment aimed to evaluate the effect of corn oil treatment on egg quality and to determine how egg size influences the effectiveness of this treatment. The experiment took place at the Hungarian University of Agriculture and Life Sciences (MATE), Buda Campus in Budapest, Hungary.

Fresh eggs were selected based on free from visible cracks. All eggs were weighed individually using the digital balance to record their initial weight. After this step, they were categorized into size groups (S, M, L, XL) and divided into two main treatments:

1. **Control group** – eggs without any coating treatment.
2. **Treated group** – eggs were dipped in food-grade corn oil for 5 seconds, then air dried.

Every week, each group consisted of 8 eggs in each size category, for a total of 256 eggs (4 sizes x 2 treatments x 8 eggs x 4 weeks).

The procedure that was used for the oil treatment was consistent below:
First, each egg from the treated group was dipped in corn oil for around 5 seconds, ensuring a uniform layer covered the entire surface. After that, eggs were placed on metal net, and air-dried at room temperature (25 ± 1 °C) for 5 hours.
After drying, all the eggs were stored at room temperature (25 ± 1 °C, 60–65% relative humidity), in a clean and ventilated area.
The eggs were placed on fiber-molded trays.

3.2. Methods

3.2.1. Weight loss

Every week, each egg was weighed first, and then we continued with measurements. Using a digital electronic scale (KERN PFB, Kern & Sohn GmbH, Balingen-Frommern, Germany), egg weights were recorded with an accuracy of ±0.01. For the treated eggs, the weight after treatment was used as the initial weight.

The following formula is used to calculate the weight loss of the eggs:

$$\text{Weight loss\%} = \frac{\text{IW of the egg at Day 0 (g) - W egg after Storage (g)}}{\text{IW of the egg at Day 0 (g)}} \times 100$$

3.2.2. Air cell size

Air cell size is measured with a digital caliper. First, a small portion of the eggshell is removed gently, then the digital caliper is inserted to measure the depth of the aircell. This method helps to evaluate the egg quality and freshness.

3.2.3. Haugh Unit, albumen index, yolk index

Each week, the eggs were weighed and then cracked on a clear glass surface, and a digital caliper was used to measure the height, length, and width of the egg yolk.

3.2.3.1. Haugh Unit

The Haugh Unit (HU), as an important indicator of albumen quality, was calculated using this formula (Silversides et al., 1993).

$HU = 100 \log(H + 7.57 - 1W^{37})$

Where H is the albumen height (mm) and W is the egg weight (g).

Table 3: Based on the values of HU, eggs can be graded as follows.

Source: Gabriela da Silva Pires et al. (2020).

Class AA	>72 HU	Superior quality
Class A	71-60 HU	High-quality albumen
Class B	59-31 HU	Lower quality than grade AA and A
Class C	<30 HU	Bad quality

3.2.3.2. Albumen Index

The Albumen Index is calculated with the following formula (Gök & Kurşun, 2025):

$$AI = \frac{\mathrm{h}}{\mathrm{d}} \text{ x } 100\%$$

Where H stands for albumen height (mm) and d for the average diameter of the albumen (mm).

Figure 3: Sample of a broken egg placed on a clear glass surface during measurements.

3.2.3.3. Yolk Index

Yolk Index helps to understand how well the yolk keeps its shape. It is calculated with the following formula (Bonchev et al., 2023):

$$\mathbf{YI} = \frac{h}{d}\, 100\%$$

Where h stands for yolk height (mm) and d for the diameter of the yolk (mm).

Higher values indicate that the yolk stays rounder and firmer. These results explain that the membrane is still strong and intact (Bonchev et al., 2023).

4. Results and discussion

4.1. Weight loss

The weight loss of eggs reflects the degree of moisture and gas exchange through the shell during storage. In our experiment, based on the results shown in Figure 5, weight loss increased progressively with time in all groups. However, the reduction of weight loss varied noticeably between the treated and control eggs. The treated eggs with corn oil lost significantly less weight compared to the control (untreated) eggs. This clearly shows the effect of oil coating in extending the shelf life of eggs.

According to the results of Two-Factor ANOVA, both treatment and storage time had a significant effect on weight loss ($p < 0.001$ and $p < 0.05$), whereas their interaction was not significant ($p > 0.05$). This demonstrates that oil coating and storage time independently influenced the amount of weight loss, but the effect of the treatment was consistent throughout the four-week storage period. This means that the coating remained effective over time, unaffected by the duration of storage.

Among the two groups, in the control group, all egg sizes (S, M, L, XL) expressed a continuous increase in weight loss from the beginning, from week one to week four. Small-sized eggs of the control group lost about 7.68% of their weight, while medium-sized (M) and large (L) eggs lost around 8.84% by week four. Meanwhile, the extra-large eggs (XL) experienced the highest loss, around 10.9%. This fast increase suggests that moisture in absence of an oiling coating, can spread more qucickly through the shell, after the second week of the storage.

In contrast, the group of treated eggs showed more stable and minimal changes than the control group, remaining below 1.7 % weight loss across all sizes. In this group, small egg size (S) increased only from 0.13% to 1.17%, medium (M) from 0.14 % to 1.13%, large(L) from 0.14% to 1.23% and extra large (XL) from 0.19% to 1.69%. These values support the idea that oil treatment acts effectively as a protective barrier, reducing water vapor transfer and preserving the internal moisture content.

The difference between the control and treated eggs became even more visible after the second week, aligning with the moment when untreated eggs started to lose weight faster.

When comparing the sizes, in both groups (control and treated), larger eggs, such as L and XL, consistently lost more weight in contrast with the smaller ones (S and M). This could be due to the internal structure of the larger eggs, which allows for moisture exchange with the environment more than the smaller ones. However, the coating seemed to work effectively across all sizes, since the proportional reduction in weight loss remained similar regardless of egg size.

Overall, these results confirm that oil coating is a simple yet highly effective method for reducing egg weight loss during storage. These findings are consistent with other studies that reported the importance and effectiveness of oiling. For example, (Ryu et al., 2011) also found that eggs coated with oil lost less weight than untreated ones during storage, while (Pham et al., 2023) explained that larger eggs tend to lose more weight in contrast with the smaller ones, even when coated, which supports the size-related differences observed in this study.

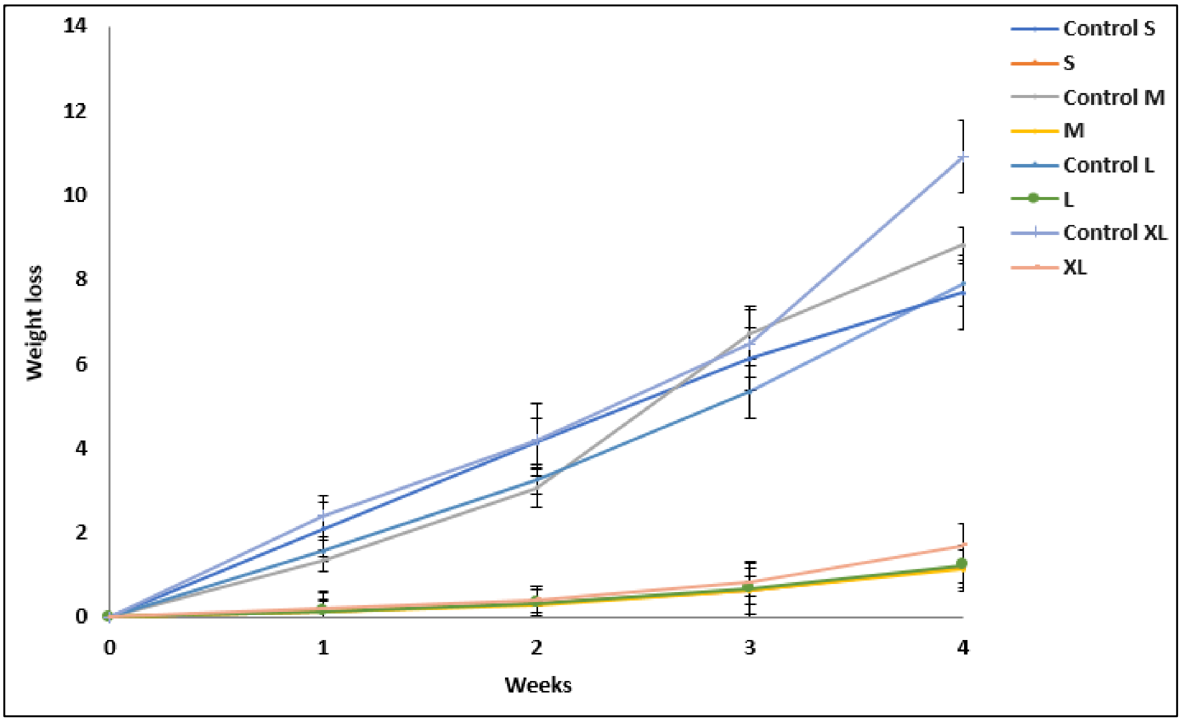

Figure 4: Effect of oil treatment on weight loss.

4.2. Haugh Unit (HU)

As we mentioned earlier, the Haugh Unit values are important to indicate the internal quality and freshness of eggs. Based on Figure 6, these values, showed a gradual decrease over the four-week storage period for all egg groups. This decrease is expected as eggs naturally lose quality over time. However, eggs that were treated with oil maintained higher Haugh Unit values compared to the uncoated control eggs throughout the whole time.

As we can see in the graph, at the beginning of storage (week 0), there was almost no difference between the groups (control and treated), with both of them showing high HU values, around 80-90, corresponding to Grade A eggs, which reflects freshness. As time passed, the difference between the two groups became more visible. By week 4, the control eggs showed a significant decrease. These values reached approximately 45.15 for small (S), 47.24 for medium (M), 43.97 for large (L), and 38.44 for extra-large (XL) eggs. These values are equivalent to Grade B or lower, which indicates a significant deterioration in albumen quality.

In contrast, the group of treated eggs maintained higher HU values at week 4. The values generally ranged from 58.4 to 64.5. Size S had a value of about 64.45, size M was 63.62, which were also sizes that performed the best, followed by size L, 59.73, and 58.44 for XL size. This indicates that the corn oil treatment was effective in preserving egg quality for a longer period of time.

When comparing egg sizes, medium (M) and large (L) treated eggs maintained the most stable HU values across storage time, indicating that these sizes benefits the most from the oil coating. This can be due to an optimal balance between shell surface area and shell pore density. On the other hand, smaller (S) and larger (L) eggs showed greater declines in HU. This may be related to the differences in shell thickness and gas diffusion rates.

These results emphasize the effect of corn oil on eggs. It shows the potential that the oiling has to slow down the loss of albumen quality and maintain freshness for a longer time. This effect can be explained by the oil forming a thin protective layer that reduces moisture and gas loss through the eggshell.

The Two-Factor ANOVA confirmed that both treatment (sample) and storage duration (time) had statistically significant effects on HU values ($p < 0.001$), while the interaction between the two was not significant ($p = 0.0647 > 0.05$). This indicates that although both coating and storage time independently affected egg quality, the coating effect remained consistent over time.

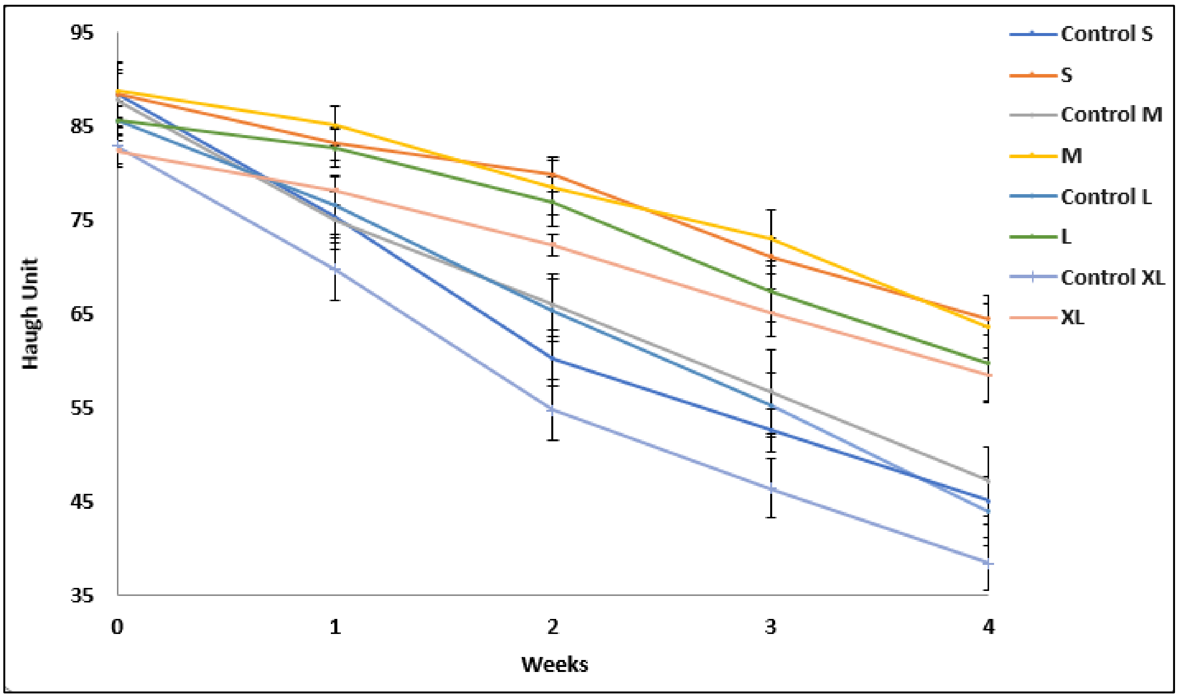

Figure 5: Changes in Haugh Unit of control and treated eggs during four weeks of storage.

Overall, these results support the fact that oiling plays a key role in maintain albumen quality and delaying fresh loss. Also, a similar study was made by (Ryu et al., 2011), who found that eggs coated with different types of oil retained higher Haugh Unit values during storage, indicating the effectiveness of oiling as a method.

4.3. Yolk Index

The yolk index (YI) as an important parameter that reflects the roundness and firmness of the yolk and as an indicator of egg freshness, showed a progressive decrease throughout the four-week storage period across two experimental groups. The experiment analyzed two groups of eggs: control (uncoated) and treated (corn-oil coated). Each group contained four different sizes of eggs (S, M, L, XL). The yolk index parameter was measured weekly, over four-week storage, to evaluate the effect of oil coating. As shown in figure 7, the yolk index showed a gradual decrease for all eggs throughout the storage period for all of egg groups. However, we can see that the decline of the yolk index was significantly less in eggs treated with corn oil compared with the control eggs.

At the beginning of the experiment, at week 0, all sizes (S, M, L, XL) of both groups showed similar values, which vary around 0.43-0.48, indicating high internal quality and freshness. These values changed over time, where the yolk index of the untreated eggs (control) decreased significantly, ranging from 0.17 to 0.23, whereas the treated eggs maintained higher values of around 0.31 to 0.33, depending on egg size.

In the group of control eggs, the yolk index continued to decrease throughout the four weeks. For small (S) eggs, the yolk index dropped from 0.48 at week 0 to 0.22 by week 4, while medium (M) eggs declined from 0.46 to 0.20. Large (L) eggs showed a more noticeable decrease from 0.43 to 0.17. Extra-large (L) eggs also decreased from 0.43 to 0.17. Based on these results, we indicate that control eggs lost firmness and yolk structure more quickly during storage. This likely happened due to higher moisture and gas exchange between the yolk and albumen. As the internal membranes weakened, the yolk became flatter, indicating a loss of freshness.

In contrast, the treated group eggs maintained higher yolk index values across all sizes. This confirms the effectiveness of the coating as a protective barrier. For small eggs (S), the yolk index decreased slightly from 0.46 to 0.33, while medium (M) eggs dropped from 0.46 to 0.31. In a similar way, large (L) eggs decreased from 0.45 to 0.32, and extra-large (XL) eggs from 0.43 to 0.31. These values demonstrate the effectiveness of corn oil as a coating material, which helped to protect the yolk and slow down quality loss.

When comparing the performance of different egg sizes in both groups (control and treated), medium (M) and large eggs (XL) maintained the highest yolk index values throughout the experiment. This suggests that their structural characteristics allow better resistance to internal quality loss. On the other hand, small eggs (S), showed faster declines, which may be attributed to their higher surface area relative to volume, causing faster moisture loss. Extra-large (XL) eggs also showed a slight decrease, which could be due to their irregularities or microcracks on the shell surface that increase permeability to air and water vapor.

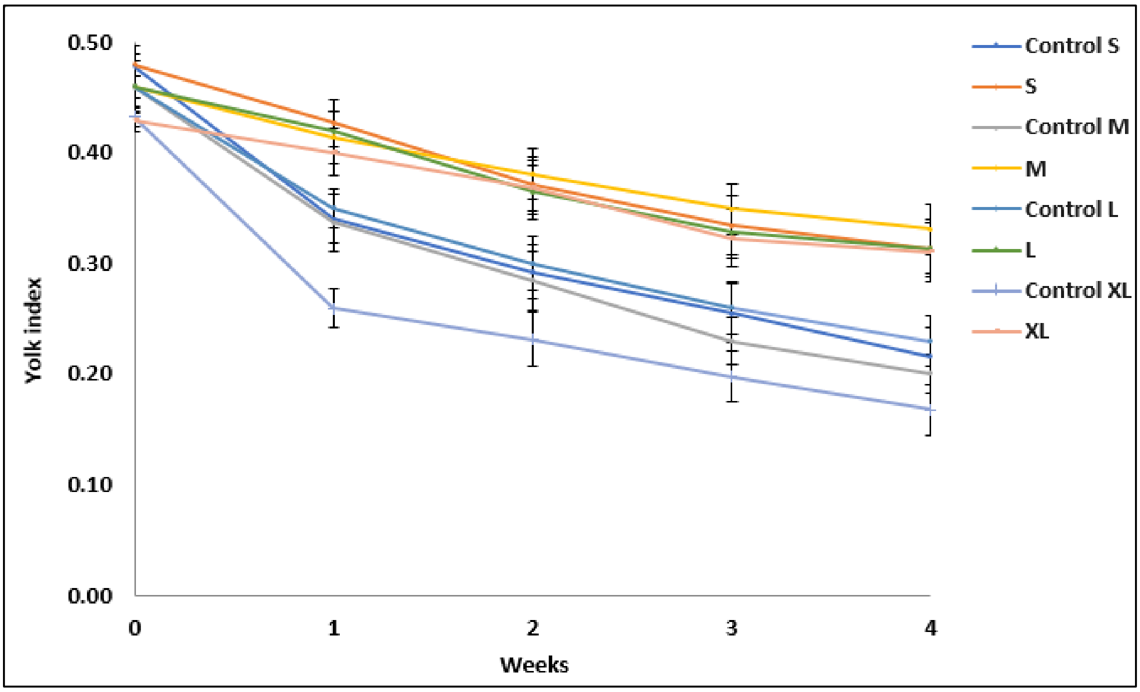

Figure 6: Yolk index of control and treated groups during four weeks of storage.

The results in the table of Two-Factor ANOVA confirmed that both groups (coated and treated), had a highly significant effect on yolk index ($p < 0.001$). However, their interaction was not significant ($p > 0.05$). This indicates that oil coating and time each influenced yolk quality independently, but the coating's beneficial effect remained consistent across the four weeks. In practical terms, this means the oil coating slowed down yolk decay, no matter how long the eggs were stored.

Our results may be compatible with other studies that found oil coatings reduce gas and moisture exchange through the shell (Ryu et al., 2011) ; (Da S. Oliveira et al., 2020), helping to preserve yolk firmness during storage. Overall, the results clearly show that corn oil coating significantly slows the decline in yolk index across all egg sizes. The treated eggs maintained higher yolk firmness and freshness in comparison with the control eggs. This confirms that corn oil coating is an effective and practical method for preserving egg quality and extending shelf life during storage.

4.4. White (Albumen) Index

The Albumen Index is another important parameter that reflects the firmness and thickness of the albumen. In this experiment, this parameter gradually decreases throughout the four-week observation period for both control and treated groups. This reflects the natural weakening of albumen structure over time. However, this decrease was lower in the treated group of eggs, indicating that the coating helped maintain albumen quality for longer.

The results of the Two-Factor ANOVA table confirmed that both treatment and storage time had highly significant effects on the white index ($p < 0.001$ for both), while their interaction was not significant ($p > 0.05$). This indicates that both the storage time and the treatment independently influenced the white index, but the oil coating effect remained consistent across all weeks. Specifically, the oil layer was effective in reducing albumen deteoriation throughout the storage period.

At the beginning of storage, both control and treated eggs had similar weight loss values of 0.06, indicating high freshness and strong albumen structure. Over time we can see a difference between the two groups (coated and treated). In the control group, a faster decline was noticed with storage time. Small (S) and medium (M) sized-eggs decreased from 0.06 to 0.02 by week 4. The large (L) and extra-large (XL) size decreased to similar values, around 0.02 to 0.03. This reduction shows how quickly the albumen in uncoated eggs thins and turns liquid. This happens as carbon dioxide escapes and Ph levels rise during storage.

On the other hand, the treated eggs showed a slower and gentler decrease in white index. Small (S) treated eggs decreased slightly from 0.06 to 0.03 and medium (M) from 0.06 to 0.03. Meanwhile the large (L) and extra-large (XL) sizes decreased similarly from 0.6 around 0.2. T These results show that corn oil coating effectively slowed the degradation of albumen quality by reducing moisture and gas exchange through shell pores. The differences between the groups (control and treated) became especially evident from week two onward.

When comparing egg sizes, all categories (S, M, L, XL) showed a similar trend of gradual decline. However, smaller eggs tended to lose white index slightly faster. This could be due to their higher surface area relative to volume, which leads to quicker dehydration. Larger eggs (L, XL) maintained slightly higher values, suggesting that the coating was more effective on eggs with thicker shells and a smaller relative surface area.

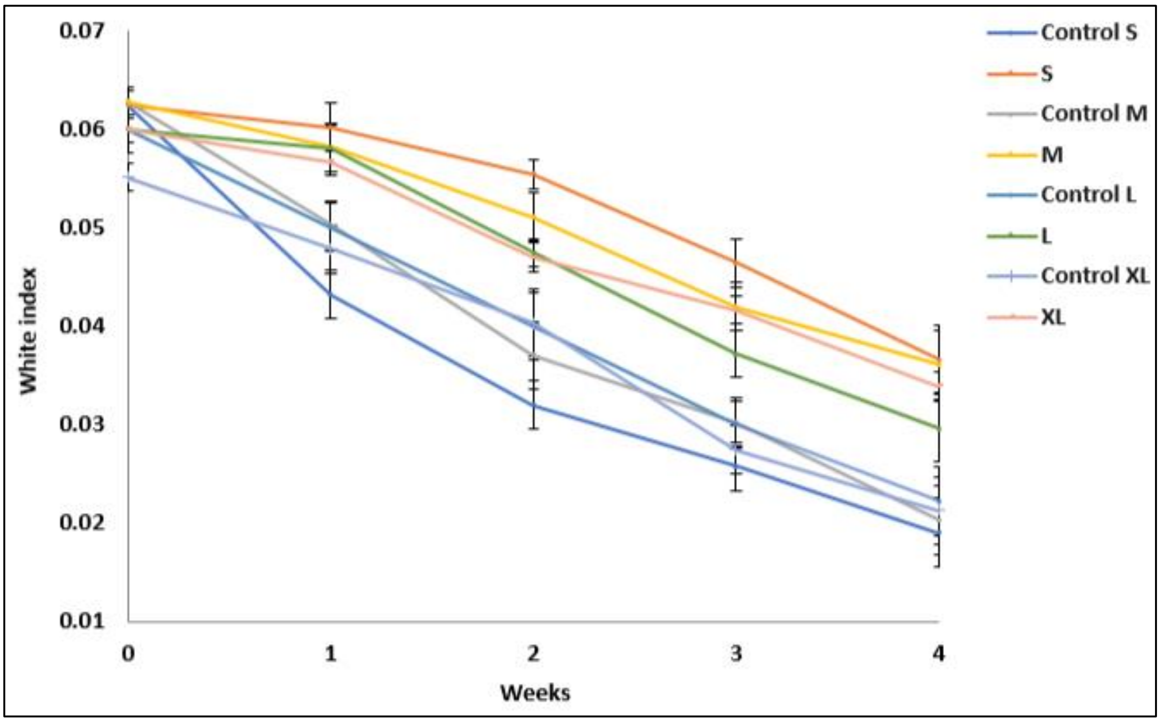

Figure 7: Albumen index of control and treated groups of eggs

Overall, these results confirm that oil treatment significantly reduced the rate of albumen quality loss. This helped to preserve internal freshness during storage. The results match earlier studies, such as those by Samli et al. (2005) and (Ryu et al., 2011) .They also found that egg coatings act as semipermeable barriers, slowing down the exchange of gas and water vapor. This delay helps to prevent albumen thinning and loss of firmness. Therefore, using corn oil as a coating is a simple and effective way to maintain the internal quality and freshness of eggs of various sizes during extended storage.

4.5. Air cell

Air cell is an important parameter that determines egg freshness. In our experiment (Figure 9), the air cell height showed an increase in both groups during the four weeks of observation. This reflects the process of internal moisture and carbon dioxide loss through the shell pores over time.

The Two-Factor ANOVA table confirmed that both treatment and time had a statistically significant effect on air cell height ($p < 0.001$), and the interaction between them was also significant ($p = 0.0029 < 0.05$). This explains the coating's influence as the storage time increased.

At the beginning of storage (week 0), all eggs showed small air cells ranging from 5.18 to 6.59 mm, confirming their initial freshness. As the weeks passed, the difference between the groups, control and treated, became more visible.

By the fourth week, the group of control eggs showed the highest increase in air cell height, reaching values around 10-11 mm, depending on egg size. In contrast, the eggs treated with corn oil showed smaller increases, generally around 7.5-8.5 mm.

When analyzing egg size, specific patterns were observed in both groups. For the treated group, the medium (M) and large (L) eggs kept a stable value of air cell size, showing a slower and smaller increase over time, from 6.16 to 7.81 mm and from 5.75 to 7.90mm. On the other hand, small (S) and extra-large (XL) eggs showed a higher increase from 5.18 to 7.22 mm and from 6.59 to 8.18 mm, which can be due to differences in the shell thickness and pore structure that affect gas permeability.

In the group of controlled eggs air cell rise was much more pronounced. Small (S) and medium (M) eggs showed the highest increase from 5.18 to 10.81 mm and from 5.18 to 11.44 mm. Large (L) and extra-large (XL) eggs increased by about 10.1mm. The oil effectiveness was showed based on these results, which indicates that it plays a crucial role in limiting internal moisture loss and slowing down the formation of larger air spaces.

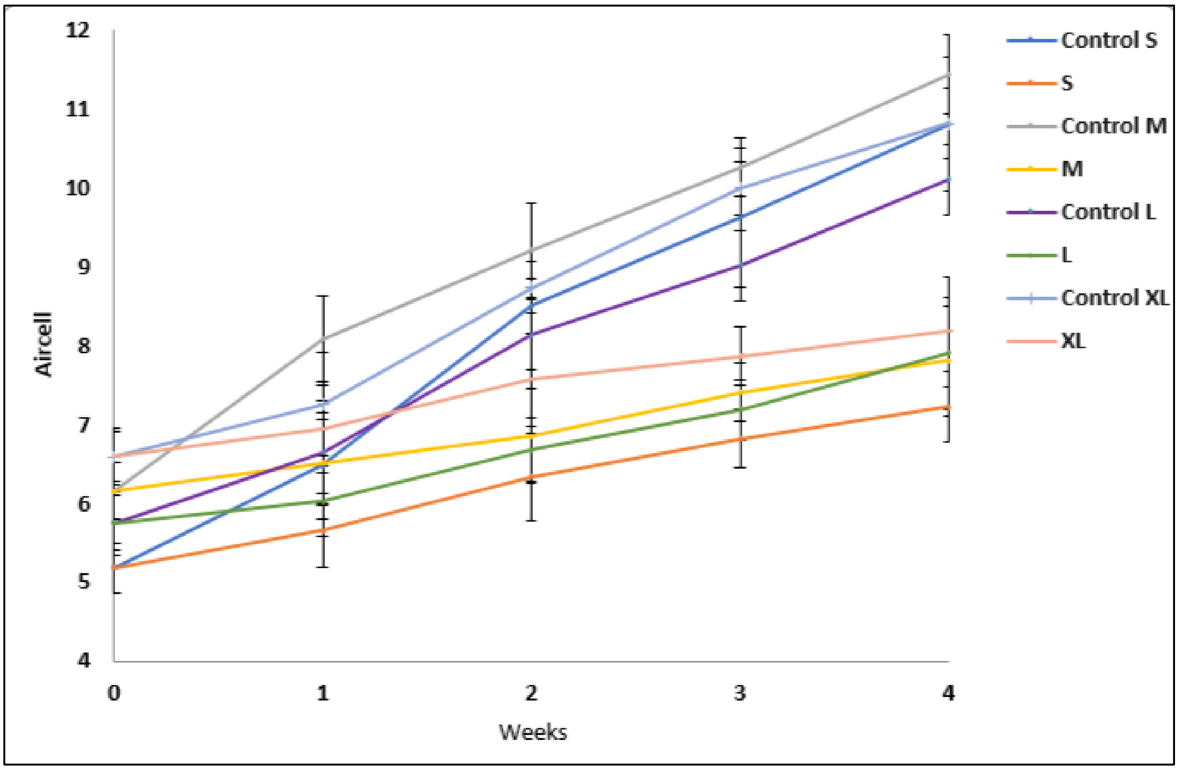

Figure 8: Changes in air cell height of control and coated eggs during four weeks.

These results are consistent with previous research. (Ryu et al., 2011) reported that oil-coated eggs showed smaller increases in air cell height during storage, in contrast with the uncoated eggs, which explains the benefits of the oiling, which helps to reduce gas permeability. Similarly, (Da S. Oliveira et al., 2020) showed that oil coatings minimize air cell enlargement by restricting the moisture and gas transfer through the shell. The studies align closely with our findings, where all of us explain the effectiveness of the oiling method, which helps to slow down the deterioration of eggs by stabilizing internal conditions and reducing the rate of air cell expansion, regardless of egg size.

5. Summary

5.1. Effect of oil treatment on the quality of four different sizes of chicken egg during shelf life

The purpose of this experiment was to evaluate how corn oil affects both the internal of chicken eggs during storage. For this study, 256 fresh eggs were taken and they were categorized into different sizes, such as small (S), medium (M), large (L), and extra-large (XL). We divided the eggs into two groups: control (untreated with oil) and treated (treated with oil). All eggs were stored at room temperature for a period of four weeks. During this time, several quality parameters were measured weekly to monitor changes in egg freshness. These parameters included weight loss, Haugh Unit, yolk index, white index, and air cell height.

According to the results, treated eggs performed better, having better quality than the control group of eggs. We can indicate this based on the results of the parameters that we measured, where weight loss increased gradually during the storage period in all groups, but coated eggs lost less moisture. By the fourth week, control eggs showed an average weight loss of 7 to 11%, depending on size. Meanwhile treated eggs stayed below 1.7%. These results show the effectiveness of the oil coating in reducing evaporation through the shell. Similarly, Haugh Unit (HU) values decreased over time for all groups, showing a natural decline in albumen quality. However, coated eggs kept higher HU values during the storage period. By week four, HU values for control eggs dropped to about 40 to 50, while coated eggs remained between 78 and 88. This shows that the oil treatment helped maintain albumen height and internal freshness. The yolk and white indices also dropped as storage continued, reflecting changes in yolk membrane strength and albumen thickness. Yet, eggs treated with corn oil had higher index values than control eggs. This suggests that the oil coating effectively slowed the decline of these parameters. Meanwhile, the air cell height increased in both groups, but the rise was slower in coated eggs. By week four, these eggs reached only 7.5 to 8.5 mm, while the uncoated eggs reached 10 to 11 mm.

Overall, these results confirmed the oil coating helps preserve egg freshness and slows quality decline during the four-week storage period. The treatment created a thin protective barrier that reduced moisture and gas exchange through the shell. About the sizes of the eggs, the oil treatment effect seemed particularly helpful for medium and large-sized eggs, which showed the most stable quality measures throughout storage. The treated eggs had lower weight loss, higher Haugh Unit values, better yolk and albumen stability, and less air cell compared to untreated eggs. To conclude, this study confirms that corn oil is a natural, simple, and effective coating material for extending the shelf life of chicken eggs.

6. Conclusion

Overall, the results of the experiment show that oil coating is an effective method. They demonstrate the advantages of using oiling as a method to extend the shelf life of eggs and maintain their freshness.

The coating as a method helps to reduce weight loss, slows the increase of air cell height, and preserves albumen and yolk quality. These results emphasize the protective role of the barrier provided by the oil, which is a thin layer that limits moisture evaporation and gas exchange through the shell pores.

In summary, the application of corn oil as a natural coating is simple, effective, and sustainable for extending the shelf life of eggs. This method can help to reduce egg quality deterioration, improve the marketability of table eggs, and minimize food waste

.

7. Recommendations

Based on the results of this study, several recommendations can be made for future research and practical applications. These suggestions are proposed to improve the effectiveness of egg preservation using natural coating methods and to explore new possibilities for extending the shelf life and maintaining the quality of eggs.

- Adding antimicrobial agents to the coating

  An idea for future research would be to test the inclusion of antimicrobial agents into the oil coating. These agents could improve the protective effect of the oil, since they can reduce bacterial growth. For example, natural extracts such as garlic or rosemary oil could be examined for their antimicrobial properties. In this way, oiling would not only act as a physical barrier but also as a biological one, improving both safety and freshness of the eggs.

- Extending the study period and increasing sample size

  Conducting the experiment over a longer period and with a larger number of eggs could help to achieve more consistent data. This would make the conclusions more reliable and applicable for industrial or commercial use.

- Evaluating the effect of oiling at different storage temperatures

  Since this experiment was performed at room temperature, it would be useful to study how oil-coated eggs behave under refrigeration or at higher ambient temperatures. Comparing these conditions would provide a clearer understanding of how temperature and storage time affect the effectiveness of the coating on egg quality.

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9. List of figures

9.1 List of Tables

10. Acknowledgements

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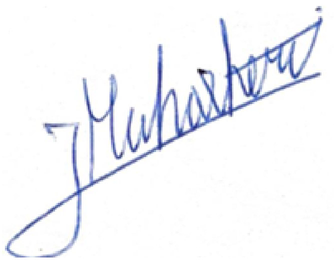

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