Formosa Journal of Science and Technology (FJST)
Vol. 5, No. 7, 2026: 1771-1788

Foam-mat Dried Kepok Banana Peel Extract Powder as a Natural Preservative for Maintaining Chicken Egg Quality

Tiurma Wiliana Susanti Panjaitan[1], Amelia Nirmalawaty[2]*
Universitas 17 Agustus 1945 Surabaya
Corresponding Author: Amelia Nirmalawaty, amelia@untag-sby.ac.id

A R T I C L E I N F O

Keywords: Kepok Banana Peel, Instant Powder, Natural Preservative, Chicken Egg Quality.

Received: 27, May
Revised: 29, June
Accepted: 25, July

A B S T R A C T

Chicken eggs are highly nutritious animal-source foods, but their internal quality declines rapidly during room-temperature storage. This study aimed to evaluate instant kepok banana peel extract powder as a natural preservative for maintaining chicken egg quality. Kepok banana peel extract was processed into instant powder using foam-mat drying with egg white as a foaming agent and dextrin as a carrier. The powder was reconstituted in water at different powder-to-water ratios, namely 1:10, 1:20, 1:30, 1:40, and 1:50. Fresh chicken eggs were immersed in the prepared solutions for 24 hours, stored at room temperature, and evaluated based on Haugh Unit, albumen index, and yolk index during storage. The results showed that storage duration caused a continuous decline in internal egg quality. The average Haugh Unit decreased from 77.56 on day 0 to 65.26 on day 7, 61.04 on day 14, and 35.39 on day 21. The albumen index decreased from 0.13 to 0.02, while the yolk index declined from 0.44 to 0.14 over the same storage period. Differences among treatment ratios were not statistically significant; however, the 1:20 ratio was identified as the most practical formulation because it maintained acceptable egg quality up to 14 days. The 1:10 ratio did not provide better preservation and showed spoilage by day 21. These findings indicate that instant kepok banana peel extract powder can be developed as a low-cost, waste-based natural preservative for extending egg shelf life under room-temperature storage

ISSN-E: 2964-6804
DOI: https://doi.org/10.55927/fjst.v5i7.108
https://journalfjst.my.id/index.php/fjst

INTRODUCTION

Chicken eggs are a vital source of animal-based protein and essential nutrients like amino acids, vitamins, and minerals, contributing significantly to human nutrition. However, they are highly perishable and their quality rapidly declines due to several factors, including water and carbon dioxide migration through the eggshell, an increase in albumen pH, a decrease in albumen viscosity, and weakening of the vitelline membrane. These changes reduce the freshness of the eggs and increase the likelihood of microbial contamination, particularly when eggs are stored at room temperature. This presents a significant challenge for food distribution, especially in environments where cold-chain storage is unavailable, such as traditional markets or household settings.

Various methods have been proposed to extend egg shelf life, including refrigeration, oil coatings, packaging, edible coatings, and the use of preservatives (Agricultural Institute, 2025). While these techniques have proven effective to some extent, they are not without limitations. For instance, refrigeration requires the availability of electricity and is not always feasible in rural or developing areas. Oil coatings and packaging may not fully address microbial growth or the underlying causes of egg quality deterioration, and consumer preference is increasingly shifting towards more natural and sustainable solutions. Therefore, the search for natural preservatives that can inhibit microbial growth, reduce quality degradation, and be applied easily and sustainably has become an important focus of research.

Among the promising natural preservatives are those derived from agricultural waste, particularly banana peel. Banana peel, which is typically discarded after the edible portion of the fruit is consumed, is rich in bioactive compounds such as flavonoids, phenolics, tannins, alkaloids, glycosides, anthocyanins, and terpenoids (Wani & Dhanya, 2025). These compounds exhibit antioxidant, antibacterial, anti-inflammatory, and other bioactive properties (Mishra & Singh, 2026), making banana peel an attractive candidate for use as a natural preservative. Studies have shown that banana peel extract can effectively extend the shelf life of food products by inhibiting microbial growth and reducing oxidative degradation. For example, Ashka et al. (2023) found that banana peel extract contains high levels of antioxidants that can help preserve food quality. Zaini et al. (2022) also reported that compounds in banana peel, such as flavonoids and phenolic compounds, are particularly effective in reducing microbial contamination and maintaining food quality. And these bioactive compounds provide a basis for food preservation applications beyond simple nutritional use (Wani & Dhanya, 2025)

The primary challenge in storing eggs at room temperature is the gradual decline in internal quality over time. The most common indicators of egg freshness are the Haugh Unit, albumen index, and yolk index. The Haugh Unit, for instance, is an indicator of egg albumen quality, with higher values representing fresher eggs. As the egg ages, the albumen thins, the pH increases, and the Haugh Unit decreases, indicating a loss of freshness. Similarly, the albumen index and yolk index, which measure the structural integrity of the

albumen and yolk, respectively, also decline over time (Garcia al., 2026), particularly in eggs stored without refrigeration. Lestari et al. (2013) explained that water migration from the albumen to the yolk, along with changes in the physical and chemical properties of the egg, contribute to the reduction in yolk and albumen quality during storage.

To address these challenges, one solution that has gained attention is the use of natural materials, particularly plant-based substances, to preserve egg quality during storage. Plant-based materials, especially those containing tannins, can form a protective layer on the eggshell surface, reducing water and gas evaporation and slowing the deterioration of internal quality. Datukramat et al. (2023) reported that banana peel extract, particularly from goroho banana varieties, can influence egg weight, albumen index, and yolk index during storage. This effect is likely due to tannins' ability to close eggshell pores and inhibit the release of gases like CO2, NH3, and N2, which contribute to the degradation of egg quality.

However, the use of liquid banana peel extract presents some practical limitations. Liquid extracts are more difficult to store and standardize, and they tend to degrade more rapidly over time. To overcome these challenges, the conversion of banana peel extract into a powder form is a promising solution. Powdered extracts have lower moisture content, are more stable, easier to store, and can be reconstituted as needed, offering greater flexibility for application. One effective technique for converting liquid extracts into powders is foam-mat drying (FMD). FMD involves using foaming agents and stabilizers to form stable foam, which is then dried at low temperatures to produce a powder with favorable reconstitution properties. Van Tai et al. (2024) demonstrated that foam-mat drying is a cost-effective, energy-efficient method that preserves the bioactive compounds in banana peel extract while maintaining their antioxidant and antimicrobial properties.

The use of egg white as a foaming agent and maltodextrin as a stabilizer can further enhance the properties of the powder. Egg white helps form a stable and porous foam structure, while maltodextrin prevents stickiness, protects sensitive compounds, and improves the physical characteristics of the powder. Studies by Khamjae and Rojanakorn (2018) and Ng and Sulaiman (2018) showed that foam-mat drying of fruit and vegetable materials can produce powders with excellent rehydration properties, stability, and physicochemical quality. These findings support the idea that banana peel extract powder can be a more stable and practical alternative to liquid extract for preserving egg quality.

Despite the promising potential of banana peel extract, most studies have focused on the use of liquid extract, with limited research on the application of powdered banana peel extract in food preservation, particularly in egg preservation. The effectiveness of the powder form is influenced by several factors, including the powder-to-solvent ratio, solution viscosity, and the interaction between the solution and the eggshell. This study aims to fill this gap by evaluating the effectiveness of instant kepok banana peel extract powder as a natural preservative for chicken eggs stored at room temperature. The eggs will be immersed in solutions of banana peel extract powder prepared at different

powder-to-water ratios, and their internal quality will be assessed through the Haugh Unit, albumen index, and yolk index during storage.

The novelty of this research lies in its integration of banana peel waste utilization, foam-mat drying technology, and egg preservation in a single practical formulation. The hypothesis is that higher concentrations of banana peel extract powder will extend the shelf life of eggs, but the effectiveness of more concentrated solutions needs to be carefully examined. Excessively concentrated solutions may not necessarily provide better preservation, and further optimization is needed. This study is expected to contribute to the development of low-cost, sustainable natural preservation technologies that utilize agricultural waste, benefiting small producers, traders, and households.

THEORETICAL REVIEW

Egg Quality Deterioration During Storage

Chicken eggs are perishable food products whose internal quality declines gradually during storage, especially under room-temperature conditions. The deterioration process occurs because eggshell pores allow the movement of water vapor and gases, particularly carbon dioxide, from the egg interior to the surrounding environment. The loss of carbon dioxide increases albumen pH, reduces albumen viscosity, and weakens the protein structure that supports albumen thickness. These changes reduce freshness and lower the functional quality of eggs during storage (Lestari et al., 2013; Martínez et al., 2021).

The main indicators used to evaluate internal egg quality are the Haugh Unit, albumen index, and yolk index. The Haugh Unit reflects albumen quality by combining albumen height and egg weight. Higher Haugh Unit values indicate fresher eggs, while lower values show albumen thinning and quality decline. The albumen index measures the structural integrity of the egg white, while the yolk index indicates the firmness and stability of the yolk. During storage, the albumen becomes thinner, the yolk becomes flatter, and the vitelline membrane weakens because water migrates from the albumen into the yolk (Garcia et al., 2026; Okonkwo et al., 2021).

Storage temperature and storage duration strongly affect these quality indicators. Eggs stored at higher temperatures deteriorate faster than eggs stored under refrigeration because biochemical reactions and moisture loss occur more rapidly. However, cold-chain storage is not always available in traditional markets, rural areas, or household settings. This condition creates a need for affordable preservation methods that can maintain egg quality without depending fully on refrigeration (Agriculture Institute, 2025; Martínez et al., 2021).

Natural Preservation Strategies for Shell Eggs

Several preservation methods have been used to extend egg shelf life, including refrigeration, oil coating, packaging, edible coating, and immersion in preservative solutions. These methods aim to reduce moisture loss, slow gas exchange, limit microbial contamination, and maintain internal egg quality. Among these approaches, natural plant-based preservatives have attracted attention because they are relatively safe, low-cost, and aligned with consumer demand for sustainable food preservation methods (Agriculture Institute, 2025).

Plant-based preservatives can protect eggs through two main mechanisms. First, bioactive compounds such as tannins, flavonoids, and phenolics can provide antioxidant and antimicrobial effects. Second, some plant extracts may form a thin protective layer on the eggshell surface, reducing pore permeability and slowing the release of carbon dioxide and water vapor. This mechanism can help maintain albumen viscosity and yolk stability for a longer period (Datukramat et al., 2021; Lestari et al., 2013).

Previous studies have shown that plant extracts may influence egg quality during storage. For example, melinjo leaf extract was reported to affect egg quality during different storage periods, while banana peel extract has been associated with changes in egg weight, albumen index, and yolk index (Datukramat et al., 2021; Lestari et al., 2013). However, the effectiveness of natural preservatives depends on the concentration, extraction method, application technique, and interaction between the solution and the eggshell surface. Excessively concentrated solutions do not always provide better preservation because they may increase viscosity and reduce uniform coating on the eggshell.

Banana Peel as a Source of Bioactive Compounds

Banana peel is an agricultural by-product that is often discarded, although it contains valuable bioactive compounds. Previous studies reported that banana peel contains phenolic compounds, flavonoids, tannins, alkaloids, glycosides, anthocyanins, and terpenoids. These compounds are associated with antioxidant, antimicrobial, anti-inflammatory, and other functional properties, making banana peel a potential material for food preservation and functional food applications (Ashka et al., 2023; Singh et al., 2016; Wani & Dhanya, 2025; Zou et al., 2022).

The antioxidant potential of banana peel is important in food preservation because oxidative reactions can contribute to quality deterioration. Phenolic compounds and flavonoids act as free radical scavengers, while tannins may contribute to antimicrobial activity and the formation of a protective barrier. Studies on different banana varieties have shown that banana peel extracts possess antioxidant activity, including DPPH radical scavenging activity, which supports their potential use as natural preservatives (Rahmi et al., 2021).

The valorization of banana peel also supports sustainable food processing. Instead of treating banana peel as waste, it can be converted into a value-added product for food preservation. This approach contributes to waste reduction, circular food systems, and low-cost preservation technology. Recent reviews have emphasized the industrial potential of banana peel bioactives for extraction, food applications, and sustainable product development (Wani & Dhanya, 2025; Zou et al., 2022).

Foam-Mat Drying for Powder-Based Natural Preservatives

Although banana peel extract has preservation potential, liquid extract has several practical limitations. Liquid extract is more difficult to store, less stable, and more prone to quality degradation during handling. It may also be less practical for small-scale users because it requires immediate preparation and has limited shelf stability. Converting liquid extract into powder can improve storage

stability, reduce moisture content, simplify transportation, and allow reconstitution before use.

Foam-mat drying is a suitable method for producing powder from liquid or semi-liquid food materials. This technique involves converting liquid extract into foam using a foaming agent, followed by drying at relatively low temperatures. The foam structure increases the surface area of the material, accelerates moisture removal, and helps produce powder with good rehydration characteristics. Foam-mat drying has been used successfully for fruit and vegetable powders, including banana powder, beetroot powder, and passion fruit aril powder (Khamjae & Rojanakorn, 2018; Khira, 2019; Ng & Sulaiman, 2018).

In foam-mat drying, egg white can function as a foaming agent because it contains proteins that help form and stabilize foam. Dextrin or maltodextrin can act as a carrier and stabilizer by reducing stickiness, protecting sensitive compounds, and improving powder characteristics. Previous studies on foam-mat drying reported that foaming conditions and drying temperature affect drying rate, total polyphenol content, and final powder quality (Haryanto, 2016; Tai et al., 2024).

Particle size and size reduction also influence the extraction and quantification of phenolic compounds in plant food matrices. Smaller particle size can increase contact between plant material and solvent, but excessive size reduction may also affect compound stability and analytical accuracy. Therefore, processing conditions must be controlled carefully to preserve the functional quality of plant-based powders (Baldelli & Aguilera, 2025).

Research Gap and Conceptual Basis of the Study

Previous studies have provided evidence that banana peel contains bioactive compounds with antioxidant and antimicrobial potential. Other studies have examined plant extracts as natural preservatives for eggs or evaluated foam-mat drying as a technique for producing stable food powders. However, limited research has integrated these three aspects into one practical preservation system: kepok banana peel waste utilization, foam-mat drying technology, and egg quality preservation under room-temperature storage.

Most studies on banana peel extract for egg preservation have focused on liquid extract. This creates a practical gap because liquid extract has limitations in stability, storage, and standardization. Powder-based banana peel extract may offer a more practical alternative because it can be stored longer, transported easily, and reconstituted in water at different ratios before application. However, the effectiveness of powder-based extract depends on the powder-to-water ratio, solution viscosity, bioactive compound availability, and coating interaction with the eggshell.

Based on this literature, instant kepok banana peel extract powder has potential as a natural preservative for chicken eggs. The bioactive compounds in banana peel may help reduce microbial activity and slow internal quality deterioration, while foam-mat drying can improve the practicality and stability of the extract. Therefore, this study evaluates the effect of different powder-to-

water ratios of instant kepok banana peel extract powder on Haugh Unit, albumen index, and yolk index during room-temperature storage..

METHODOLOGY

Research Design

This study aims to experimentally evaluate the effectiveness of instant kepok banana peel extract powder as a natural preservative for chicken eggs stored at room temperature. The design of the experiment revolves around immersing chicken eggs in different concentrations of banana peel extract powder reconstituted in water, followed by observing and analyzing the internal quality of the eggs during storage. The primary goal of this study is to assess how varying concentrations of banana peel extract powder influence key egg quality indicators such as the Haugh Unit, albumen index, and yolk index during storage. These parameters are important indicators of egg freshness and internal quality, and by monitoring them over a period of time, this research aims to determine the preservation efficacy of banana peel extract powder compared to control eggs.

The rationale for using banana peel extract as a preservative is grounded in the well-documented bioactive compounds found in banana peels, such as flavonoids, phenolics, tannins, and other secondary metabolites, which exhibit significant antioxidant and antimicrobial properties. The premise of this study is that banana peel extract can be an effective natural preservative that extends shelf life by reducing microbial activity and mitigating oxidative degradation. Moreover, the process of converting the banana peel extract into powder form using foam-mat drying (FMD) improves its stability and practicality for application in food preservation. This method enables the extract to be stored in a more stable form and easily reconstituted as needed for use.

Previous studies have shown that plant-based extracts, such as banana peel, can effectively preserve food by inhibiting microbial growth and slowing the oxidation process. Specifically, studies have demonstrated that banana peel extract, when applied to food products such as eggs, can help maintain internal quality by reducing the migration of water from the albumen to the yolk and by slowing the thinning of the albumen, which leads to a decrease in Haugh Unit value over time (Datukramat et al., 2023; Isnaini et al., 2023). Foam-mat drying, the technique selected for this study, has been proven to be effective for producing powders from liquid extracts while retaining their bioactive properties. It is a low-cost, time-efficient method that also prevents the degradation of sensitive compounds during drying (Tai et al., 2024; Ng & Sulaiman, 2018).

Materials

The materials used in this study include fresh kepok banana peel, clean water, 70% alcohol, egg white, dextrin, and fresh chicken eggs. Kepok banana peel was chosen as the source of the bioactive extract because it has been shown to contain significant amounts of flavonoids, tannins, phenolic compounds, and other bioactive constituents that are beneficial for both antioxidant and antimicrobial activity (Rahmi et al., 2021; Ashka et al., 2023). The use of egg white

as a foaming agent is supported by previous studies, which have shown that egg white can help form a stable foam structure that is essential for foam-mat drying. Dextrin, a carbohydrate derived from starch, was chosen as a stabilizing material to help reduce the stickiness of the foam, prevent degradation of the bioactive compounds, and improve the overall stability of the final powder product.

The chicken eggs used in this experiment were carefully selected for their intact shells and the absence of visible cracks to ensure the integrity of the experimental model. These eggs were treated as perishable food items, as egg quality deteriorates during ambient storage due to factors such as carbon dioxide loss, albumen thinning, and the movement of water from the albumen into the yolk. Studies have shown that the physical properties of the egg, such as the albumen height and yolk membrane strength, significantly decrease as storage time increases (Lestari et al., 2013; Isnaini et al., 2023). Thus, the eggs in this study are modeled as perishable foods to closely simulate real-life conditions where eggs are stored without refrigeration.

Preparation of Instant Kepok Banana Peel Extract Powder

The preparation of the banana peel extract powder involved several steps: cleaning, extraction, foaming, drying, and storage. The banana peels were initially washed under running water to remove any dirt, dust, or foreign materials. After cleaning, the peels were cut into smaller pieces to increase the surface area for extraction. Increasing the surface area is important because it allows for better contact between the plant tissue and the solvent, improving the extraction efficiency of bioactive compounds (Baldelli & Aguilera, 2025).

The cut banana peels were then immersed in 70% alcohol for 5 minutes as a sanitation step to remove any microbial contamination before the extraction process. Following the sanitation, the material was drained and then subjected to an aqueous extraction. The extraction process involved using a 1:3 ratio of banana peel to water, followed by heating the mixture at 75–82°C for 1.5 hours to facilitate the transfer of soluble bioactive compounds into the aqueous phase. The heat treatment ensured that the bioactive compounds were effectively extracted while also allowing for a greater yield of polyphenols, flavonoids, and other beneficial compounds (Haryanto, 2016)

After the extraction process, the liquid extract was filtered using a fine cloth to separate any solid residues from the liquid. This filtrate was then prepared for the foam-mat drying process. To create the foam, 500g of the filtered extract was mixed with 125g of egg white and 75g of dextrin. The mixture was whipped at high speed for 30 minutes to incorporate air and form a stable foam matrix. The egg white aids in forming a stable, porous foam structure, while dextrin helps to reduce stickiness and improves the stability of the final powder (Haryanto, 2016).

The foamed mixture was then dried in an oven at 65°C for 10 hours. The drying process is critical for reducing the moisture content of the extract, which is essential for the long-term stability of the powder. Once the drying process was completed, the dried material was ground into a fine powder. The final powder was stored in a sealed container to minimize moisture absorption and prevent contamination from the surrounding environment (Haryanto, 2016).

Preparation of Treatment Solutions and Egg Immersion

The prepared instant banana peel extract powder was reconstituted in water according to the treatment ratios established in the study. Five different powder-to-water ratios were used: 1:10, 1:20, 1:30, 1:40, and 1:50. These ratios were selected to determine the impact of varying concentrations of the banana peel extract powder on the preservation of egg quality during storage. The choice of these ratios was based on previous studies indicating that higher concentrations of plant extracts tend to exhibit more significant antimicrobial activity and preservation effects, although excessive concentration may negatively affect the interaction between the solution and the eggshell surface (Saraswati, 2015; Datukramat et al., 2023).

Fresh chicken eggs were immersed in the prepared banana peel powder solutions for 24 hours. After the immersion period, the eggs were removed from the solution, drained, and stored at room temperature. The eggs were then subjected to quality evaluation at different time intervals, starting from day 0 and continuing at days 7, 14, 21, and 28. The egg quality parameters Haugh Unit, albumen index, and yolk index were measured at each interval to assess the impact of the banana peel extract on the preservation of internal egg quality.

Observation of Egg Quality Parameters

Egg quality was assessed using the Haugh Unit, albumen index, and yolk index. The Haugh Unit combines the height of the albumen and the weight of the egg, providing an indicator of albumen quality and overall egg freshness. The albumen index reflects the structural integrity of the albumen, while the yolk index measures the firmness and stability of the yolk. These indicators are widely used in the egg industry to assess freshness and internal quality. The eggs were observed for physical changes, such as thinning of the albumen and changes in yolk shape, which are common signs of quality deterioration.

Data Analysis

The data obtained from the Haugh Unit, albumen index, and yolk index measurements were analyzed using statistical methods, including analysis of variance (ANOVA). The aim was to determine if the concentration of the banana peel extract powder significantly affected the preservation of egg quality. The analysis also focused on comparing the different treatments to identify the optimal concentration that maintained the best internal quality of the eggs over the storage period. The findings from this study will contribute to understanding the effectiveness of banana peel extract powder in preserving egg quality and will offer practical insights into the use of natural preservatives in food systems.

RESEARCH RESULTS

Effect of Instant Kepok Banana Peel Extract Powder on Egg Quality Haugh Unit

The Haugh Unit is one of the most widely used indicators for evaluating the internal quality of eggs. This parameter combines albumen height and egg weight to provide a measure of freshness. Higher Haugh Unit values indicate better albumen quality and fresher eggs, while lower values suggest albumen thinning and a decline in freshness. In the context of this study, the Haugh Unit

was measured in chicken eggs treated with instant kepok banana peel extract powder solution at varying powder-to-water ratios, ranging from 1:10 to 1:50. The treatment groups were designated as P1 (1:10), P2 (1:20), P3 (1:30), P4 (1:40), and P5 (1:50), and the eggs were stored at room temperature for 28 days.

The results indicated a consistent decline in Haugh Unit across all treatment groups as storage duration increased (Fig. 1). On day 0, the average Haugh Unit was 77.56, which indicated that the eggs were still relatively fresh. After seven days of storage, the average Haugh Unit decreased to 65.26, showing a noticeable decline in albumen quality. By day 14, the average Haugh Unit further declined to 61.04, and by day 21, the Haugh Unit decreased substantially to 35.39, indicating marked deterioration in internal quality. This pattern supports previous studies that have found a decrease in Haugh Unit over time, which is associated with the loss of carbon dioxide through the eggshell, an increase in albumen pH, and structural weakening of the ovomucin–lysozyme complex (Lestari et al., 2013; Isnaini et al., 2023).

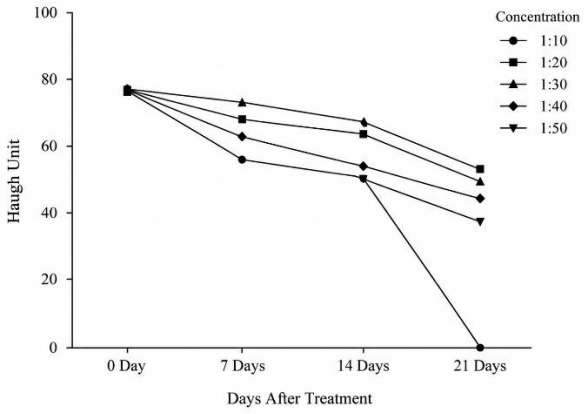

Figure. 1. Haugh Unit After Store at Room Temperature

Interestingly, the study found that while all treatments showed a decrease in Haugh Unit over time, the differences between treatment groups (i.e., different concentrations of banana peel extract powder) were not statistically significant. This finding suggests that the varying concentrations of the banana peel extract powder (from 1:10 to 1:50) did not produce a distinct impact on the relationship between albumen height and egg weight during the observation period. However, the data suggests that a 1:20 concentration of banana peel extract powder offered the most favorable results, as this treatment was able to maintain acceptable egg quality up to 14 days of storage. This supports the notion that a moderate concentration of banana peel extract is most effective in preserving egg quality, whereas higher concentrations may increase solution viscosity, reduce the uniformity of coating, or hinder effective interaction between bioactive compounds and the eggshell surface.

The decline in Haugh Unit observed in this study aligns with the known physiological and physicochemical mechanisms of egg deterioration. As eggs age, the loss of carbon dioxide through the eggshell increases the pH of the albumen, which causes albumen thinning and a decrease in its viscosity. Banana

peel extract powder, containing tannins, flavonoids, and phenolic compounds, is believed to contribute to antimicrobial and barrier effects. These bioactive compounds may help form a protective layer on the eggshell, reducing pore permeability and slowing the deterioration process by preventing gas exchange and moisture evaporation (Singh et al., 2016; Zou et al., 2022; Ashka et al., 2023). However, the present study suggests that while banana peel extract powder can delay the degradation process, it may not fully prevent the deterioration of albumen quality, especially over longer storage periods.

Albumen Index

The albumen index is a critical measure of the structural integrity of the egg white. It is calculated by comparing the height of the thick albumen to its average diameter, and it reflects the ability of the albumen to maintain its structure after the egg is broken. A higher albumen index indicates that the albumen remains thick and compact, while a lower value suggests that the albumen has become watery and spread out. The albumen index is particularly sensitive to the breakdown of the albumen gel structure, which occurs when carbon dioxide is lost and albumen pH increases.

In this study, the albumen index decreased progressively during storage. At the beginning of the observation period, the average albumen index was 0.13, indicating that the albumen retained its structural integrity. After seven days of storage, the albumen index decreased to 0.08, and by day 14, it dropped further to 0.05. On day 21, the albumen index reached 0.02, indicating significant thinning of the albumen (Fig. 2). This pattern is consistent with previous studies, which have found that albumen thinning is one of the first signs of internal egg quality deterioration during storage (Lestari et al., 2013; Isnaini et al., 2023).

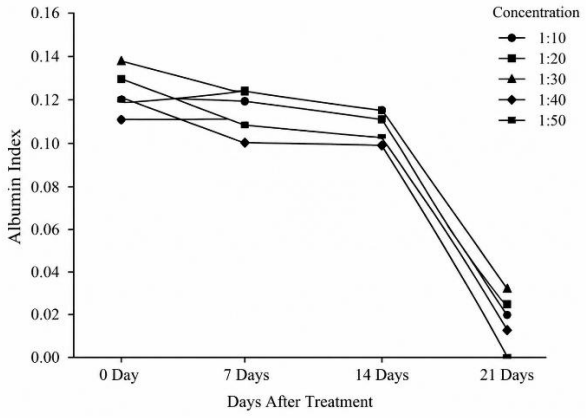

Figure. 2. Albumin Index After Store at Room Temperature

The decrease in albumen index can be attributed to the breakdown of the albumen gel structure and the weakening of the ovomucin network. As albumen alkalinity increases, its stability decreases, and the thick albumen becomes less viscous, resulting in a lower albumen index. The study found that although the treatment with instant banana peel extract powder delayed the thinning of the albumen, it did not completely prevent it. This suggests that while banana peel

extract powder may offer some preservation benefits, the inherent biochemical changes in the albumen due to storage conditions are difficult to fully mitigate.

Statistical analysis indicated that differences among the treatment ratios were not significant for albumen index, meaning that varying concentrations of banana peel extract powder did not produce a measurable difference in maintaining albumen structure. However, the 1:20 ratio was identified as the most favorable treatment, as it provided the best balance between effectiveness and ease of application. A solution that is too dilute may not contain enough bioactive compounds to preserve the egg quality, while a solution that is too concentrated may reduce the uniformity of coating and hinder effective preservation.

Yolk Index

The yolk index is another important parameter for evaluating egg quality. It measures the relationship between the yolk height and yolk diameter, and a higher yolk index indicates that the yolk remains firm, rounded, and structurally stable. In contrast, a lower yolk index suggests that the yolk has become flatter, indicating a weakening of the vitelline membrane. This phenomenon is often linked to water migration from the albumen to the yolk during storage, a process that leads to yolk enlargement and membrane degradation. The yolk index is a key indicator of internal quality deterioration, as a decline in yolk index reflects the structural weakening of the yolk.

In this study, a clear decline in yolk index was observed over the storage period. On day 0, the average yolk index was 0.44, indicating that the yolk was still relatively firm and fresh. After seven days of storage, the yolk index decreased to 0.33, followed by a further decrease to 0.27 on day 14. By day 21, the average yolk index dropped to 0.14, indicating significant weakening of the yolk structure (Fig. 3). These results are consistent with previous studies, which have shown that the migration of water from the albumen to the yolk is a primary factor contributing to yolk deterioration during storage (Lestari et al., 2013).

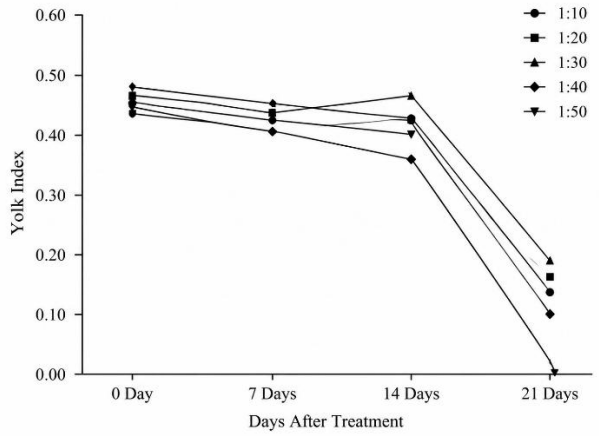

Figure. 3. Yolk Index After Store at Room Temperature

Despite the application of instant kepok banana peel extract powder, the study found that the decline in yolk index was similar to that observed in untreated eggs. This suggests that the banana peel extract powder, while effective

in preserving other aspects of egg quality, did not fully prevent yolk deterioration. The decline in yolk index in treated eggs may be attributed to the inability of the extract powder to completely halt the migration of water from the albumen to the yolk during room-temperature storage. This aligns with the findings of Datukramat et al. (2023) and Isnaini et al. (2023), who noted that while natural extracts can slow down the deterioration of egg quality, they may not entirely prevent the natural biochemical changes that occur over time.

Similar to the Haugh Unit and albumen index, there was no significant difference in yolk index between the treatment ratios. However, the descriptive data suggests that the 1:20 ratio provided the best balance between concentration and effectiveness. The 1:20 treatment was able to maintain yolk quality for up to 14 days, whereas the 1:10 treatment showed signs of spoilage by day 21. This finding supports the notion that higher concentrations of banana peel extract do not necessarily provide superior preservation. Instead, an optimal concentration may be required to ensure the effectiveness of the preservative without causing unintended side effects such as excessive viscosity or poor coating distribution.

Overall Effects on Eggshell

The overall effect of the banana peel extract powder on the eggshell is closely related to its ability to form a protective barrier that reduces moisture and gas exchange through the shell. As the banana peel extract contains bioactive compounds such as tannins and flavonoids, it is expected to act as a barrier on the eggshell surface, reducing permeability and preventing the loss of moisture and carbon dioxide. However, the present study suggests that while the banana peel extract powder had some beneficial effects on preserving the internal quality of the egg, it did not fully prevent the natural deterioration processes associated with egg aging.

The application of banana peel extract powder, particularly at the 1:20 ratio, showed promising results in extending the shelf life of eggs for up to 14 days, but the effects were limited over longer periods. This suggests that while the powder form of banana peel extract can provide a useful short-term preservation strategy, further optimization of the formulation, concentration, and application methods is necessary to improve long-term preservation. The findings of this study provide valuable insights into the use of banana peel extract powder as a natural preservative and contribute to the growing body of research on the valorization of agricultural waste for food preservation purposes.

DISCUSSION

Effect of Storage Duration on Internal Egg Quality

The findings from this study clearly demonstrate that storage duration is the most significant factor influencing the internal quality of eggs treated with instant kepok banana peel extract powder solution. As storage time increased, there was a consistent decline in the Haugh Unit, albumen index, and yolk index. By day 21, the average Haugh Unit had dropped substantially from an initial 77.56 to 35.39, indicating a marked deterioration in internal quality. The decline in Haugh Unit is a well-established indicator of egg freshness, as it reflects thinning of the albumen and the loss of viscosity due to changes in the protein

structure, particularly the weakening of the ovomucin-lysozyme complex (Lestari et al., 2013). This progressive decline supports the known physiological mechanisms of egg deterioration, where carbon dioxide escapes through the eggshell pores, causing an increase in pH and weakening the albumen structure. The present study confirms that the natural preservative treatment, while effective in extending the shelf life to a limited extent, cannot fully prevent the natural biochemical changes associated with egg aging.

Isnaini et al. (2023) similarly reported that, despite using natural extracts, ambient storage conditions remain a dominant factor influencing the rate of egg quality deterioration. The reduction in internal quality parameters like the Haugh Unit is consistent with previous studies on egg storage, where the loss of carbon dioxide and increased alkalinity lead to structural weakening and thinning of the albumen. The results of this study suggest that banana peel extract powder may slow down the deterioration process but not entirely halt it, indicating that this treatment should be considered as a shelf-life extension strategy rather than a complete preservation solution.

Haugh Unit Response to Instant Kepok Banana Peel Extract Powder Solution

The Haugh Unit results indicate that while all treated eggs experienced a decline in internal quality, the decline became most pronounced after 14 days of storage. On day 0, the eggs maintained an average Haugh Unit of 77.56, which is within the acceptable range for fresh eggs. However, by day 7, the Haugh Unit had already decreased to 65.26, and by day 14, it dropped further to 61.04. The most significant drop occurred by day 21, where the average Haugh Unit was reduced to 35.39. These results suggest that the preservation capacity of instant kepok banana peel extract powder solution is most effective within the first 14 days of storage, after which the preservation effect diminishes significantly.

This trend aligns with previous findings on the effectiveness of plant-based preservatives, which have been shown to slow down, but not prevent, the deterioration of egg quality over extended storage periods (Pires et al., 2019). The absence of statistically significant differences among the different concentrations of banana peel powder (ranging from 1:10 to 1:50) suggests that increasing the concentration of the extract did not result in a proportional improvement in preservation. This is an important finding, as it highlights that natural preservatives do not always operate linearly, and other factors such as solubility, viscosity, and the ability to form a uniform layer on the eggshell surface must also be considered in their effectiveness (Bhalerao & Narkhede, 2025).

The ideal treatment ratio in this study was found to be 1:20, which maintained better egg quality compared to other concentrations, providing a balance between preserving bioactive compounds and ensuring effective interaction with the eggshell. This observation supports earlier studies by Datukramat et al. (2023) and others, who suggested that a moderate concentration of natural preservative is more effective than a highly concentrated solution. High concentrations may increase solution viscosity, making it difficult to achieve a uniform coating, which in turn limits the interaction between the preservative and the eggshell surface.

Albumen Index and Albumen Deterioration

The albumen index is another key indicator of egg freshness, reflecting the structural integrity of the albumen. This study showed a consistent decrease in albumen index over time, with values dropping from 0.13 on day 0 to 0.02 on day 21. This progressive decline is indicative of albumen thinning and the weakening of the albumen's protein structure, which is commonly observed during egg storage at room temperature. The breakdown of albumen structure is largely attributed to the loss of carbon dioxide, which causes the albumen pH to increase, leading to a weakening of the ovomucin network and a reduction in albumen viscosity (Isnaini et al., 2023).

The present study found that even with the application of banana peel extract powder, albumen deterioration continued throughout the storage period. This suggests that while the preservative may slow the degradation process, it cannot completely prevent the physiological changes that occur during storage. The continued decrease in albumen index supports the conclusion that natural preservatives can delay, but not fully prevent, the degradation of internal egg quality when stored at ambient temperatures (Lestari et al., 2013).

The presence of tannins, flavonoids, and phenolic compounds in banana peel extract is believed to contribute to the preservation of egg quality by reducing microbial activity and forming a protective layer on the eggshell surface (Singh et al., 2016; Zou et al., 2022). However, the results indicate that the protective effect of banana peel extract powder on the albumen index was not strong enough to fully prevent albumen thinning over the longer storage period. The albumen thinning observed in this study is consistent with the findings of previous research, which identified the weakening of the ovomucin network as one of the first signs of internal quality deterioration in eggs (Isnaini et al., 2023).

Yolk Index and Vitelline Membrane Stability

The yolk index is an essential parameter for assessing yolk stability. A higher yolk index indicates a firm, well-structured yolk, while a lower yolk index suggests a flattened yolk and weakened vitelline membrane. This study observed a clear decline in yolk index, from 0.44 on day 0 to 0.14 on day 21, reflecting significant weakening of the yolk membrane and enlargement of the yolk. The decline in yolk index is primarily attributed to water migration from the albumen to the yolk during storage, which causes yolk enlargement and membrane degradation (Lestari et al., 2013; Okonkwo et al., 2021).

While the banana peel extract powder treatment delayed the decline in yolk index, it did not prevent it altogether. The findings suggest that the treatment was effective in slowing the deterioration of the yolk membrane, but its impact was limited, particularly beyond 14 days of storage. This result is consistent with earlier studies that showed the role of natural preservatives in delaying, but not halting, the deterioration of egg quality (Isnaini et al., 2023). The decline in yolk index observed in this study further supports the idea that banana peel extract powder can serve as a preservation tool, but its effects are constrained by the natural biochemical changes that occur during storage.

The absence of statistically significant differences in yolk index across the various treatment concentrations further underscores the idea that excessive concentration does not necessarily lead to improved preservation. The most effective treatment, as indicated by the yolk index, was the 1:20 ratio, which maintained yolk structure more effectively than higher concentrations. This finding is in line with the overall conclusion that the optimal concentration of banana peel extract powder lies in moderate amounts, which offer a balance between bioactive compound availability and functional application.

Overall Effects on Eggshell and Preservation Mechanisms

In terms of overall preservation effects, banana peel extract powder demonstrates potential for extending the shelf life of chicken eggs under room-temperature storage conditions. The bioactive compounds present in banana peel, particularly tannins and phenolics, likely contribute to a reduction in microbial activity and the formation of a protective layer on the eggshell. This layer helps to limit gas exchange and moisture evaporation, which are key factors in egg deterioration. However, the results suggest that the protective effect of banana peel extract powder is limited, as eggs treated with the powder still experienced significant quality deterioration after 14 to 21 days of storage. However, soaking with this powder can extend the shelf life of eggs at room temperature. Martinez et al. (2021) stated that eggs suitable for human consumption can be stored for a maximum of 9 days at room temperature.

The foam-mat drying technique used to create the banana peel extract powder was essential for ensuring the stability of the bioactive compounds during storage. Foam-mat drying has been shown to preserve the physical properties and reconstitution characteristics of plant-based powders (Tai et al., 2024; Ng & Sulaiman, 2018). However, the study also highlights that the preservation effectiveness of banana peel extract powder is not solely determined by the concentration of the powder but also by factors such as solubility, viscosity, and the uniformity of the solution's interaction with the eggshell.

In conclusion, while the instant kepok banana peel extract powder solution was able to preserve egg quality for up to 14 days, it was not effective enough to fully prevent deterioration during longer storage periods. The 1:20 ratio of banana peel extract powder to water emerged as the most practical and effective formulation, providing a balance between bioactive compound concentration and physical application. Further studies are needed to optimize the formulation and explore additional preservation methods to improve the long-term storage potential of eggs using natural preservatives.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that instant kepok banana peel extract powder has potential as a natural preservative for chicken eggs stored at room temperature. The main findings show that egg internal quality declined progressively during storage, as indicated by decreases in Haugh Unit, albumen index, and yolk index. The Haugh Unit decreased from 77.56 on day 0 to 35.39 on day 21, while the albumen index declined from 0.13 to 0.02 and the yolk index decreased from 0.44 to 0.14. These results confirm that storage duration remained the dominant factor affecting egg quality. However, the application of instant

kepok banana peel extract powder solution contributed to maintaining acceptable quality for up to 14 days.

Among the tested powder-to-water ratios, the 1:20 formulation was identified as the most appropriate treatment because it provided a practical balance between concentration and preservation performance. The more concentrated 1:10 formulation did not produce superior quality retention and showed spoilage by day 21, indicating that increasing preservative concentration does not necessarily improve effectiveness. This study contributes to the existing body of knowledge by integrating banana peel waste valorization, foam-mat drying technology, and egg preservation into a practical natural preservative formulation. The findings support the use of agricultural by-products as value-added food preservation materials. Future studies should examine microbial quality, shell pore structure, total phenolic content, antioxidant activity, and broader storage conditions to clarify the preservation mechanisms and optimize formulation performance.

REFERENCES

Agriculture Institute. (2025, May 22). *Effective egg preservation techniques to extend shelf life*. https://agriculture.institute/poultry-products-technology

Ashka, F., Dubey, P. K., & Kumar, S. (2023). Banana peels as bioactive ingredients: A systematic review of nutritional and pharmacological attributes. *Journal of Food Chemistry & Nanotechnology, 9*(S1), S577–S587. https://doi.org/10.17756/jfcn.2023-s1-073

Baldelli, A., & Aguilera, J. M. (2025). Size reduction and particle size influence the quantification of phenolic-type compounds and antioxidant activity in plant food matrices. *Trends in Food Science & Technology, 162*, 105081. https://doi.org/10.1016/j.tifs.2025.105081

Datukramat, D. F., Hadju, R., Yelnetty, A., & Tamasoleng, M. (2021). Pengaruh penggunaan larutan kulit pisang goroho (*Musa acuminata* L.) terhadap sifat fisik telur ayam ras. *Zootec, 41*(1), 174–180.

Garcia, J. S., Gast, R. K., Read, Q. D., & Jones, D. R. (2026). The impact of egg handling and storage temperature on shell eggs stored for 27 weeks: Egg quality. *Poultry Science, 105*(2), 106264.

Haryanto, B. (2016). Pengaruh konsentrasi putih telur terhadap sifat fisik, kadar antosianin, dan aktivitas antioksidan bubuk instan kulit manggis (*Garcinia mangostana* L.) dengan metode *foam mat drying*. *Jurnal Kesehatan, 7*(1), 1–8. https://doi.org/10.26630/jk.v7i1.112

Isnaini, F. H., Andriani, V., & Sopandi, T. (2023). Internal quality and functional properties of kampung chicken eggs immersed with water extract of red kidang banana peel (*Musa acuminata* Red Dacca). *Seminar Nasional Hasil Riset dan Pengabdian: Inovasi Sains, Pendidikan, dan Bioteknologi untuk Pengembangan Masyarakat: Tantangan dan Peluang dalam Penelitian dan Pengabdian*.

Khamjae, T., & Rojanakorn, T. (2018). Foam-mat drying of passion fruit aril. *International Food Research Journal, 25*(1), 204–212. http://www.ifrj.upm.edu.my/25%20(01)%202018/(26).pdf

Khira, S. M. (2019). *Foam mat drying of banana pulp for preparation of banana powder* [Master's thesis, Junagadh Agricultural University]. Krishikosh.

Lestari, S., Malaka, R., & Garantjang, S. (2013). Pengaruh level ekstrak daun melinjo (*Gnetum gnemon* Linn.) dan lama penyimpanan yang berbeda terhadap kualitas telur. *Jurnal Sains & Teknologi, 13*(2), 184–189.

Martínez, Y., Diaz Soliz, N., Bejarano, M. A., Paz, P., & Valdivie, M. (2021). Effect of storage duration and temperature on daily changes in external and internal egg quality of eggs from Dekalb White® laying hens. *European Poultry Science, 85*, 1–14. https://doi.org/10.1399/eps.2021.329

Mishra, N., & Singh, S. (2026). Nutritional and bioactive potential of banana peel: A sustainable functional food resource. *Food Science Journal, 11*(1), 170–177.

Ng, M. L., & Sulaiman, R. (2018). Development of beetroot (*Beta vulgaris*) powder using foam mat drying. *LWT, 88*, 80–86. https://doi.org/10.1016/j.lwt.2017.08.032

Okonkwo, J. C., Offiaukwu, C., Okonkwo, I. F., & Marire, B. N. (2021). Effect of storage method and storage duration on chicken egg quality. *International Journal of Environmental & Agriculture Research, 7*(8), 13–16. https://doi.org/10.5281/zenodo.5335999

Rahmi, A., Hardi, N., & Hevira, L. (2021). Aktivitas antioksidan ekstrak kulit pisang kepok, pisang mas, dan pisang nangka menggunakan metode DPPH. *Jurnal Ilmu Farmasi dan Farmasi Klinik, 18*(2), 77–84.

Singh, B., Singh, J. P., Kaur, A., & Singh, N. (2016). Bioactive compounds in banana and their associated health benefits: A review. *Food Chemistry, 206*, 1–11.

Tai, N. V., Hao, H. V., Han, T. T. N., Giau, T. N., Thuy, N. M., & Thanh, N. V. (2024). Effect of foaming conditions and drying temperatures on total polyphenol content and drying rate of foam-mat dried banana powder: Modeling and optimization study. *Journal of Agriculture and Food Research, 18*, 101352. https://doi.org/10.1016/j.jafr.2024.101352

Wani, K. M., & Dhanya, M. (2025). Unlocking the potential of banana peel bioactives: Extraction methods, benefits, and industrial applications. *Discover Food, 5*, 8. https://doi.org/10.1007/s44187-025-00276-y

Zou, F., Tan, C., Zhang, B., Wu, W., & Shang, N. (2022). The valorization of banana by-products: Nutritional composition, bioactivities, applications, and future development. *Foods, 11*(20), 3170. https://doi.org/10.3390/foods11203170