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FULL PAPER

The effect of concentration calcium chloride and immersion time on changes in colour and texture of fresh-cut mangosteen

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Abstract

Fresh-cut mangosteen is a popular product, containing functional components that are good for health. The weakness is the deterioration of colour and texture. The application of calcium chloride can delay the deterioration of fresh-cut mangosteen. This study aimed to determine the effect of the concentration of calcium chloride and immersion time on changes in the colour and texture of fresh-cut mangosteen in cold storage. Preparation of fresh-cut mangosteen was carried out by removing the skin with the application of calcium chloride solution using concentrations of 0.5, 1.0, 1.5, and 2.0% (w/v) and immersion times of 10, 20, and 30 mins. The design used was completely randomized with three replications to observe changes in browning and quality namely texture, acidity, total dissolved solids, water content, and weight loss. The treatment of calcium chloride concentration, immersion time, and their interactions affected all variables of browning and quality changes of fresh-cut mangosteen. To conclude, the best treatment that can delay browning and the quality changes of the fresh-cut mangosteen fruit is a concentration of 1% calcium chloride with an immersion time of 10 mins to 9 days at a cold storage temperature of 7±1°C.

1. Introduction

Mangosteen, popularly known as the "Queen of tropical fruits" is a delicious fruit with high economic value. It contains bioactive compounds capable of increasing the body's immunity such as vitamins, minerals, antioxidants, anthocyanins, and xanthones, which are needed in the current Covid-pandemic. Mangosteen like other perishable commodities changes such as damage to the skin (hardening, cracking, rough) and fruit flesh (transparent and decaying) and the presence of yellow sap (Wathoni *et al*., 2019). Physiological damage to the non-edible fruit parts such as the skin often determines consumer preferences, even though the flesh of the fruit or edible parts is still suitable for consumption. Mangosteen has a relatively high number of non-edible parts, which contributes to household waste (Zhang *et al*., 2020). This has led to an increase in sales of edible parts through a minimal process known as fresh-cut (Nicolau-Lapeña *et al*., 2021). In addition, it is driven by the need for the consumption of quality products (fresh, healthy, comfortable, safe, and nutritious) and lack of preparation time (Suriati *et al*., 2020a; Suriati *et al*., 2020b). Some of the advantages of minimal process products include providing consumers with a variety of choices, obtaining the fresh amount needed, access to quality products, and reduction in volume and cost of transportation (Nicolau-Lapeña *et al*., 2021; Suriati and Suardani, 2021; Suriati *et al*., 2021)

The disadvantage of fresh-cut fruit is that its quality decreases rapidly and has a shorter shelf life compared to whole fruit (Suriati *et al*., 2020c). The minimal process results in tissue injury, therefore, the fruit undergoes physiological, pathological, and physical changes (Silvetti *et al*., 2021). When fruit is cut, peeled, or experiences any form of injury, the tissue responds with an increase in respiration rate, ethylene production, consumption of sugar, lipids, and organic acids, and degradation of sensory components (Cofelice *et al*., 2019). The sensitivity of fresh-cut damage is also due to the speed of ripening, softening, and decreased fruit integrity during storage (Suriati *et al*., 2020a). The application of calcium chloride with the dyeing method combined with cold storage is capable of maintaining the quality of fresh-cut fruit. According to research results by Wani *et al*. (2021), calcium can suppress product respiration rate, delay ageing, increase hardness, reduce rot and extend shelf life.

Immersion in calcium chloride results in the

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formation of cross-bonds between calcium and pectin, which leads to the formation of calcium pectate in fruit tissue. The calcium pectate formed slows down the activity of polygalacturonate, causing the structure of the lamella cell wall to be maintained firmly (Ebrahimi and Rastegar, 2020). According to Huang *et al*. (2020), exogenous treatment with 1% calcium chloride can delay the browning reaction and softening of zucchini fruit slices and increase the stiffness of strawberries during cold storage. However, there is no information on the application of calcium chloride solution in mangosteen fresh-cut, especially in terms of concentration and immersion time. The temperature has also been discovered to contribute to some post-harvest setbacks. Therefore, cooling from upstream to downstream is very important for fresh-cut mangosteen fruit, to minimize the effects of mechanical injury, and decrease enzyme activity and speed of metabolism, which further prolongs the shelf life of the product (Tabassum and Khan, 2020). Consequently, a study on the application of calcium chloride combined with cold storage in fresh-cut mangosteen is needed. Therefore, this study aims to determine the effect of the concentration of calcium chloride and immersion time on changes in the colour and texture of fresh-cut mangosteen in cold storage.

2. Materials and methods

2.1 Research site

This study was carried out at the Food Analysis Laboratory and Processing Laboratory Faculty of Agriculture, Warmadewa University, Denpasar, Bali, Indonesia.

2.2 Fresh-cut mangosteen materials

The material used was Aceh's mangosteen fruit, which was obtained from Panji Village, Sukasada District, Buleleng Regency, Bali Province, Indonesia. The mangosteen fruit Aceh type, which was optimally ripe (105 days after flowering) with no defects or rot, was used in this study. The criteria for selection were greenish-yellow skin colour with 50% pink spots spread on the fruit skin, fruit shaped like a pressed ball, fruit flesh consisting of 5-8 segments, fresh green petals, and fruit weight 130 - 180 g.

2.3 Preparation of fresh-cut mangosteen

The fruit was minimally processed (fresh-cut) by peeling and removing the skin and left in the form of a single segment and further treated with a solution of calcium chloride at different concentrations and immersion times according to treatment. Afterwards, it was drained, dried for 20 mins, packed in a plastic box equipped with 2 of 0.5 cm diameter holes on the lid and stored in a chiller at 7±1°C.

2.4 Experiment design

The design used was completely randomized with three replications to observe changes in browning (colour difference, browning index) and quality namely texture, acidity, total dissolved solids, water content, and weight loss. Factor I involved the concentration of calcium chloride solution (0.5%, 1.0%, 1.5% and 2%). Meanwhile, factor II involved the immersion time (10, 20, and 30 mins). The fresh-cut mangosteen was then stored in cold temperatures (7±1) °C and observed periodically on days 3, 6, and 9.

2.5 Variables analysis

The colour difference ΔE (coordinate L*a*b*) was analyzed using a spectral colourimeter (CS-280, Zhejiang China). ΔE is the total colour difference between the same fresh cut fruit at the time of observation with day 0. To determine the total colour difference, use the following formula:

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{0.5}$$

Where L = L * control (fresh cut fruit day 0) – L * sample, a = a * control – a * sample and b = b * control-b * sample.

Browning Index is assessed by measuring the total browning area of each fresh-cut fruit using L* a* b* coordinates based on Dadali *et al.* (2007), with the following formula:

$$IB = \frac{100\,(x - 0.31)}{0.71} \qquad x = \frac{(a^* + 1.75L^*)}{5.645L^* + a^* - 3.012b^*}$$

Where IB = Browning index, L* = brightness, a* = reddish green and b* = bluish yellow

The texture of fresh-cut mangosteen was analyzed using a texture analyzer (TA. XT plus C, UK) at speed: distance (10:8). Acidity was tested using a digital pH meter (Hanna HI 8424, Romania). Parameters of total dissolved solids were tested using a refractometer (950,032 B-ATC, France). Moisture content was tested in an oven (Memmert, Germany), and a digital scale was used for weight loss.

2.6 Statistical analysis

The data obtained in this study were statistically tested using Analysis of Variance. The test was continued with Duncan's Multiple Range Test to discover the real difference in the mean of treatment data.

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3. Results and discussion

3.1 Colour difference (ΔE)

Consumers determine appearance as criterion for product selection. Colour is the main key to food selection and acceptance preferences and even affects the threshold of taste, sweetness perception, and liking, which are usually followed by texture. Changes in colour due to biochemical processes include browning, chlorophyll and carotene degradation, and bleaching. Browning is caused by cuts that produce signals through tissues and induce enzyme synthesis in metabolic pathways and increase the production of phenolic compounds (Cui *et al*., 2020). Fresh-cut fruit is very easily damaged due to a lack of protective skin. Furthermore, Xu *et al*. (2020), reported that pulp is highly susceptible to dehydration, discolouration, and decay.

Observations showed that increasing the concentration of calcium chloride decreased the value of ΔE fresh-cut mangosteen (Figure 1). In the opinion of Sathiyaseelan *et al*. (2021), calcium treatment assists in withstanding the rate of discolouration of fresh-cut fruit during storage. It has also been mentioned that calcium is effective in preventing the discolouration of fresh-cut apples and pears. During storage, it was observed that there was an increase in the value of ΔE on fresh-cut mangosteen until the 9th day. Similarly, a prolonged immersion time is also able to increase ΔE fresh-cut mangosteen and the value obtained was 3.05-36.07. Another factor that causes discolouration is an increase in pale reversibility with surface dehydration from the outer layer (Sikora and Świeca, 2018).

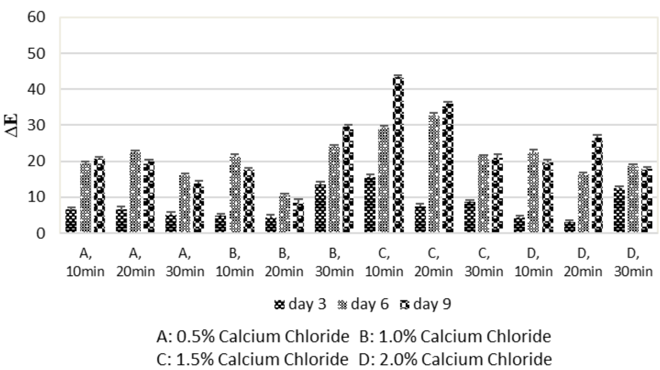

Figure 1. Colour difference (ΔE) fresh-cut mangosteen with treatment calcium chloride concentration (%) and immersion time (mins)

3.2 Browning index

Enzymatic browning is one of the main causes of the decline in the quality of fresh-cut products (Tinello and Lante, 2018). It occurs due to the oxidation of phenolic compounds by the enzyme polyphenol oxidase (PPO), in which quinone compounds undergo polymerization to form melanin's that are brown, reddish, or black (Mirshekari *et al*., 2019). The observations showed that the treatment of calcium depending on the concentration and immersion time and their interactions showed very significant differences (Figure 2). It was observed that increasing the concentration of calcium chloride decreases the browning index of fresh-cut mangosteen. Cutting causes mechanical damage by removing the natural protection of the epidermis and destroying the internal compartment that separates enzymes from the substrate so that it triggers the browning process.

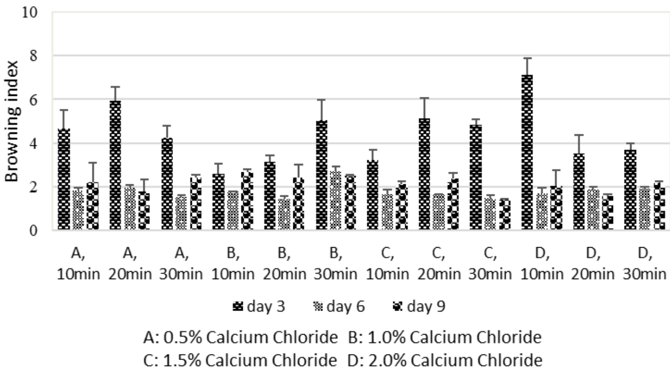

Figure 2. Browning index fresh-cut mangosteen with treatment calcium chloride concentration (%) and immersion time (mins)

Furthermore, prolonged immersion time in calcium chloride solution reduces the mangosteen fresh-cut browning index (Figure 3). Some fruits have quite high phenolic compounds including mangosteen; therefore, the cut surface undergoes browning quickly. This change has an important influence on visual impact by decreasing consumer and market acceptance and reducing the nutritional value of the product (Xu *et al*., 2020). Increased index browning is caused by vitamin C degradation, Maillard reactions, and anthraquinone oxidation. Furthermore, fruits have living tissue, therefore the enzymatic browning process still occurs and shelf life is reduced in case of injury (Nicolau-Lapeña *et al*., 2021). The injury also induces the

Figure 3. Fresh-cut mangosteen before and after treatment calcium chloride, fresh-cut mangosteen visual display with calcium chloride solution treatment.

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synthesis of several enzymes involved in the browning reaction. Consequently, the synthesis of phenolic compounds substrate by the enzyme phenylalanine ammonia-lyase (PAL) becomes oxidizable by polyphenol oxidase (PPO), producing brown polymers that contribute to browning the commodity tissue. Furthermore, PPO oxidizes flavonoids and chlorogenic acids into chocolate compounds (Zheng *et al*., 2019). Meanwhile, prolonged immersion time reduces the browning index of fresh-cut mangosteen. This shows that treatment with calcium chloride effectively maintains the colour and quality of mangosteen fresh-cut until the 9th day.

3.3 Texture

The texture is a critical characteristic of the quality of fresh-cut products. The texture of fresh-cut mangosteen is shown in Figure 4. A high concentration of calcium chloride increases the texture of fresh-cut mangosteen until the 6th day and decreased afterwards. This was due to the interaction between calcium and pectin in the cell wall, which is characterized by the formation of cross bonds between pectates and divalent ions of calcium. This bond inhibits softening for the texture to be maintained. According to the study, it was stated that immersion tomatoes at a concentration of 6% have a higher texture value compared to those without treatment. A similar statement was made by Nicolau-Lapeña *et al*. (2021), that there is a positive relationship between calcium concentration and fruit texture, which was indicated by an increase in the texture of apples due to the administration of 4% calcium. Furthermore, Wani *et al*. (2021), reported that Ca treatment is capable of maintaining the strawberry texture of 5.33 N until 17 days of storage. According to Saba and Sogvar (2016), Ca^{2+} is also capable of maintaining and enhancing the integrity and mechanical properties of cell walls and inhibiting fruit softening. In addition, a prolonged immersion time has a significant effect on improving texture, therefore calcium chloride is effective in maintaining the texture of fresh-cut mangosteen.

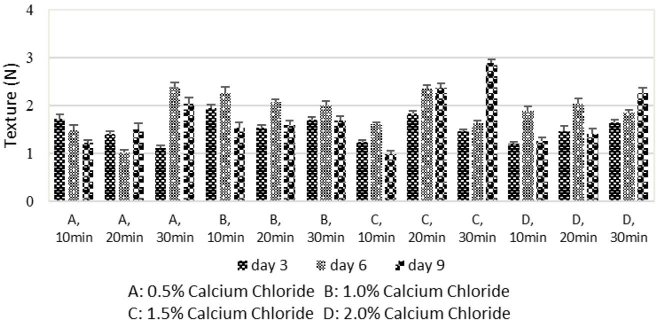

Figure 4. The texture of fresh-cut mangosteen with the treatment calcium chloride concentration (%) and immersion time (mins)

However, the texture of fresh-cut mangosteen decreases after storage for 6 days. Some previous studies stated that this decrease is caused by cell wall degradation (Liu *et al*., 2021). Therefore, softening of the fruit is one of the undesirable changes during storage. Hertog *et al*. (2017), The decreased levels of hardness in stored fruit are caused by the degradation of hemicellulose and pectin into water-soluble pectic acid. According to Nicolau-Lapeña *et al*. (2021), structures such as cell walls, middle lamellae, and cell membranes undergo biochemical changes during maturation, which cause a loss of cohesion between cells leading to softer and weaker structures. One of the main polysaccharide cell walls i.e. pectin plays an important role in maintaining fruit texture (Zheng *et al*., 2019). Softening is mainly caused by pectinolytic and proteolytic enzymes due to damage to the cell wall of fruit tissue during mechanical operations. These enzymes affect the morphology, structure of the middle lamella of the cell wall, cell turgor, moisture content, and biochemical components. Meanwhile, pectinase enzymes such as pectin methyl esterase hydrolyse the methyl ester pectin bonds to produce pectic acid and methanol. Polygalacturonate which hydrolyses ikatan1-4 glucoside bonds from anhydrous galacturonic acid units causes texture degradation due to the hydrolysis of pectin polymers. Therefore, calcium treatment effectively inhibits fresh-cut softening (Saba and Sogvar, 2016).

3.4 Acidity

The acidity is one of the important parameters that determine the success of the next coating process. Treatment depending on the concentration and immersion time in calcium chloride solution and their interactions has a significant effect on the acidity of fresh -cut mangosteen. The value of the acidity of fresh-cut mangosteen during 9 days of storage is shown in Figure 5. Fresh-cut mangosteen has an acidity in the range of

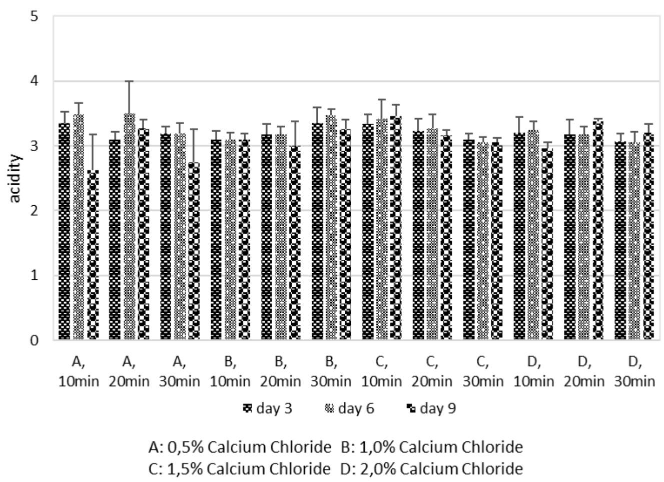

Figure 5. The acidity of fresh-cut mangosteen with treatment calcium chloride concentration (%) and immersion time (minutes).

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2.95-3.50. Calcium chloride causes the acidity of fresh-cut mangosteen to increase during storage This also indicates the breakdown of carbohydrates into sugar or a reduction in total acid because it is used as a substrate in the process of respiration (Liu *et al*., 2021). Furthermore, prolonging the immersion time of fresh-cut mangosteen in calcium chloride solution increases acidity. However, the process of increasing and decreasing the acidity depends on the total acid content in the fruit. Furthermore, according to Awad *et al*. (2021), the acid content of fruits will reach a maximum during growth which then decreases during storage.

3.5 Total dissolved solids

The treatment with calcium chloride depending on the concentration and immersion time and their interaction has a very significant effect on the total dissolved solids of fresh-cut mangosteen during storage. The total dissolved solids of fresh-cut mangosteen are shown in Figure 6. It is seen that the total dissolved solids of fresh-cut mangosteen increased during storage from 21.00-25.30°Bx. Furthermore, the higher concentration of calcium chloride increased the number of total dissolved solids. This was due to the increasing number of calcium ions that bind with fruit pectic acids to form Ca-pectates, which inhibit the process of respiration and the breakdown of sugar into organic acids. Sobral *et al*. (2017), reported that the Total dissolved solids inhibited the decrease in ascorbic acid and had a positive effect on the prevention of the oxidation process, therefore extending the shelf life. Furthermore, immersion of fresh-cut fruit in calcium chloride increased the calcium content in tissues which is capable of reducing respiration rate. According to Cofelice *et al*. (2019), decreased respiration rates delay the change of starch to glucose. In addition, during the storage process, the Total dissolved solids increase due to fruit ripening and will continue to increase during storage. At the end of storage, a decrease in glucose levels occurs because it was continuously used as a respiration material throughout the storage process. According to Zheng *et al*. (2012), when starch hydrolysis forms glucose, the fruit glucose levels increase. However, the decrease in fruit glucose levels occurs, because it is used as a basic ingredient for the respiration process.

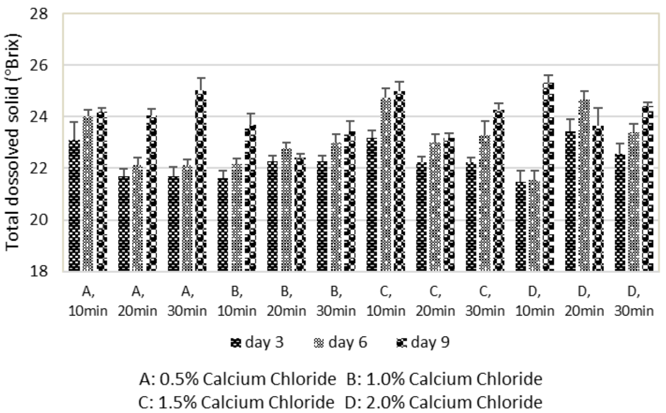

Figure 6. Total dissolved solids of fresh-cut mangosteen with treatment calcium chloride concentration (%) and immersion time (mins)

3.6 Water content

Water content is an essential factor that affects fruit quality (Colás-Medà *et al.*, 2016). Furthermore, the physicochemical and microbiological quality of food is affected by water. The observations showed that the treatment with calcium chloride depending on the concentration and immersion time and their interaction has a very significant effect on the water content of fresh -cut water mangosteen during storage. The water content value of fresh-cut mangosteen was 78.85-83.91% as shown in Figure 7. According to Palakawong and Delaquis (2018), mangosteen has a water content of 82.6±0.2%. High water content was obtained with 1% calcium treatment and an immersion time of 1 min. This implies that the treatment with calcium chloride was able to maintain the water content of fresh-cut mangosteen fruit during storage. Colás-Medà *et al*. (2016) reported that changes in pear hardness are related to changes in water mobility. Calcium is capable of strengthening the cell structure and affecting hardness by increasing membrane integrity for cell turgor pressure to increase as well (Khaliq *et al*., 2015). Meanwhile, according to Zhang *et al*. (2020), calcium ions form cross-linking causing the pectin to be soluble in water. Consequently, water remains in the tissue, therefore the application of calcium in fresh-cut mangosteen can maintain tissue integrity and turgor cells for the fruit quality to be maintained.

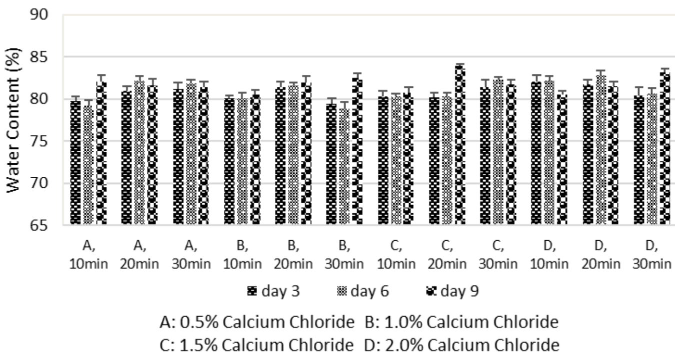

Figure 7. The water content of fresh-cut mangosteen with treatment calcium chloride concentration (%) and immersion time (mins)

3.7 Weight loss

The treatment with calcium chloride depending on the concentration and immersion time and their interaction showed very significant differences in the

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weight loss of fresh-cut mangosteen (Figure 8). It was observed that calcium treatment causes an increase in weight loss until day 6 and decreases on day 9. Researchers have also reported that storage time is closely related to fruit weight and sugar content (Park *et al*., 2020). According to Nia *et al*. (2021), weight loss in fresh fruit is due to water loss. Therefore, treatment with calcium chloride at high concentrations is capable of reducing weight loss in fresh-cut mangosteen fruit. This is because the interaction of calcium with pectin in cell walls limits water loss (Kirtil *et al*., 2014). Furthermore, the addition of calcium leads to rigidity of the cell wall. This is due to the binding of calcium with pectic acid to form Ca-pectate, which reduces water permeability, therefore, reducing the rate of respiration and transpiration and inhibiting fruit weight loss (Khaliq *et al*., 2015).

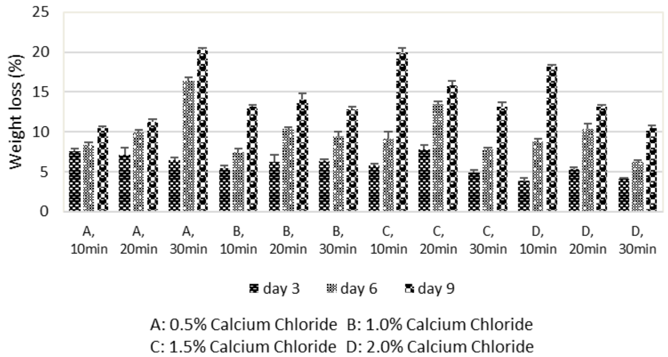

Figure 8. Fresh-cut mangosteen weight loss with treatment calcium chloride concentration (%) and immersion time (mins)

Increased weight loss is due to the metabolic processes of respiration and transpiration that occur during storage and fruit ripening, which leads to the loss of water and other organic matter. Awad *et al*. (2021), stated that plant tissues are in equilibrium with the atmosphere at the same temperature. Therefore, fresh-cut products are more susceptible to water loss because internal tissue is exposed due to skin and cuticle loss. Meanwhile, water in the intercellular space of whole fruit is not directly exposed to outside air, but in fresh-cut due to the process of cutting the interior tissue is exposed, leading to a drastic increase in the rate of evaporation. This was following the statement of Khaliq *et al*. (2015), that weight loss occurs immediately after the product is harvested and the rate of weight loss depends on the surface area of the product and environmental conditions. Furthermore, prolonged immersion time in calcium chloride solution results in the decreased weight of fresh-cut mangosteen.

4. Conclusion

The treatment of calcium chloride concentration, immersion time, and their interactions affected all variables of browning and quality changes of fresh-cut mangosteen. The best treatment that can delay browning and the quality changes of the fresh-cut mangosteen fruit is a concentration of 1% calcium chloride with an immersion time of 10 mins to 9 days at a cold storage temperature of (7±1)°C.

Conflicts of interest

The authors declare that there were no commercial or associative interests representing a conflict of interest in connection with this manuscript. Also, there were no financial and personal relationships with other people or organizations, capable of inappropriately influencing the report.

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