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Analysis Of the Ripping Rate of Banana Fruit Coated with Biofilm Based on Polyvinyl Alcohol Chitosan Composite

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ABSTRACT

The Banana (Musa spp) was a fruit whose rate of ripening increased after harvest. The respiration rate was an indicator of the fruit's shelf life. This cause banana to have a short shelf life and become easily damaged, necessitating the technology to reduce the ripening rate of fruit, such as coating it with biofilm. This research seeks to establish the optimal ethylene concentration on the composite chitosan PVA produced by evaporation of a colloidal chitosan solution with CNC. The produced solution was then applied to the surface of the banana using the immersion method, and seven-day changes in weight loss, color change, sugar content, and ethylene gas production were detected. Post-harvest management of bananas tries to preserve the fruit's freshness and shelf life. The research is done to improve the shelf life of bananas by composite biofilm. The data result shows that from all variants, the composite biofilm contains chitosan, PVA, 10% glycerol, Citric acid, and 5% CNC, which is indicated to have the potential to increase the shelf life of banana fruit. Because they prevent respiration and the water evaporation processes in bananas, these properties allow banana fruits to stay fresh longer.

Keywords: *Biofilm, Chitosan Physical Quality, Chitosan PVA, Chemical Quality, Self Life.*

1. INTRODUCTION

The banana plant (Musa spp) is native to Southeast Asia and is a member of the Musaceae family. Indonesia is one of the world's leading banana-producing nations. India is the sixth-largest producer of bananas in the world, following India, brazil, china, Ecuador, and the Philippines [1]. As a banana-producing nation, bananas are a readily available fruit. Still, their shelf life could be better since they belong to the group of climacteric fruits, whose quality has declined at a higher rate of ripening after harvesting.

Typically, bananas are gathered when old and immature; therefore, cooking can be carried out naturally or artificially. The ripening of bananas is a genetically programmed and highly complex process that begins with color, texture, scent, and flavor changes. During the ripening process of bananas, the water content decreases due to respiration and transpiration processes, reducing banana weight [2,3]. Bananas are a fruit that can gather before they are ripe, but they can undergo a rapid ripening process after being gathered, making banana perishable with a short shelf life.

Harvested bananas will suffer an increase in respiration rate and ethylene gas production. Ethylene (C_2H_2) is an unsaturated gaseous carbon compound at room temperature [4]. Bananas are among the plants whose metabolism produces ethylene gas, which plays a part in the ripening process of fruit. The generation of ethylene gas can hasten fruit ripening, wilting, aging, and decomposition. Bananas will mature faster if their ethylene gas content is high. In addition to ethylene gas, additional variables can influence the ripening of bananas, namely the respiration rate.

After harvest, the respiration rate of the fruit is a good measure of how long it will keep. Fruits with a high respiration rate tend to spoil quickly. The respiration rate during fruit ripening is influenced by the concentration of CO_2 and O_2 gases, as stated by Fransiska et al. (2013) [5]. Bananas continue to ripen after being harvested because the fruit is continuously respiring and producing ethylene gas, drastically reducing the fruit's shelf life. In order to prevent bananas from ripening prematurely, it is necessary to use ingredients that prevent the movement of these gases. Adding a coating to fruit is one method to keep it fresh for extended periods. Common plastics made from petroleum can use to create coatings. Traditional plastics, on the other hand, pose a problem because they break down slowly in the environment. Coatings made from natural materials are one solution to this problem because they break down quickly in the environment. Coatings made from natural materials biodegrade faster than traditional plastics.

Coating, a film applied to fruit to prevent spoilage from bacteria and oxidation, is a type of coating. Coatings are advantageous because they pose no health risks to humans and break down quickly in the environment. Materials like polysaccharides, proteins, lipids, and chitosan can use to create the biofilm. Because it contains polysaccharide groups that makeup biofilms, chitosan can be an appealing material for novel food packaging. In nature, chitosan, a linear polysaccharide made from chitin polymer derivatives, is second only to cellulose in abundance [6]. Chitosan extracted from the crustacean's cell walls can use to prevent rot [7]. Biodegradability, biocompatibility, antibacterial activity, nontoxicity, and flexible chemical and physical properties all work in chitosan's favor, making it a promising material for use in various industrial contexts, especially in food packaging [8]. Mechanical qualities (concerning tensile strength values, elastic modulus, resistance to elongation at break), heat, and low water resistance are some of the shortcomings of chitosan when used alone in food packaging materials [9].

Nanoparticle technology offers packaging alternatives when preserving perishable foods like fruits and vegetables. If nano chitosan combines with metal oxide nanoparticles like SiO_2, ZNO, TiO_2, or MgO, the hydrophilic nature of chitosan alone is exacerbated. Combining those factors enhances antimicrobial, UV-protective, hydrophilic, and ferromagnetic characteristics. PVA can be used in producing SiO2 composite films.

Tian et al. (2018) conducted research that demonstrated how nanocomposites of AgO, TiO_2 and SiO_2 might extend the shelf life of rice by delaying the decay process and decreasing the oxidation of fat and protein [10]. Loquat fruit (Eriobotrya japonica Lindl), which has a limited shelf life at room temperature, can be preserved by covering it with chitosan/SiO_2 nanoparticles. The most prevalent biopolymer found in nature is cellulose. Other compounds, such as *cellulose nanocrystals* (CNC) and *cellulose nanofibers* (CNF), will be created through chemical and mechanical treatment of these substances. Meanwhile, CNC is inexpensive, eco-friendly, and has excellent mechanical and thermal qualities. CNC crystals are elongated rods, ranging in size from 1 to 100 nm in diameter and tens to hundreds of nanometers in length. As a result of the CNC structure, hydrophilic nanomaterials can make with the ability to diffuse in a matrix composed of water-soluble polymers. Polymer composites, such as chitosan and *polyvinyl alcohol* (PVA), have previously been found to benefit from adding cellulose derivatives derived from agricultural waste as reinforcement [11].

PVA is a synthetic thermoplastic with widespread application due to its decomposability and biocompatibility. PVA has excellent transparency and film-forming capabilities, is hydrophilic, and gradually dissolves in water as the temperature rises. Stability, biocompatibility, and mechanical strength can all be improved in chitosan/PVA composites compared to either component alone, as has been observed on multiple occasions [12]. As reported in a journal by Zhuang et al., the properties of PVA strongly support the synthesis of composite films with chitosan and alginate. Specifically, PVA is more flexible (higher elongation at break) and protective (higher barrier) against oxygen and odors than other types of plastic films [13]. Compared to a single PVA film, a chitosan/PVA composite film, with a weight ratio of 25:75, has superior water protection qualities and excellent antibacterial activity [14]. The numerous active hydroxyl groups along the molecular chain contribute to PVA's outstanding property by forming hydrogen bonds in the structure [15].

Previous research has shown that biofilm-based nanocomposites can be formed by combining chitosan with either CNC or another reinforcing material. For example, after harvest, bananas are coated with a biofilm-based chitosan-PVA composite to delay the ripening process and increase their shelf life. At the same time, the research being conducted involves the application of biofilm-based chitosan-PVA composite on bananas, which is expected to inhibit the release of ethylene gas so that the ripening process of the fruit takes longer. The fruit's shelf life is extended. PVA is a versatile material utilized in many applications because it is biocompatible, biodegradable (breaks down quickly in the presence of oxygen), and has a specific melting point in the water. PVA is a good film-forming, elastic, high tensile strength, and hydrophilic.

Bananas stored with a biofilm made from a PVA/chitosan composite will keep for a more extended period. Pva-chitosan composite biofilms shield fruit from gas mass transfer to the environment, bacterial contamination, and oxidation. Because of its polysaccharide group, also present in PVA chitosan-based biofilm composites, chitosan is an appealing solution as a new food packaging. Chitosan and PVA can be used to make biofilm. The goals of this research were to determine the impact of PVA chitosan composite coating on the storage life of muli bananas and to identify the characteristics of ethylene gas generation on the ripening rate of muli bananas coated and not coated with PVA chitosan composite.

2. METHODOLOGY

This research was carried out in several stages. Including the preparation of solution materials, the creation of chitosan solution, the formation of chitosan film composites, the coating of bananas, the storage of bananas, and the evaluation of the results. Figure 1 shows the diagram of the research scheme. First, assemble the *High-Speed Homogenizer* (HSH) and prepare a chitosan solution to make biofilm coating (PVA, Chitosan) useful for testing storage life, color, mass, and ethylene gas production. The research was conducted at the *Center of Excellence* (CoE) Universitas Sultan Ageng Tirtayasa's Faculty of Engineering in Cilegon.

2.1. Preparation of the Solutions

Citric acid solution (0,1 M) was prepared by dissolving 0,25 gr citric acid powder with aquadest in a 100 ml volumetric flask and then stirred at 300 rpm using a magnetic stirrer at room temperature for 15 min. At the same time, 0,8 gr of PVA powder was prepared for the ratio of Chitosan/PVA 80/20 by dissolving the PVA powder aqua dest in a 100 ml volumetric flask and then stirred at 300 rpm while heated up to 75 °C to get a clear solution.

For the Chitosan solution, we mixed 3.2 g of chitosan in a 0.1 M citric acid solution that had been prepared in a 100 ml volumetric flask, then stirred for 2 hours until homogeneous, then filtered with tissue paper to separate impurities or material that is not dissolved.

2.2. Preparation of Coating Suspensions

In a 500 ml beaker, the prepared PVA solution is gradually added and stirred with a high-speed homogenizer at a speed of 5000-10000 rpm. The filtered chitosan solution pours into the separator flask and slowly adds it to the PVA solution until the entire chitosan solution is used; the speed then increases the homogenizer is to 20,000 rpm and stirs for 1 hour. Then 10% glycerol, add and stir for another 30 minutes. Next, slowly lower the speed until the stirring stops. Then sonicate with an ultrasonicator for 30 minutes for a more homogeneous suspension.

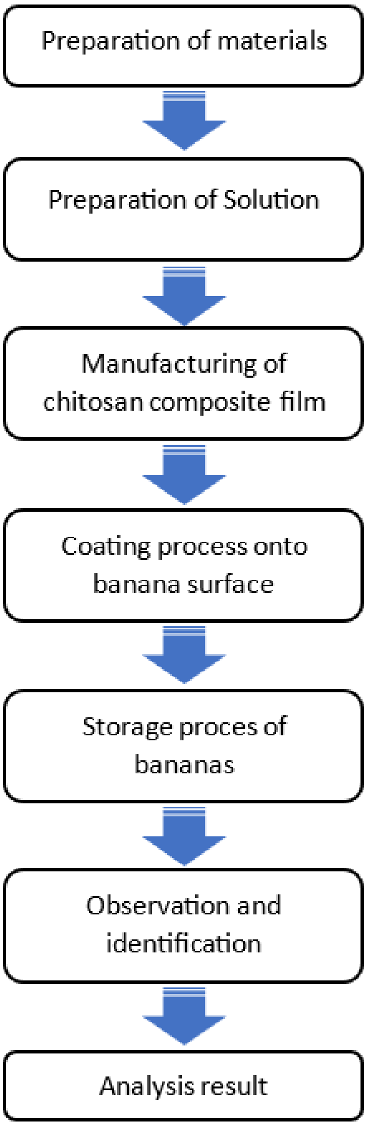


Figure 1. Diagram of research scheme.

To make nanofiller suspensions, 5% CNC nanofiller (total dry weight basis of Chitosan/PVA) is slowly added into the matrix suspension at 20,000 rpm for 30 minutes stirring. Next, 10% glycerol w/w (from the total dry mass of chitosan and PVA) is added for another hour. Next, the speed of the homogenizer slowly lowers until it stops and sonicates with an ultrasonicator for 30 minutes.

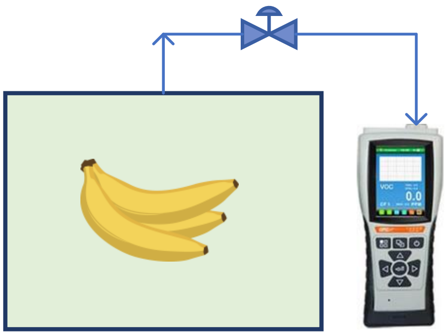
2.5. Procedure for Coating the Bananas

The various solution of composite biofilm was applied to the banana surface using the immersion method. The biofilm then allows it to dry out organically. This layer will create a thin protective layer on the banana exterior.

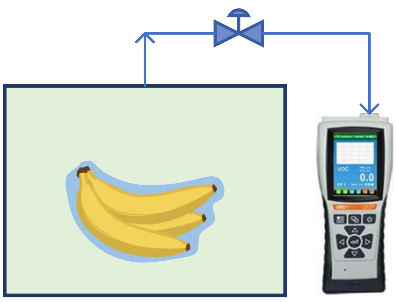
2.6. Parameter Measurement

The measurement of glucose levels is carried out by a BRIX meter, as shown in Figure 2. A few drops of the banana liquid sample at room temperature are added to measure the Brix value.

Figure 2. Measuring glucose levels in bananas using a BRIX meter.



(a)



(b)

Figure 3. The concentration of ethylene gas was measured by an ethylene gas detector for (a)non coating the banana, and (b) coating the banana.

An ethylene gas detector measures the ethylene content in bananas. The amount of ethylene gas in a sample is identified (Figure 3). An ethylene gas standard calibrates the gas detector—a digital balance scale measures mass banana loss over time. The bananas were monitored, and the time and date of each observation were recorded.

3. RESULTS AND DISCUSSION

This research aims to carry out polymer blending as a coater to improve the shelf life of bananas. So that bananas can be stored for extended periods, and their quality remains relatively high. The combination of chitosan as a bio-polymers is blended with PVA as a biodegradable synthetic polymer. The most optimum ratio of the proportion of chitosan/PVA is 80/20 [8].

Adding CNC as a filler could offer a mechanical influence on the preceding biofilm, making it more flexible. These additives have the potential to boost film strength and water resistance. Chitosan treated with CNC filler demonstrated the desirable biofilm/coating mechanical characteristics.

3.1. Visual Discoloration of Banana Skin

The color shift that happens through the fruit's skin, especially bananas, is one of the quality markers. Figure 1 depicts the addition of 10% glycerol, citric acid, and 5% CNC to the CB sample. The addition of 5% CNC plays a vital function in preventing the formation of ethylene gas during the ripening of bananas, hence preserving the green color of the peel. Due to its crystal structure, 5% CNC serves primarily as a filler. It can also be a barrier against moisture absorption and a stabilizer for the produced film molecules [8]. CNC at a concentration of 5% is used to optimize the crosslinker process since a higher concentration of CNC will generate biofilms with better mechanical qualities.

The color of bananas that have experienced a more significant discoloration is shown in bananas without coating. Bananas undergo a ripening process when their color changes from green to yellow. This ripening process occurs due to the presence of the hormone ethylene, which is indicated by a color change from green to yellow and followed until it becomes brownish yellow, which means the presence of decay, the appearance of yellow pigments from the degradation of chlorophyll in banana peels. As climacteric fruits, bananas tend to enhance the generation of ethylene gas and its respiration rate, accelerating the ripening process.

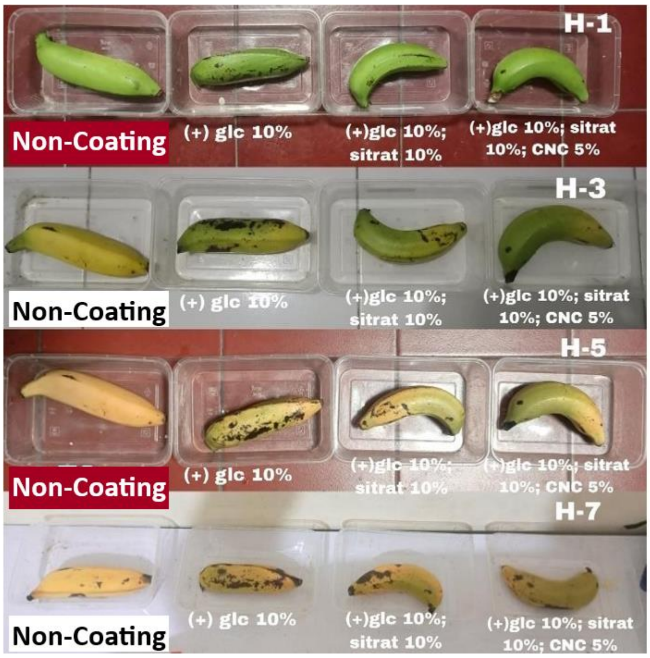


Figure 1. Visible discoloration of a banana skin.

Bananas treated to the coating technique were coated with 10% glycerol to ensure that their respiration and transpiration processes were inhibited. Adding 10% glycerol and citric acid to the PBC sample specifically prevented the yellowing of banana peels.

The addition of citric acid functions as a crosslinker, adding new properties without sacrificing those of the original complex. The citric also inhibits the bananas ripening process and the glucose generated. The citric acid also inhibits the browning or browning process of bananas.

3.2. Formation of Ethylene Gas

The generation of ethylene gas is a sign that bananas are respiration. Hence the rate of respiration in bananas may be determined by studying the formation of ethylene gas. This investigation utilized a gas detector capable of displaying the amount of ethylene gas generated.

Figure 2 depicts the formation of ethylene gas produced from bananas. Uncoated bananas produce more ethylene than coated bananas. The graphics show that sample 4 is the lowest level of bananas that produce ethylene gas. Combining citric acid and 5% CNC filler's percolation layer development achieves ethylene gas inhibition. As a result, the amount of ethylene gas produced in the fourth sample dropped significantly.

3.3. Banana Weight Loss

The banana weight loss undergoes due to respiration and transpiration —a loss of portion water in the banana resulting in a loss of mass fruit. Evaporation is the cause of lost water content [16]. A higher respiration rate will cause quicker product depreciation. Respiration is oxygen consumed to produce energy and generate CO_2 and H_2O as byproducts. Coating a banana with a biofilm is to reduce evaporation. The banana mass value is measured using a digital scale within seven days of storage to examine the loss of banana weight. The weight reduction results are shown in Figure 3.

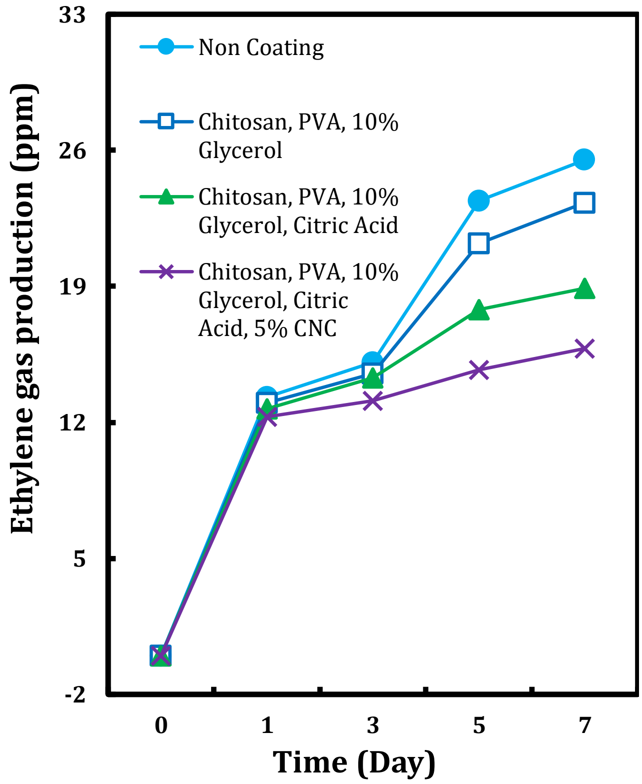


Figure 2. Effect of chitosan content on ethylene gas release.

The film coating reduces the banana's weight loss than non-coating bananas. The weight loss value of uncoated bananas is 3 %, 3,8 %, and 5,45 % on the third, fifth, and seventh days. Sample 2, with values 0,2%, 0,22%, and 0,75 % on the third, fifth, and seventh days had the smallest weight loss values, respectively. The chitosan and glycerine content can limit the water vapor transmission rate [17]. The glycerol causes the spacing between molecules to shrink, reducing the permeability of gases (O_2 and CO_2) entering the tissue.

The coating works as a semi-permeable protective barrier that slows gas interaction between the fruit and the environment lowers respiration, water loss, and oxidation reactions, and thus aids in increasing the banana's shelf life [18,19].

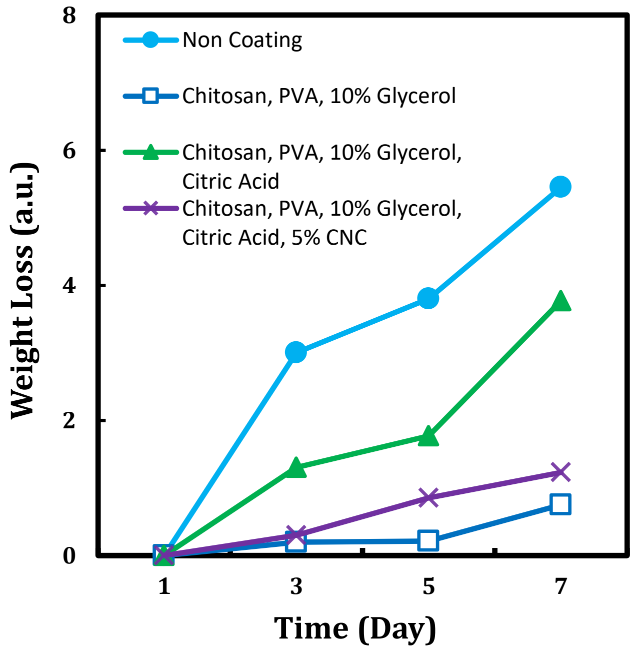


Figure 3. Effect of Chitosan-PVA Film Coating on weight Loss of Banana Fruit.

3.4. Banana Sugar level

According to Pujimulyani (2009), fruit ripening is caused by glucose increases [2]. The glucose content can be used to measure banana ripeness. The coating was added to slowest bananas ripening by observing their sugar level, as shown in Figure 4. The glucose increases through the conversion of polysaccharides to glucose during the banana ripening process [20].

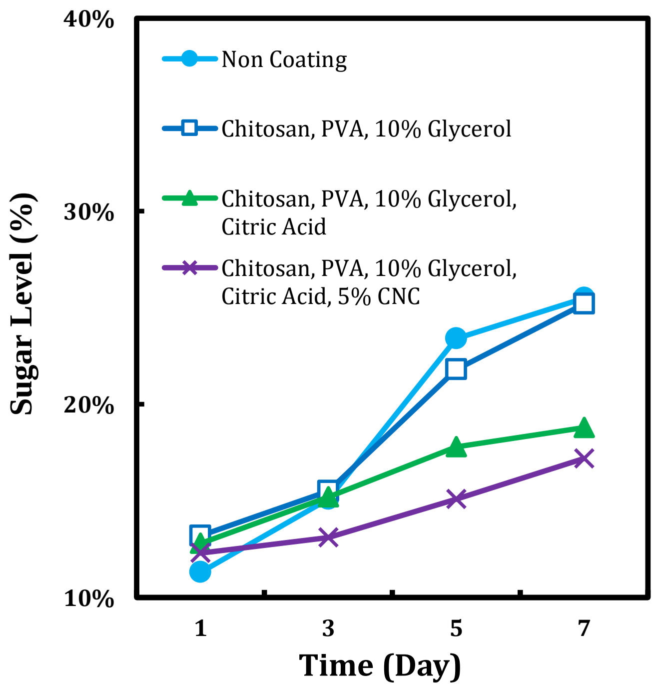


Figure 4. The bananas coating affects the increase of sugar content.

The sugar content (glucose concentration) of non-coating bananas on the third, fifth, and seventh days, is increased by 16.5%, 21.4%, and 25%, respectively. It is identical to the second sample, which is coated with Chitosan, PVA, and 10% glycerol. Sample 4 shows a significantly lowest sugar content value of 13,10%, 15,10%, and 17,20% on the third, fifth, and seventh days.

From all these samples, we can see that the addition of citric acid and CNC slowed down the phase transformation of polysaccharides into glucose because they inhibit respiration [21]. This biocomposite coating can restrict the amount of oxygen that enters the banana fruit, so impeding the reaction of glucose breakdown and slowing respiration. On the other hand, the presence of glycerol does not affect the rate of phase transformation [22].

4. CONCLUSION

Research has been conducted to increase the shelf life of bananas with a biofilm composite layer. Coating variations were compared by comparing non-coating bananas with those coated using a chitosan mixture. PVA varied with 10% glycerol, citric acid, and 5% CNC at a predetermined composition. The experimental results showed that of all the variants, biofilm composites containing chitosan, PVA, 10% glycerol, citric acid, and 5% CNC were indicated to have the potential to increase the shelf life of bananas. Because it slows down the respiration and evaporation of water in bananas, this property allows them to stay fresh longer.

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