Journal of Applied Horticulture, 22(3): 189-195, 2020

Journal of Applied Horticulture
ISSN: 0972-1045

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

Luh Suriati[1*], I Made Supartha Utama[2], Bambang Admadi Harsojuwono[2], Ida Bagus Wayan Gunam[2]

*[1]Faculty of Agriculture, Warmadewa University. [2]Department of Agricultural Engineering, Faculty of Agricultural Technology, Udayana University. *E-mail: suryatiluh1@gmail.com*

Abstract

Fresh-cut mango is a very popular product commonly consumed due to its health and safety benefits to the community. The rise in cutting results, which increases respiration, ethylene production, oxidation, and browning processes, 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, with the nanoparticle used to determine the edible coating capability. This study, therefore, aims to determine the influence of incorporation nano-additive material and its concentration to extend the shelf life of the mango. The complete random design was used to determine the factorial pattern of citric, ascorbic, and potassium sorbate acid using a concentration of 0.15, 0.3, and 0.45 %. The mixture of nano-additives consists of citric acid, ascorbic acid, and potassium sorbate at a concentration of 0.15 %, which is the best formulation for Ecogel. The characteristics of fresh-cut fruit coated with Ecogel are suitable at a temperature of 7 ± 1 °C until day 6. Therefore, Ecogel prolongs the shelf-life of fresh-cut mango.

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

Introduction

The present increase in the consumption rate of fruits, particularly mangoes across the world, has increased tremendously due to the stimulated consumer awareness of its health benefits, storage technology, transportation, and marketing systems. In addition, it has also become a global strategy in improving the level of public health. Mango fruits contain bio-active components such as phenolic compounds, carotenoids, organic acids, vitamins, and fibres that are beneficial to health. As sides being tasty, it also serves as a functional food that facilitates digestion, reduces obesity, and boosts immunity. Subsequently, it also functions as an antioxidant, anticancer, anti-inflammatory, and antimicrobial (James and Ngarmsak, 2010).

Mango fruit is a commodity which tends to rotten easily. The physiological damage of the edible parts such as the skin often determines the preference of consumers, however, the inedible pieces are approximately between 22-29%, and it is usually a household waste donor (Utama *et al*., 2016). This leads to an increase in the sale of edible parts, from the minimum process referred to as fresh-cut, which is driven by the consumption needs of the consumers, namely fresh, healthy, comfortable, safe, and nutritious without adequate preparation time (Galgano *et al*., 2015).

Some of the advantages include satisfying the desires of the consumers, by placing a variety of options in one package, providing the necessary fresh materials, facilitating the quality of products purchased, 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 such as color, smell and flavor, decreased fruit integrity, and microbial growth (Galgano *et al*., 2014). The treatment of storage temperature and the use of edible coating are some of the ways to preserve fresh-cut products till it is purchased by consumers (Siddiqui *et al*., 2011).

The edible coating is an environmentally friendly and biodegradable food packaging, which consists of a thin edible layer (Rahman *et al*., 2017). It also serves as carriers of additives, chemical change barriers, physical, biological, and mass transfer barriers (Sánchez-Machado *et al*., 2017). Furthermore, the applications also tend to improve its appearance, retain moisture, prevent weight loss, and also serve 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. However, the constraints on fresh-cut products are the difficulty of the strain on the surface of sliced fruit that is hydrophilic. In addition, it is safe to apply the edible coating with several types of additives on fresh-cut mango fruit (Sánchez-Machado *et al*., 2017).

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 citric acid additives, ascorbic acid, potassium sorbate, and calcium chloride (Siddiqui *et al*., 2011). Subsequently, antioxidant 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 substances such as sorbate acid are also used to avoid microbes in fresh-cut products.

The ability of an edible coating to serve as an additive matric is strongly influenced by 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, and controls the discharge (Sekhon, 2010). Nowadays, the nano food field technology has gained considerable attention. An example of its application is the nano-additive used on a wide range of products, including edible coating food packaging (Hewet, 2013). The type and concentration of nano-additives on 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, increases the bio-availability of active ingredients, prevents chemical reactions and extends shelf life. Utama *et al*. (2011) reported that temperature contributes to some post-harvest setbacks of 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 the treatment of mango fruit storage temperature. This research, therefore, aims to achieve the following: 1) determine the type and concentration of nano-additives that produce the best formulation of Ecogel and 2) the characterization of fresh-cut 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. The material used is an aloe vera plant obtained from the village of Taro Gianyar Bali, which 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 edible coating of Aloe gel (Ecogel) with nano-additive: The complete random design spit plot pattern was employed. Additionally, factor I type of nano-additives consist of citric acid, ascorbic acid, potassium sorbate, and its mixture, while factor II of 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 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 additive, 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 % (b/V) were added during warming up at 70±1 °C for 5 minutes. The Ecogel is cooled at room temperature for 1 hour, while the nanoparticle size was produced using the Probe sonicator, which lasted for 30 minutes. The Ecogel is stored at a cold temperature (7 ± 1°C) for 15 days. The variables observed in this study were colours, 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 minute. 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, the level of vitamin C, total acid, and soluble solids (AOAC, 2019).

Results and discussion

Colour different (ΔE) of Ecogel: The parameters used to assess the change in the color of Ecogel before and after the addition

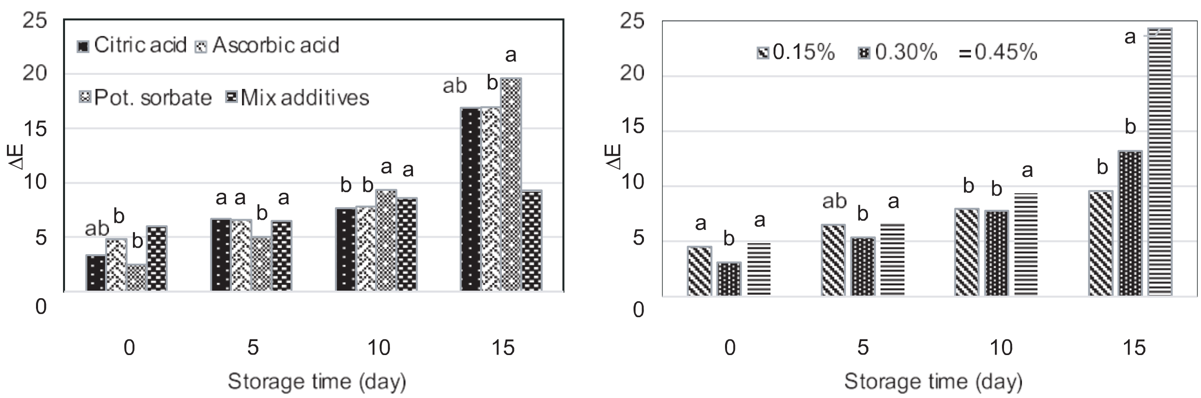

Fig. 1. Colour different of Ecogel (ΔE) on type and concentration of nano-additives

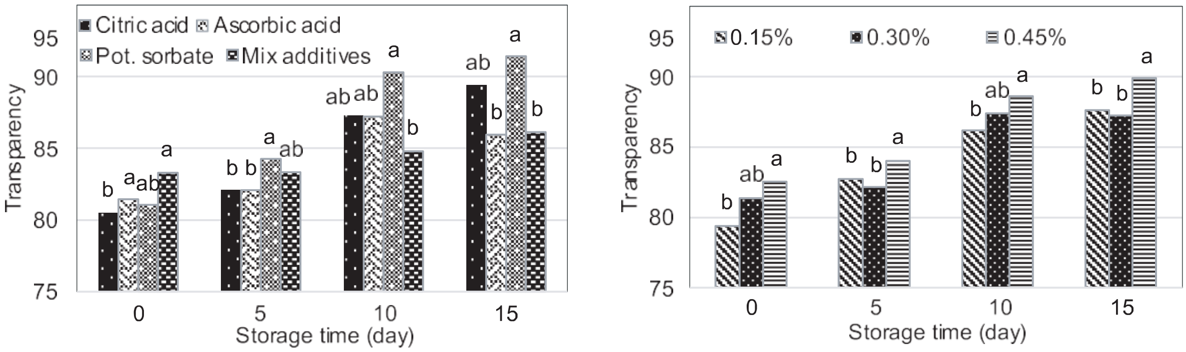

Fig. 2. Ecogel transparency on type and concentration of nano-additive

of nano-additive is ΔE. Based on observation, the value of ΔE in all types of treatment and concentrations of nano-additives insignificantly 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 is able to maintain the colour with the value of ΔE considered before applied as a coating on food products. Ecogel with low ΔE produces a visual appearance of the coated product, which tends to be slightly different from the original item. A smaller ΔE implies that it is approaching 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 showed in Fig. 1.

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 is suspected because an increase in nano-additives is 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 is 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 showed in Fig. 2 with an increase in the mixture of the additives and relative stability transparency till day 15 when compared to the others. The combination of the three additives produces 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. Therefore, the characteristics of edible coating are colourless and transparent (Galgano *et al*., 2015).

The viscosity of Ecogel: 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. This is in accordance with previous researches, which stated that an increased concentration of filler material in a solution tends to raise the viscosity, as shown in Fig. 3 (Saberi *et al*., 2016). The mixture of nano-additives, namely citric acid, ascorbic acid, and potassium sorbate is able to synergize and strengthen the cohesion of Ecogel polymer bonding and also leads 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 is active and 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 the treatment, addition of preservatives, and other additives such as potassium sorbate, citric acid, and ascorbic acid (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 is conducted by the addition of 0.05-0.5 % ascorbic acid and 0.01-0.5 % citric acid.

pH of Ecogel: A solution is either acidic, alkaline, or neutral depending on the concentration of H^+ ion or OH^- ion. An increase in H^+ ions leads to an increasingly acidic solution (pH decreases), on the contrary, fewer OH^- ions increase the alkalinity(Atina,

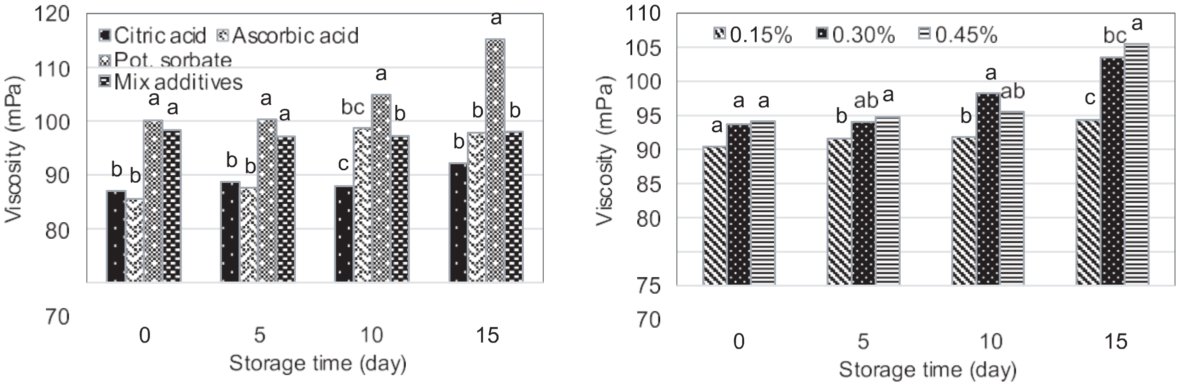

Fig. 3. Viscosity of Ecogel (mPa) in type treatment and concentration of nano-additives

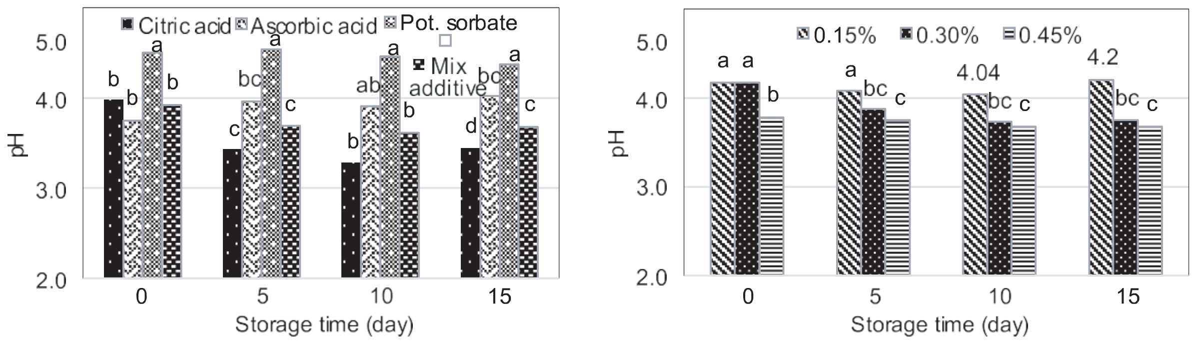

Fig. 4. Ecogel pH in type treatment and concentration of nano-additives

2015). 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. The addition of potassium sorbate to Ecogel produces 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. Ecogel in acidic conditions inhibits the growth of most microorganisms and extends its shelf life (Suriati, 2020). The change in pH value occurs due to changes in the hydrogen balance. 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 produces a pH of approximately 4. The average pH value of Ecogel is shown in Fig. 4.

Thickness of Ecogel: The thickness is used to determine the functionality used to protect the coated material. The addition of active ingredient in a solution is needed to produce an active edible coating. Different types of active ingredients are used; however, they possess distinctive properties. Lim *et al*., (2020) reported that the use of different active ingredients has an impact on the properties of the various edible coatings. For example, the addition of sorbate in edible starch-based coating increases its permeability value. The active nature of edible coating is dependent on its constituent, namely the types and quantities of the main and auxiliary components. The results from previous immersion showed that there was no significant change in thickness, which ranges from 0.24 to 0.26 mm. An increase in the addition of nano-additives improved the polymer composition of the Ecogel matrix and enlarges the total solids, thereby producing a thicker layer (Tarfaoui *et al*., 2018).

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 tool. The numerical color codes are L*a*b* data 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 showed in Fig. 5. The brightness (L*) of the mango without Ecogel continues to decline throughout the storage duration, while those with Ecogel are relatively stable till day 6 and decreases drastically on the 9th day. The value of L* in mango fruit with Ecogel is approximately (2.8-42,38), while without it is (32.38-51.99). Therefore, it is 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; and 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

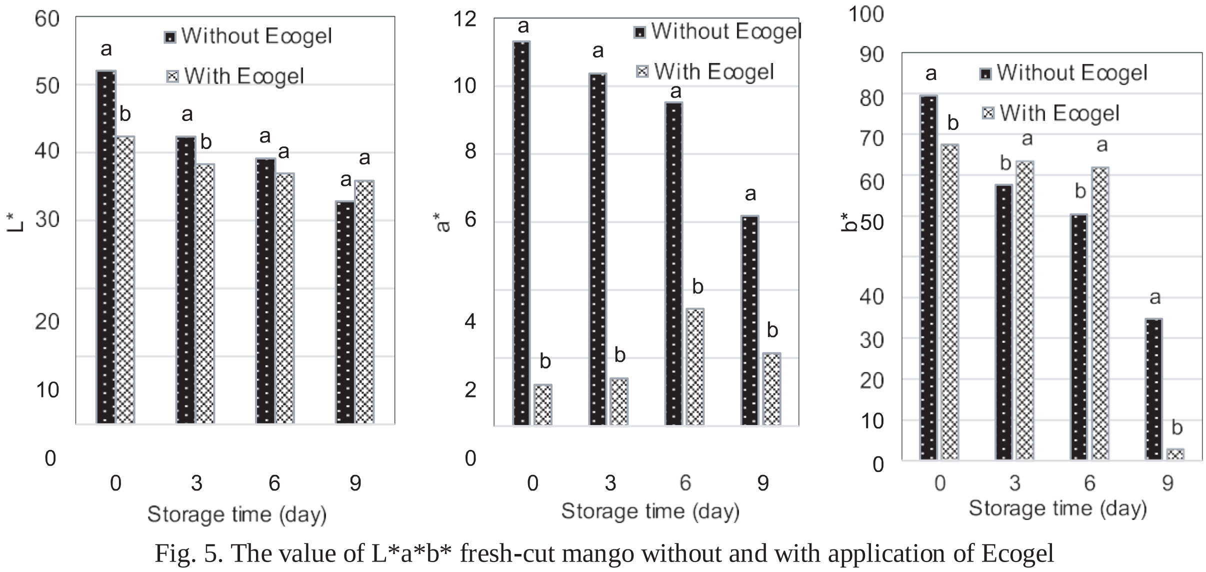

Fig. 5. The value of L*a*b* fresh-cut mango without and with application of Ecogel

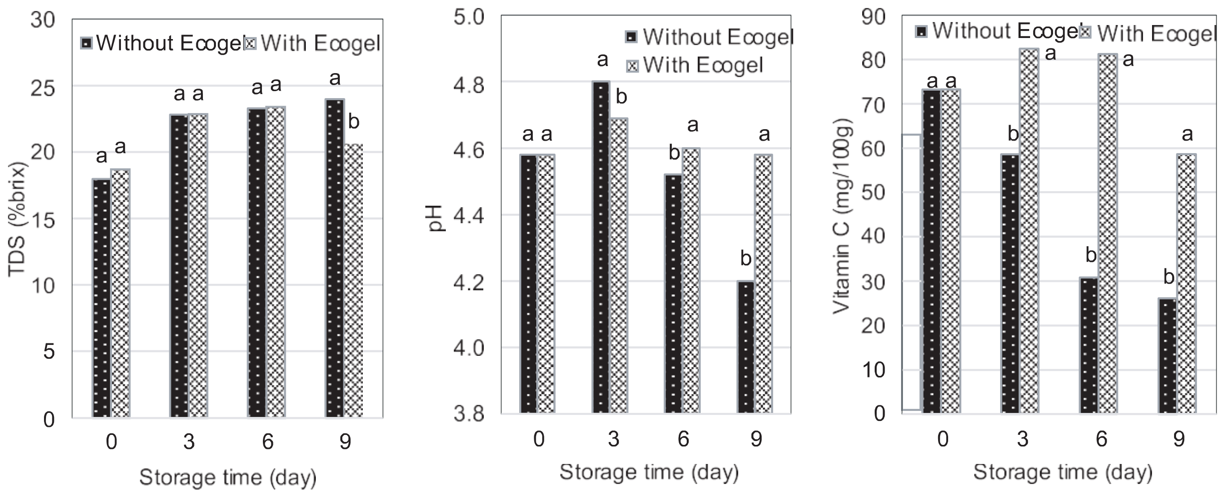

Fig. 6. pH, total soluble solid and vitamin C fresh-cut mango without and with aplication of Ecogel

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 is able to maintain the fresh-cut yellow color of the mango till the 6th day, after which it drastically turns 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 is observed that fresh-cut mango stored at a temperature of 7±1°C experienced symptoms of chilling injury.

pH of Fresh-cut mango: Organic acids are a major component of cell builders, which undergo changes during the maturation of the fruit. It was discovered that mango contains citric, malate, and ascorbic acid. Subsequently, 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. The changes in pH which occurred during the storage of the mango fruit in this study are shown in Fig. 6. The results from the research showed that Ecogel maintains the pH of fresh-cut Mango, this is observed in the noticeable difference during storage. This is because the Ecogel protects the fruit in order to prevent acid reshuffle. Fresh-cut mango covered with uncoated Ecogel showed a significant increase on the 3rd day while its grapevine decreased drastically on day 9. The mango fruit used was optimal riped, therefore maturation occurred on day 3. The decline in pH occurred because the fresh-cut mango started to develop into the post-harvest period (fermentation), thereby producing undesirable acids. This organic acid, in addition, affected the flavour as well as the scent of fruit, therefore it is used to determine the quality of fruits (Batista-Silva *et al*., 2020).

The total soluble solid of fresh-cut mango: The Ecogel treatment does 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, the reading is expressed as a Brix degree. 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 some type of climacteric fruits, such as mango, tend to increase during cell maturity (Batista-Silva *et al*., 2020). Several types of sugar 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 caused by the optimal ripe fruit. The value of the total dissolved solids ranges 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 of fresh-cut mango: Vitamin C is one of the nutrients that act as an antioxidant and effectively addresses free radicals that destroy cells and tissues from oxidative damage inflicted by radiation. Mango fruits contain several beneficial nutrients, such as vitamin C, which is highly needed by the body. The level in mangoes is strongly influenced by their varieties, environments, places, fertilizers, maturity levels, etc. The level of vitamin C keeps increasing till the fruit is ripe, and decreases when the maturity level has been exceeded, as shown in Fig. 6. The loss of vitamin C is possible because 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. However, it is converted to glucose when cooked. 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 the release of CO_2.

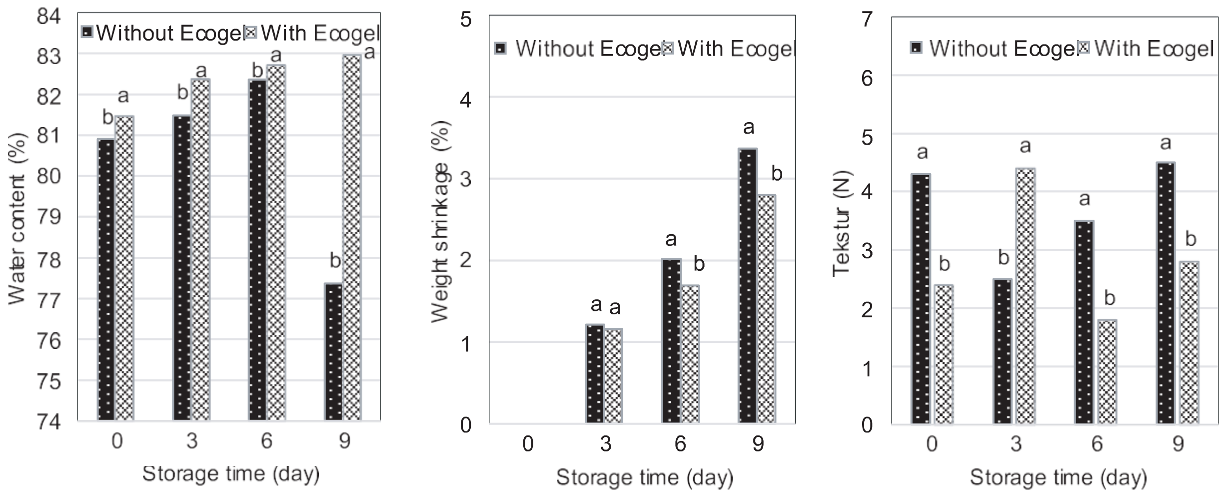

Fig. 7. Water content, shrinkage the weight and texture of fresh-cut mango without and with aplication of Ecogel.

Water content of fresh-cut mango: 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, 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-pinkies 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, reduce water and loss of aroma, delay discoloration, and Improves appearance (Sánchez-Machado *et al*., 2017).

Weight shrinkage of fresh-cut mango: The weight of fresh-cut mango increases during 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 tends to shrink more at 1.21-3.37 % during the 9 days storage as shown in Figure 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 inflict damages.

The texture of fresh-cut mango Changes in hardness 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 violence during the storage period is showed in Fig. 7. The longer the storage, the more the value of the texture drops. Zhang *et al*., (2018) stated that on 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, consequently the hardness of fruit decreases and becomes mushy (Batista-Silva *et al*. 2020).

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

Acknowledgments

The authors are grateful to the Ministry of Research, Technology and Education Republic of Indonesia and the Rector of Warmadewa University for funding and supporting this research. The authors are also grateful to all colleagues for their assistance.

References

AOAC, 2019. *Official Methods of Analytical of the Association of Official Analytical Chemist (AOAC) International*, 21th ed Vol 1. Editor George W. Latimmer Jr. Washington DC.

Al-Hasan A.A. and M.H. Norziah, 2012. Starch gelatine edible films: water vapor permeability and mechanical properties as affected by plasticizers. *Food Hydrocolloids*, 26: 108-117.

Alikhani, M., 2014. Enhancing safety and shelf life of fresh-cut mango by application of edible coatings and microencapsulation technique. *Food Science & Nutrition*, 2(3): 210-217.

Ayranci, E. and S. Tunc, 2004. The effect of edible coatings on water and vitamin C loss of apricots (*Armeniaca vulgaris* Lam.) and green peppers (*Capsicum annuum*, L.). *Food Chem*., 87: 339-342.

Batista-Silva W., V.L. Nascimento, D.B. Medeiros, A. Nunes-Nesi, D.M. Ribeiro, A. Zsögön and W.L. Araújo, 2020. Modifications in organic acid profiles during fruit development and ripening: correlation or causation? *Frontiers in Plant Science*, 1: 20.

Dadali G., D.K. Apar and B. Ozbek, 2007. Colour change kinetics of okra undergoing microwave drying. *Drying Technology*, 25: 925-936.

Dhall, R. K, 2013. Advances in edible coatings for fresh fruits and vegetables: a review. *Journal: Critical Review Food Science Nutrition*, 53(5): 435-450.

Ergun, M. and E.F. Satici, 2012. Use of *Aloe vera* gel as biopreservative for 'Granny Smith' and 'Red Chief' apples. *J. Anim. Plant Sci*, 22(2): 363.

Galgano, F., N. Condelli, F. Favati, V. Di_Bianco, G. Perretti and M.C. Caruso, 2015. Biodegradeable packaging and edible coating for fresh-cut fruits and vegetables. *Ital. J. Food Sci*., 27.

Garcia, E and D.M., 2002. *Fresh-cut Fruits and Vegetables: Science, Technology, and Market - Preservative Treatments for Fresh-cut Fruits and Vegetables*, Edited by Olusola Lamikanra. CRC Press. Florida. 452.

Hewet, E.W., 2013. *Postharvest Innovation: Current Trends and Future Challenges in the Global Market*. Institute of Food Nutrition and Human Health, Massey University, Auckland, New Zealand.

James, J.B. and T. Ngarmsak, 2010. *Processing of fresh-cut tropical fruits and vegetables: a technical guide*. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific Bangkok

Lim, G., S. Jang and K.B. Song, 2020. Physocal and antimicrobial properties of Gelidium comeum/nano-clay composite film containing grapefruit seed extract or thymol. Journal of Food Engineering, 98(4): 415-420.

Marpudi, S. L., L.S.S. Abirami, R. Puskhala and N. Shrividya, 2011. Enhancement of storage life and quality maintenance of papaya fruits using *Aloe vera* based antimicrobial coating. *Indian Journal of Biotechnology*, 10(1): 83-89.

Mikkonen, K. S. and M. Tenkanen, 2012. Sustainable food-packaging materials based on future biorefinery products: xylans and mannans. *Trend in Food Science Technology*, 28(2): 90-102.

Rahman, S., P. Carter and N. Bhattarai, 2017. *Aloe vera for tissue engineering applications*. Department of Chemical, Biological and Bioengineering, North Carolina A&T State University, Greensboro, USA.

Maughan R.G, 1984. Method to increase color fastness of stabilized aloe vera. US Patent 4-446.131. Google Patent.

Saberi, B., S. Chockchaisawasdee, J.B. Golding, C.J. Scarlett and C.E. Stathopoulos, 2017. Physical and mechanical properties of a new edible film made of pea starch and guar gum affected by glycols, sugars and polyols. *Int. J. Biol. Macromol*, 104: 345-359.

Sanchez-Machado, D.I., J. Lopez-Carvantes, Raquel-Sendon and A. Sanches-Silva, 2016. *Aloe vera*: ancient knowledge with new frontiers. *Trends in Food Science & Technology*, 61: 94-102.

Sekhon B.S, 2010. Food nanotechnology – an overview. *Nanotechnology, Sci. App.*, 3: 1-15.

Siddiqui W., I. Chakraborty, J.F. Ayala-Zavala and R.S. Dhua, 2011. Advances in minimal processing of fruit and vegetables: a review. *Journal Scientific Industrial Research*, 70: 823-834.

Suriati, L., I.G.P. Mangku, and I.N. Rudianta, 2018. The characteristics of *Aloe vera* gel as an edible coating. *IOP Conf. Ser.: Earth Environ. Sci*, 207 (2018) 012051.

Suriati, L, 2018. Studies the resistance to oxidation and the changes phases against the characteristics of physicochemical *Aloe vera* gel. *J. Biol. Chem. Research*. 35(2): 670-679.

Suriati1, L. and I.M.S. Utama, 2019. Characteristic fillet of *Aloe vera* gel as edible coating. *J. Phys.: Conf. Ser.* 1402 (2019) 066021.

Suriati1, L., I.M.S. Utama, B.A. Harsojuwono and I.B.W. Gunam, 2020. Stability Aloe vera gel as edible coating. *IOP Conf. Series: Earth and Environmental Science*, 411 (2020) 012053.

Tarfaoui M., K. Lafdi, I. Beloufa, D. Daloia and A. Muhsan, 2018. Effect of graphene nano-additives on local mechanical behavior of derived polymer nanocomposites. Polymer (Basel), 10(6): 667.

Utama, I.M.S., Y. Setiyo, I.A.R. Pratiwi-Puja, N.S. Antara, 2011. Controlled atmosphere studies to slow down Arumanis mango fruit quality reduction during storage. *J. Hort. Indonesia*, 2(1): 27-33.

Utama, I.M.S. and L. Kitinoja, 2016. Post-harvest vegetable losses in smallscale agribusiness chains of Bali, Indonesia. *CAPSA palawija newsletter*, 32: 2.

Zambrano-Zaragoza M.L., R. González-Reza, N. Mendoza-Muñoz, V. Miranda-Linares, T.F. Bernal-Couoh, S. Mendoza-Elvira and D. Quintanar-Guerrero, 2018. Nanosystems in edible coatings: A novel strategy for food preservation. *Int. J. Mol. Sci*. 19: 705. doi:10.3390/ijms19030705.

Zhang, L., S. Zhao, S. Lai, F. Chen and H. Yang, 2018. Combine effect of ultrasound and calcium on the chelate-soluble pectin and quality of stawberries during storage. *Carbohidrate Polymer*, 200: 427-435.