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Ecogel incorporated with nano-additives to increase shelf-life of fresh-cut mango

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Abstract

Fresh-cut mango is a very popular product commonly consumed due to its health and safety benefits to the community. The fruit cutting results in increased respiration, ethylene production, oxidation, and browning processes which tends to shorten its life. Edible coating of aloe gel (ecogel) serves as an additive matrix to extend the life of fresh-cut mango with the incorporation of antioxidant, acidulant, and antimicrobial additives. The edible coating ability is strongly influenced by molecular structure, size and chemical constituents. This study aimed to determine the influence of nano-additive material and its concentration in ecogel to extend the shelf life of the mango. The factorial complete randomized design was used to determine the effect of citric, and ascorbic acid and potassium sorbate using a concentration of 0.15, 0.3, and 0.45 %. Citric acid, ascorbic acid and potassium sorbate at a concentration of 0.15 %, was best for formulation of ecogel. The quality of fresh-cut fruit coated with ecogel and stored at a temperature of 7 ± 1 °C until 6 day was acceptable. Therefore, ecogel prolongs the shelf-life of fresh-cut mango.

Key words: Edible coating, *Aloe vera* gel, self-life, mango

Introduction

The consumption rate of fruits, particularly mangoes across the world has increased due to consumer awareness, health benefits, storage technology, transportation, and marketing systems. Mango fruits contain bio-active components such as phenolics, carotenoids, organic acids, vitamins, and fibres that are beneficial to health. Besides being tasty, it also serves as a functional food that facilitates digestion, reduces obesity, and boosts immunity. It also functions as an antioxidant, anticancer, anti-inflammatory and antimicrobial (James and Ngarmsak, 2010).

Mango fruit is a commodity which tends to rot easily. The physiological damage of the edible parts often determines the preference of consumers, however, the inedible portions are approximately between 22-29 %, and it is usually a household waste (Utama *et al.*, 2016). This leads to an increase in the sale of edible parts with minimal processessing referred as fresh-cut. These food stuffs are fresh-like and require a minimal time of preparation before consumption and should be healthy, safe and nutritious (Galgano *et al.*, 2015).

Some of the advantages include a variety of options in one package, providing the necessary fresh materials, facilitating the quality of products, reducing the volume and cost of transportation. However, fresh-cut products are easily damaged (perishable) and the shelf life is shorter than the whole fruit (Alikhani, 2014). The minimal process results in the decay of tissues thereby subjecting the material to physiological, pathological, and physical damages such as increased tissue respiration, production of ethylene and unexpected metabolites, degradation of sensory components *viz*., color, smell and flavor, decreased fruit integrity, and microbial growth (Souza *et al.*, 2004; Galgano *et al.*, 2014). The suitable storage temperature and the use of edible coating are some of the ways to preserve fresh-cut products till it is purchased by the consumers (Siddiqui *et al.*, 2011).

The edible coating is an environment friendly and biodegradable food packaging, which consists of a thin edible layer (Rahman *et al.*, 2017). It also serves as carrier of additives, chemical, physical, biological change, and weight loss barriers (Sánchez-Machado *et al.*, 2017). Furthermore, the applications also tend to improve its appearance, retain moisture, prevent weight loss, and also serves as an antimicrobial substance (Dhall, 2013). The primary advantage of using edible coating is that some of the active ingredients tend to be incorporated into the polymer matrix and consumed with food, thereby maintaining its nutrition and sensory attributes.

Some natural ingredients such as aloe gel are used as preservatives because it consists of a polysaccharide containing functional components (Ergun and Satici, 2012; Suriati, 2020). According to Rahman *et al.* (2017), it also contains over 75 chemical compounds. The advantages of using aloe gel as an edible coating are due to its biodegradability, oxygen permeabilization, antioxidant power, low toxicity effects, inexpensiveness, and easy to apply (Sánchez-Machado *et al.*, 2017). In addition, it is also limited to instability, easy to dilute, oxidized, discolored, and increased enzymatic activities. The viscosity decreased dramatically when stored at room temperature for approximately 24-36 hours (Suriati, 2018). The consistency and stability of aloe gel are maintained with the addition of additives like citric acid, ascorbic acid, potassium sorbate, and calcium chloride (Siddiqui *et al.*, 2011). Antioxidants, citrate and ascorbic acid are incorporated into the edible coating in order to control oxygen permeability and a decline in vitamin C during storage (Ayranci and Tunc, 2004). Antimicrobial substance such as sorbate acid is also used to avoid microbes in fresh-cut products.

The ability of an edible coating to serve as an additive matrix is strongly influenced by its molecular structure, size, and chemical constituents. Also, the small particle size (nano) generates a larger surface area, thereby increasing the solubility, absorption of active compounds (Sekhon, 2010). Nowadays, the nano food technology has gained considerable attention. An example of its application is the nano-additives used on a wide range of products as edible food coating packaging (Hewet, 2013). The type and concentration of nano-additives in edible coatings need to be examined because they tend to extend the shelf life of fresh-cut mango fruit. According to Zambrano-Zaragoza *et al.* (2018), the application of nanotechnology in food products significantly contributes to the delivery of bio-active compounds, protects antioxidants, increase the bio-availability of active ingredients, prevents chemical reactions and extends shelf life. Utama *et al.* (2011) reported that temperature contributes to some postharvest lossess in mango fruit. Therefore, the monitoring upstream and downstream temperature is crucial to minimize the effects of mechanical injuries, enzyme activity, and metabolic rate of the shelf life of fresh-cut products (Garcia and Barrett, 2002). In accordance with this fact, it is necessary to conduct research on the formulation and application of ecogel with various additives and storage temperature as the treatment. This research, therefore, aims to determine the type and concentration of nano-additives that produce the best formulation of ecogel and characterize fresh-cut mango fruit, coated with ecogel at a storage temperature of 7±1 °C.

Materials and methods

This research was conducted at the Food Analysis Laboratory of Warmadewa University and the Laboratory, Bioindustries of Udayana University from February to October 2019. The tools used are digital pH meter, refractometer, spectral colorimeter CS-280, chiller, viscometer NDJ8S, oven, Probe sonicator Q125 misonic USA and Texture analyser. *Aloe vera* plant obtained from the village of Taro Gianyar Bali, and was preserved with an edible coating obtained from Panji Buleleng. Additive substances such as citric acid, ascorbic acid, potassium sorbate, and analytical materials were acquired from Denpasar.

Formulations of edible coating of aloe gel (ecogel) with nano-additive: The complete randomized design with two factors was employed. Factor I was type of nano-additives *viz*., citric acid, ascorbic acid, potassium sorbate, and its mixture, while factor II was the additive concentration of 0.15 0.30 and 0.45 %. Ecogel was produced by sorting the aloe vera leaves, and washed with water to remove the yellow mucus, and stripped using a stainless steel knife (Suriati, 2018). Furthermore, continuous treatment was carried out by the process of homogenization, which lasted for 5 minutes. Also, 1 % of glycerol was added to the aloe gel extract as an emulsifier with additives, citric acid, ascorbic acid, potassium sorbate, and a mixture of the three added to stabilize the ecogel. The additives with concentrations of 0.15, 0.30, and 0.45 % (W/V) were added during warming up at 70±1 °C for 5 min. The ecogel was cooled at room temperature for 1 hour, while the nanoparticle size was produced using the probe sonicator, which lasted for 30 minutes. The ecogel was stored at a cold temperature (7±1°C) for 15 days. The variables observed in this study were colour, transparency (Dadali *et al.*, 2007), pH (AOAC, 2019), and viscosity. The data obtained in this research was further tested with ANOVA.

Application of ecogel on mango fruit: The fresh-cut mango was dried for 20 minutes with the best formula of ecogel applied for 1 min. The products were packed in plastic boxes, stored at a temperature of 7±1°C, and observed periodically for 15 days. The variables were weight, shrinkage, colour L*a*b* (Dadali *et al.*, 2007), texture, water content, vitamin C, total acid, and soluble solids (AOAC, 2019).

Results and discussion

Colour difference (ΔE) of ecogel: The parameter used to assess the change in the color of ecogel before and after the addition of nano-additive is ΔE. Based on observation, the value of ΔE in all types of treatment and concentrations of nano-additives non significantly increased till day 10. A significant colour difference occurred on the 15th day of storage, although this was not observed in the additive mix treatment. However, a mixture of the three nano-additives was able to maintain the colour indicated by the ΔE value. Ecogel with low ΔE produced a visual appearance of the coated product, which tends to be slightly different from the original product. A smaller ΔE implies that it approached the base color with an increased concentration of nano-additives. This is in accordance with the research conducted by Saberi *et al.* (2016) which stated that the concentration of additives in edible coating peanut starch tends to increase ΔE. The average value of ΔE on the various types of treatments during storage and the concentration of nano-additives is shown in Fig. 1.

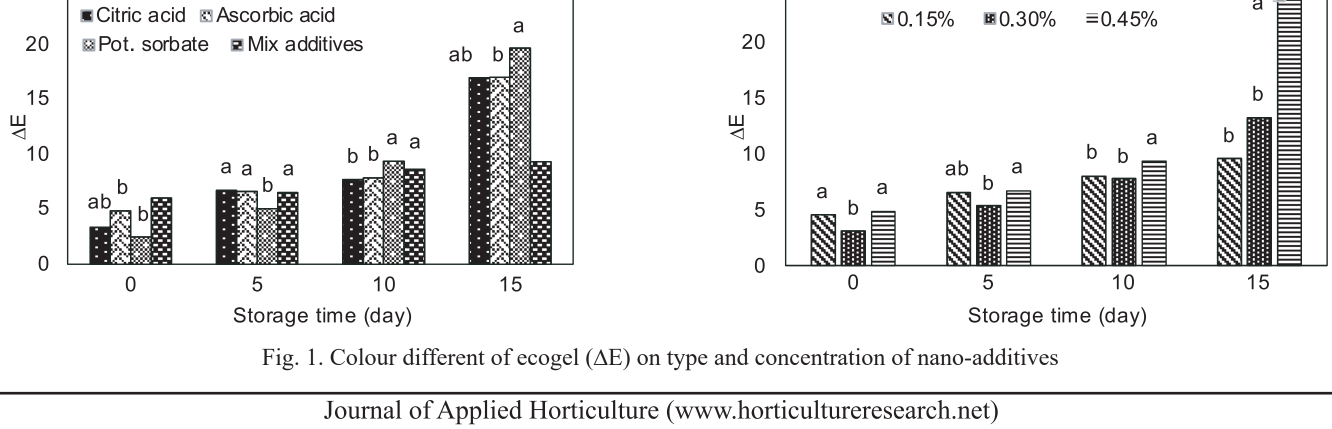

Fig. 1. Colour different of ecogel (ΔE) on type and concentration of nano-additives

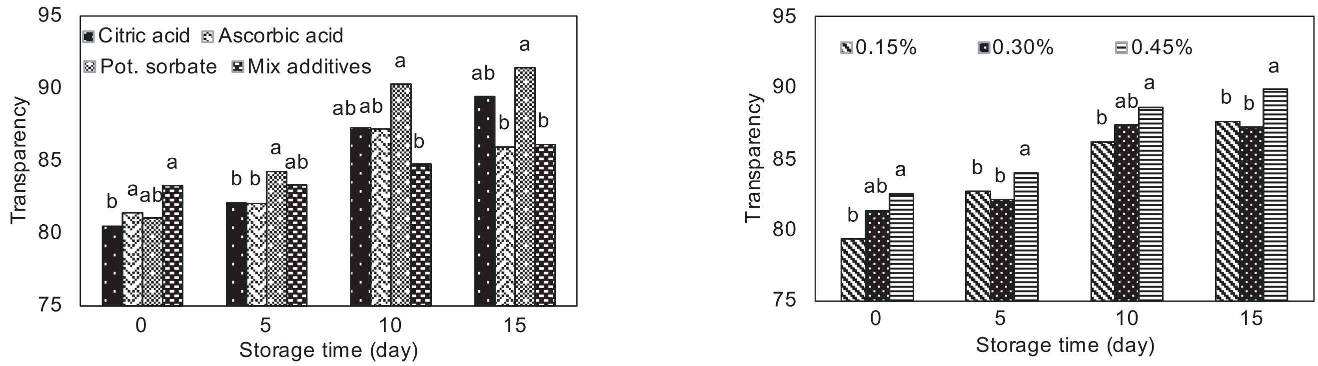

Fig. 2. Effect of type and concentration of nano-additive on ecogel transparency

Transparency of ecogel: The results from the research based on the type of treatment and concentration of additives during storage showed increased ecogel transparency. This seems to be because of an increase in nano-additives, likely to produce various colour changes with a rise in bonding mobility. Al-Hasan and Norziah (2012) reported that the degree of transparency of an edible film usually increased with the addition of sorbitol. The addition of additives under high humidity causes the polymer tissues to expand and decreases inter molecular forces, thereby, increasing the transparency value. The transparency of ecogel during storage is shown in Fig. 2 with an increase in the mixture of the additives and relative stability transparency till day 15 as compared to the others. The combination of the three additives produced a transparent clear white ecogel display. The concentration of the nano-additive produced the lowest transparency value at 0.15 %, and this produced the most translucent ecogel display without changing the appearance of the coated product. The edible coating was colourless and transparent as also reported by Galgano *et al.* (2015).

The viscosity of ecogel: Increased concentration of filler material in a solution increased the viscosity (Fig. 3). This is in accordance with previous research (Saberi *et al.*, 2016). Viscosity is the resistance to the flow of liquids, and the ratio of shear stress to shear rate. It occurs when there is an increase in the bonding structures of the gel and water cells. The mixture of nano-additives, namely citric acid, ascorbic acid, and potassium sorbate was able to synergize and strengthen the cohesion of ecogel polymer bonding and also lead to stable viscosity during storage. Therefore, the consistency and stability of aloe gel are maintained with the addition of additives (Mikkonen and Tenkanen, 2012; Suriati, 2018). The nano-additives of concentration 0.15 % also produced the lowest and relatively stable viscosity value. The migration of nano-additive into the bonds of acetyl Glucomannan of aloe gel increases the molecular weight of ecogel. Therefore, the greater the molecular weight, the slower the flow rate of the solution, and this increases the value of viscosity. The enzyme that acts on the aloe gel also has an effect on the bonds of compounds and viscosity of the gel (Sánchez-Machado *et al.*, 2017).

The stabilization process was properly conducted by warming of the preservatives, and other additives such as potassium sorbate, citric acid, and ascorbic acid as suggested by Suriati (2019). The addition of these acids tends to reduce the activity of polyphenols oxidase and potassium sorbate, which acts as an antimicrobial substance. According to Maughan (1984), the stabilization of aloe gel was conducted by the addition of 0.05-0.5 % ascorbic acid and 0.01-0.5 % citric acid.

pH of ecogel: The addition of potassium sorbate to ecogel produced the highest pH 4.29-4.54 during storage, while the addition of citric acid produced the least pH value of 3.02-4.26. The average pH value of ecogel is shown in Fig. 4. Ecogel functions effectively, assuming it has a pH similar to the coated fruit. This is due to the adhesiveness or ability to form cross bonds with its polymer and pectin compounds contained in the fruit. Ecogel in acidic conditions inhibits the growth of most microorganisms and extends its shelf life (Suriati, 2020). However, an increase in pH value is due to the decrease in organic acid content and its formation during storage. Furthermore, the concentration of additives contributes to the lowering of the pH of ecogel during storage. According to Marpudi *et al.* (2011), the addition of citric acid and ascorbic acid to the aloe vera solution produced a pH of approximately 4.

Application of ecogel on fresh-cut mango fruit

Colour (L*a*b*) of fresh-cut mango: This measurement was carried out by utilizing the numerical color codes obtained with the chromameter. The numerical color codes are L*a*b* data

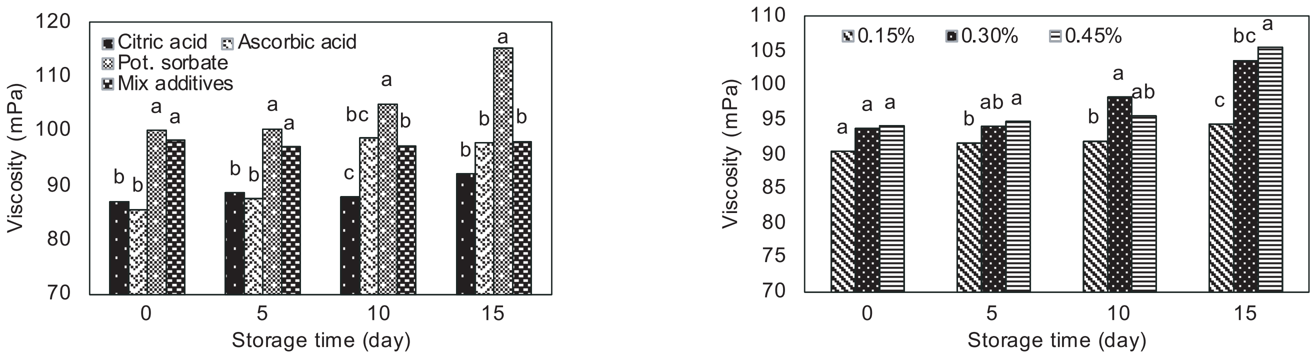

Fig. 3. Effect of type and concentration of nano-additive on viscosity of ecogel (mPa)

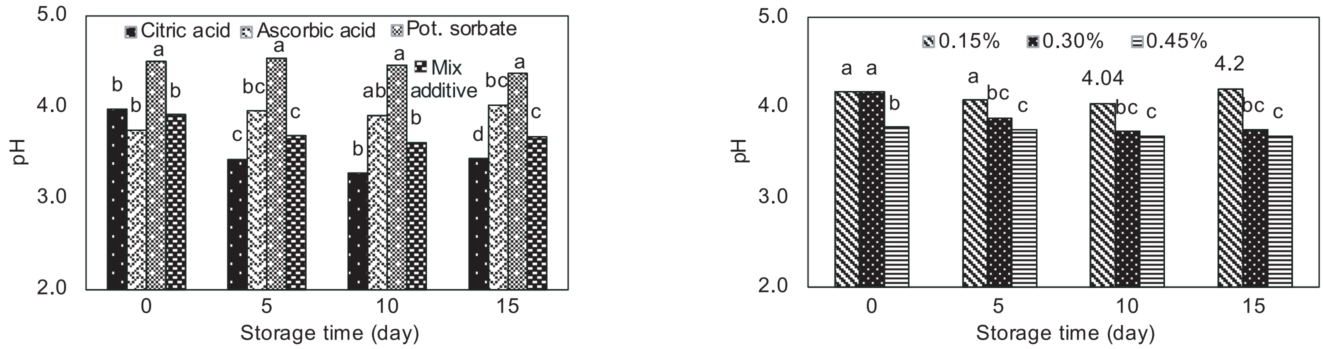

Fig. 4. Ecogel pH under different types of additive treatment and concentration

and often referred to as "Hunter" notation. The average value of L*a*b* for fresh-cut mango during storage is shown in Fig. 5. The L* notation depicts the reflected light, which consists of white, gray, and black accordion color. However, when there is a decline or increase in the L* value, it means that the fruit color is either getting darker or brighter during storage. The changes in the L* values during the experiment are shown in Fig. 5. The brightness (L*) of the mango without ecogel continued to decline throughout the storage duration, while those with ecogel were relatively stable till day 6 and decreased drastically on the 9th day. The value of L* in mango fruit with ecogel was approximately (2.8-42.38), while without it was (32.38-51.99). Therefore, it was able to retain the brightness of the mango till the 6th day, due to the fact that it tends to withstand the rate of respiration and color degradation. Edible coatings act as a barrier between water vapor and gas exchange (O_2, CO_2) and also serves as a carrier additive (Dhall, 2013; Sánchez-Machado *et al.*, 2017). The application tends to improve the appearance of bright and shiny colours (Ergun and Satici, 2012; Dhall, 2013). The a* notation in hunter is a chromatic color that consists of a mixture of red and green, additionally, the value of the mango fruit is coated with an ecogel at 1.21-3.45, and 6.19-11.32, without coating. The use of ecogel tends to delay the maturation process or inhibit the development of red mango fruits. The maturation mechanism is triggered by the respiratory process, which involves the availability of oxygen around the fruit. The ecogel, which serves as the primary packaging protects fresh-cut mango from environmental influences, such as the effects of gas (O_2, CO_2), water, evaporation, odour, microorganisms, dust, shock, vibration and pressure. Oxygen gas is crucial in food packaging because it is the primary substance in some reactions that affect the food shelf life, namely microbial growth, discoloration, lipid oxidation, rancidity, maturation of fruits and vegetables (Mikkonen and Tenkanen, 2012; Dhall, 2013). The b* notation is a mixture of blue and yellow colours, with the value for fresh-cut mango using ecogel at approximately 1.21-3.45, and 6.19-11.32 without its usage. Therefore, it was able to maintain the fresh-cut yellow color of the mango till the 6th day, after which it drastically turned brown on day 9. Cold storage decelerates the metabolic process to extend the shelf life, however when it lasts for a long period, it tends to disrupt metabolism, thereby causing the death of tissues in the fruit. From observations conducted on the generated L*a*b* during storage that lasted for 9 days, it was observed that fresh-cut mango stored at a temperature of 7±1°C experienced symptoms of chilling injury.

pH: The changes in pH which occurred during the storage of the mango fruit are shown in Fig. 6. The results from the research showed that ecogel maintained the pH of fresh-cut Mango, this was observed in the noticeable difference during storage. This is because the ecogel protects the fruit in order to prevent acid reshuffle. Reports show that mango contains citric, malate, and ascorbic acid and unripe fruits contain several organic acids that tend to decline during its maturation. Decreased acidity is essential in the maturation of mango fruit, and it alters the pH value. Fresh-cut mango covered with uncoated ecogel showed a significant increase on the 3rd day while in grapevine it decreased drastically on day 9. The mango fruit used was optimally ripe,

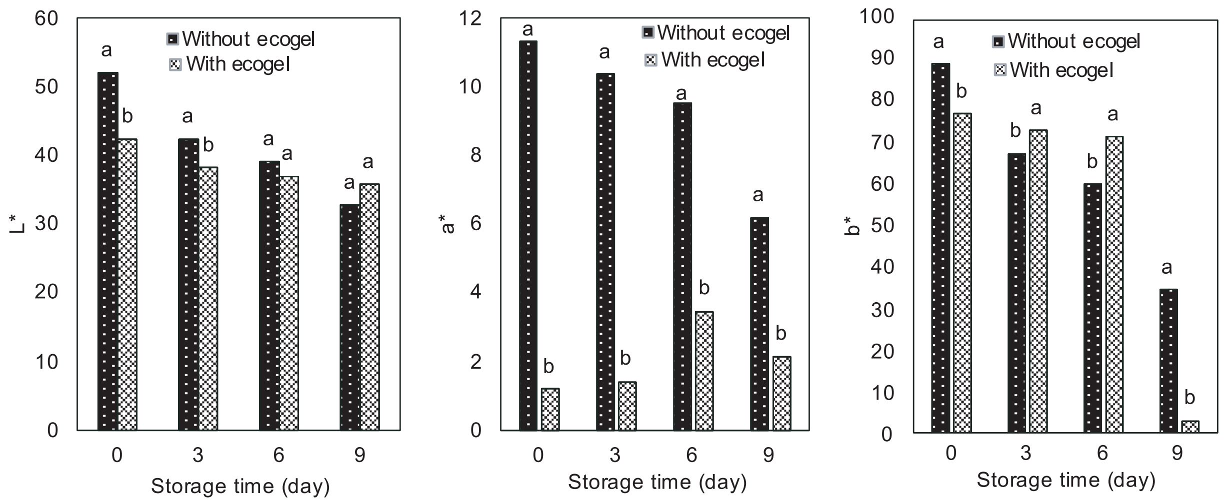

Fig. 5. The L*a*b* value of fresh-cut mango without and with application of ecogel

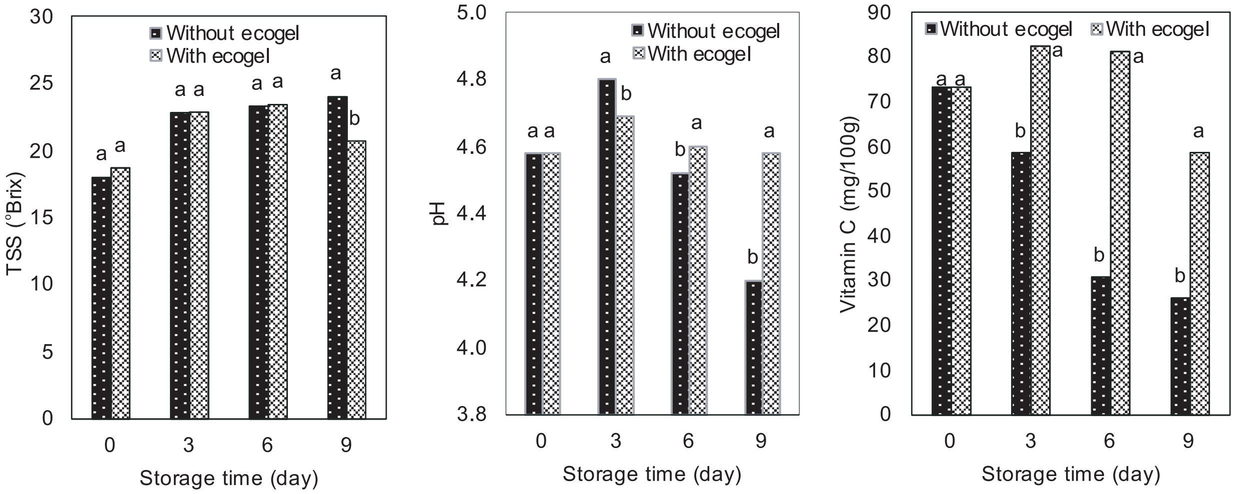

Fig. 6. Total soluble solids, pH and vitamin C in fresh-cut mango without and with aplication of ecogel

therefore maturation occurred on day 3. The decline in pH occurred because the fresh-cut mango started to develop into the fermentated products, thereby producing undesirable acids. Although, organic acid, in addition, affected the flavour as well as the aroma of fruit, therefore it determines the quality of fruits (Batista-Silva *et al.*, 2020).

The total soluble solid: The ecogel treatment did not have a significant effect on the total soluble solid of the fresh-cut mango during storage. The observation of dissolved solids in mango fruit was conducted with the aid of a refractometer assuming most of the dissolved solids are sugar. Mango fruit consists of water, proteins, fats, and carbohydrates, which consist of starch, sugar, and pectin. Unripe fruits such as apples, mangoes and bananas contain a lot of starch. The starch content of some fruits continues to increase, even during the maturity of the cell. Sometimes, the sugar contents of few climacteric fruits, such as mango, tend to increase during cell maturity (Batista-Silva *et al.*, 2020). Several types of sugars are found in fruits, however the real content only includes three kinds of sugar, namely glucose, fructose, and sucrose. The results from the observation showed that during storage, there was an increase in the total amount of dissolved solids, which was possibly due to optimal ripe stage of fruit. The value of the total dissolved solids ranged from 18-24 °Brix, furthermore the total parameter correlated with the symptoms of chilling injury, which is observed in the conversion of starch reshuffle process into glucose.

Vitamin C: The level of vitamin C kept increasing till the fruitwas ripe, and decreased when the maturity level has been exceeded, as shown in Fig. 6. The loss of vitamin C is possibly because of oxidation occurred during storage due to the presence of air that penetrates the pores of the packaging. Vitamin C is easily soluble in water, thereby causing it to be active in a juice that contains more water than fibre that is coarse starch. Additionally, it is acidic, therefore it is more stable in acid than alkaline solutions. Vitamin C levels decrease with the maturity level of the fruit. Transpiration, which is affected by temperature and length of duration, causes the fruit to lose its water content and also damages the production of acid oxidase enzyme stored in the tissue. Simultaneously, the fruit absorbs O_2 which results in an increase in the oxidation of vitamin C and release of CO_2.

Water content: The water content of the fresh-cut mango coated with nano-additives is presumed to increase by day 9 because during storage, there is a process of respiration that tends to reshuffle carbohydrates and this results in the production of water. On the contrary, water content in the fresh-cut without ecogel increased until day 6 after which it decreased on the 9th day. Therefore, ecogel is able to withstand the loss of water from fresh-cut mango during storage, and this is because those with nano-additives form a polymer with cross-linked binding the acetyl group which is stronger in retaining water. Coating with nano-additives is in high demand due to the nature of its acceptable barrier and structural integrity (Dhall, 2013; Galgano *et al.*, 2015). The application of the edible coating on the surface of fruit pieces processed minimally aims to provide a modified atmosphere, gas transfer inhibitors, reduced water and loss of aroma, delayed discoloration, and improved appearance (Sánchez-Machado *et al.*, 2017).

Weight shrinkage: The weight of fresh-cut mango increasedduring storage, because it is a climacteric fruit which showed an increase in rapid respiration immediately after harvesting. Generally, climacteric fruits get ripened on the tree, however, it is harvested before the initial climax (Batista-Silva *et al.*, 2020). The fresh-cut mango with ecogel coating treatment had an average weight of 1.16-2.88 % which tended to shrink more at 1.21-3.37 % during the 9 days storage as shown in Fig. 8. According to Batista-Silva *et al.* (2020), cold storage has an influence on refrigerated materials, such as weight loss. Shrinkage in fruit during storage is mainly caused by loss of water, which also reduces the quality and inflicts damages.

Texture: Changes in firmness during storage were measured based on the fruit resistance to the texture analyser suppressor at a speed and distance of 10 and 20, respectively. Alterations in firmness during the storage period is shown in Fig. 7. The longer the storage, the more the value of the texture drops. Zhang *et al.*, (2018) stated that uncoated fruits experienced a decline during storage. Therefore, decrease in the hardness of mango fruit occurred due to the process of maturation because those kept for a longer period became increasingly soft as a result of the influence of pectolytic enzymes. During storage, there is a partial change in protopectin, which is insoluble in water, thereby lowering the cohesion of the cell walls that binds cells to one another,

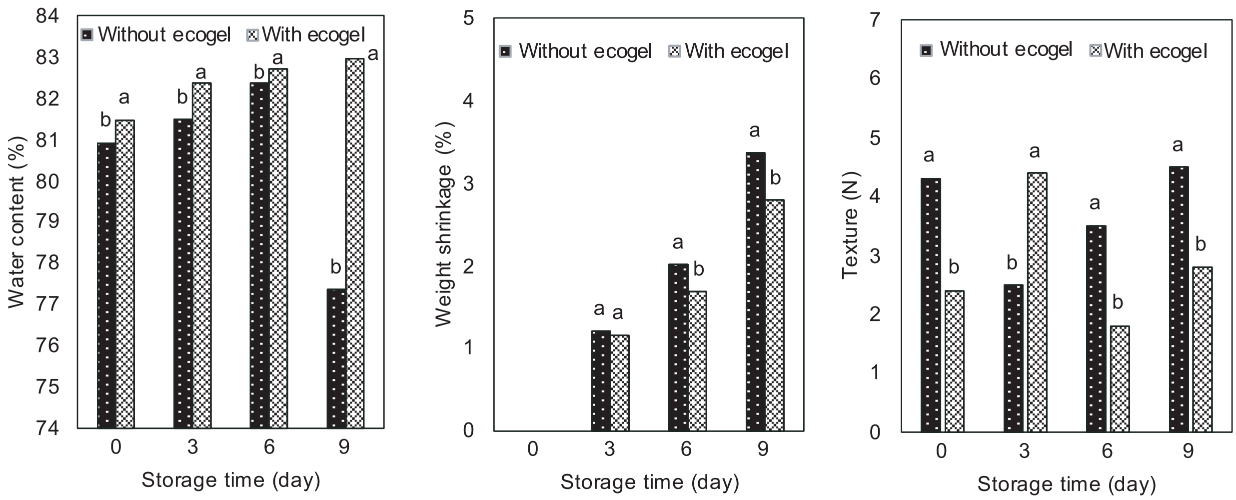

Fig. 7. Water content, shrinkage the weight and texture of fresh-cut mango with and without aplication of ecogel.

consequently the hardness of fruit decreases and becomes mushy (Batista-Silva *et al.*, 2020).

In conclusion, the mixture of nano-additives consisting citric acid, ascorbic acid, and potassium sorbate at a concentration of 0.15 %, was the best formulation for ecogel. The characteristics of fresh-cut fruit coated with ecogel were suitable at a temperature of 7 ± 1°C until day 6. Therefore, ecogel prolongs the shelf-life of fresh-cut mango.

Acknowledgments

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