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Study of modified breadfruit starch (*Artocarpus communis*) edible coating with red galangal extract (*Alpinia purpurea*) on the quality of sapodilla (*Manilkara zapota* L.)

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Abstract

Tropical areas like Indonesia have an abundance of economically useful plants known as the sapodilla (*Manilkara zapota* L.). There are edible coatings available to preserve the delicacy of the sapodilla. Finding the optimal ratio of red galangal extract to breadfruit starch edible coating was the aim of this study in order to enhance the sapodilla fruit's quality. The study employed an experimental method employing Factorial RAL (completely randomized design) with several treatments of breadfruit starch concentrations, including concentrations of 1%, 2% and 3% that were stored at cold (8°C) and room temperatures. Based on the findings of the study, it can be concluded that a 2% concentration of breadfruit starch at cold temperatures (8°C) with a shelf life of 18 days was the best concentration treatment with a water content value of 77.5478%, a weight loss of 11.4123% and a total number of microbe colonies of 1.22E+7 CFU/g.

1. Introduction

The sapodilla fruit is one of the many types of fruits found in Indonesia. The sapodilla fruit has a high economic value. According to data from the West Sumatra Central Bureau of Statistics, sapodilla production fluctuated between 2016 and 2020. The production of sapodilla reached 7,276 tons in 2016, 6,891 tons in 2017, 8,706 tons in 2018, 5,600 tons in 2019 and 8,247 tons in 2020. Tanah Datar District produces the most sapodilla fruit in all of West Sumatra.

Sapodilla fruit (*Manilkara zapota* L.) is susceptible to postharvest deterioration. Physical, mechanical and microbiological forms of damage may be incurred. The perishable nature can result in problems that are detrimental to both farmers and business owners. In general, ripe sapodilla fruit can be maintained in good condition for 3 to 5 days. The short shelf life of sapodilla, the abundance of sapodilla production during the main harvest and distribution delays have resulted in the price of sapodilla falling rapidly and reducing the selling price to a point where it cannot be sold well on the market (Putri *et al*., 2021). The level of fruit maturity is determined by the climacteric tendency of the fruit, the day after flowering, and the physical condition of the fruit such as the color of the fruit skin. The process of determining the ripeness of harvested fruit is usually done by random sampling as measured by the dissolved solids of the fruit. Quality parameters are shown in differences in starch content, total dissolved solids, hardness, acidity and fruit color (Garnida *et al.*, 2022). 16 to 20% of sapodilla fruit is sweet. Sapodilla meat contains fat, protein, vitamins A, B and C, phosphorus, calcium and iron minerals, as well as folic acid, which aids in the formation of human red blood cells. According to Rahayu and Eris (2017), the sapodilla fruit has a skin that is so thin that it causes the fruit to rot quickly and has a short shelf life. Harvested sapodilla fruit continues to produce ethylene rapidly and abruptly from the ripening phase to the decay and damage caused by the sapodilla plant, which is still carrying out respiration and metabolism processes. One of the measures that can be taken to improve the quality of sapodilla fruit is to apply a layer of edible coating after harvest.

The edible coating is a thin membrane composed of consumable ingredients. Edible coatings on foodstuffs can be used to create a protective layer because they function as a barrier capable of retaining moisture against certain gases and regulating the migration of water-soluble components that influence nutritional composition changes (Abdel Aziz and Salama, 2021). Giving a thin layer on the surface of fruit or vegetables serves to keep the gas contained in the fruit from escaping, and inhibits water vapor and oxygen contact so

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that physiological processes can be inhibited. The coating that is given to fruits or vegetables usually does not contain harmful compounds so they can be consumed with these fruits or vegetables (Khalid *et al*., 2022).

The purpose of edible coatings is to prolong the fruit's shelf life, preserve its quality, prevent it from quickly rotting and slow the rate of respiration and ripening. In addition to controlling gas exchange, edible coatings can block moisture that is detrimental to products (O_2, CO_2 and ethylene). Hydrocolloids (proteins, polysaccharides and alginates), lipids (fatty acids, acyglycerols, or waxes) and composites are the three classifications of edible coatings (Raghav *et al.,* 2016). One of the starches and polysaccharide/ carbohydrate groups that can be used to create edible coatings is breadfruit starch.

Breadfruit is a source of carbohydrates with sufficient potential to be developed as a staple food, but it has not yet become a staple food for Indonesians, although breadfruit production is rising. In relation to this issue, it is necessary to increase and maximize the benefits of breadfruit through the processing of breadfruit into starch because breadfruit has a relatively short shelf life. Additionally, breadfruit starch can be used as a raw material for the production of edible coatings. Because the hydrophilic nature of starch affects film stability, edible coatings made from starch have a low resistance to water, which can shorten the shelf life of the material, allowing moisture and microorganisms to easily enter and deteriorate food ingredients (Kumar *et al*., 2022)

Adding other ingredients with hydrophobic properties or antimicrobial properties is one method for addressing the increase in the physical and functional properties of starch-based edible coatings. Adding red galangal (*Alpinia purpurata*) is one of the options. According to Tang *et al*. (2018), the principal components of red galangal extract are terpenoids, phenylpropane with branched phenol chain chains, and phenol ethers. This substance is bactericidal (including against mycobacteria), fungicidal and capable of destroying lipophilic viruses. According to Maringgal *et al*. (2020), the essential oil and hydrodistilled liquid extract of red galangal contained 42 essential oil constituents, with α-pinene, β-pinene and β-caryophyllen serving as the principal components. Antimicrobial terpenoid compounds are experts at damaging bacterial cell membranes, whereas essential oils are experts at preventing the growth or killing of bacteria by interfering with the process of forming membranes or cell walls so that they are not formed completely or at all, resulting in a disruption of cell osmotic pressure and the death of microorganisms. According to Ferreira *et al.* (2018), the essential oils of the red *Alpinia purpurata* (*Zingiberaceae*) cultivar can prevent and inhibit the growth and development of gram-positive and gram-negative bacteria.

This study's objective was to determine the optimal concentration of breadfruit starch edible coating with the addition of red galangal extract for enhancing the quality of sapodilla fruit.

2. Materials and methods

2.1 Materials and instruments

The tools used in this study were knives, blenders, spoons, filters, plastic tubes, thermometers, filter paper, label paper, aluminum foil, stopwatches, filter cloths, a set of chemical analysis tools, a refractometer, a force gauge, a digital scale, a mixer cooler, basin, oven, 80 mesh sieve, vortex scientifica, incubator, petri dish, pipette, micropipette and heating magnetic stirrer. The main ingredients in this study were 300 sapodilla fruits, breadfruit starch, red galangal extract, distilled water and sodium metabisulfite.

2.2 Research preparation

This experiment utilized a completely randomized design (CRD) with the addition of red galangal extract and storage temperature. The concentrations of breadfruit starch employed were 1%, 2% and 3% (Ringo *et al*., 2021). The research involved the preparation of equipment and materials, the production of breadfruit starch, red galangal extract, edible coating solutions and the collection of data.

The sapodilla used in this study was collected directly from Tanah Datar District, West Sumatra, farmer's gardens. The harvested sapodilla fruit was transported to the Food and Agricultural Product Processing Engineering Laboratory within the Department of Agricultural Engineering and Biosystems for cleaning. Using clean water (sorting) and drying, the sapodilla cleaning procedure was to remove dirt from the sapodilla fruit (Ringo *et al.*, 2021). Numerous samples were utilized at each storage temperature (cold temperature and room temperature), along with three replicates and a control, with each storage temperature having three replicates. Each repetition consisted of 1 unit of sapodilla fruit, which caused daily damage to 12 sapodilla fruits at cold temperatures and 12 sapodilla fruits at room temperature. This study included destructive observations on 276 sapodilla fruits (five observations) and non-destructive observations on 24 sapodilla fruits (one observation), for a total of 300 sapodilla fruits as samples. The measurement of this research was conducted using the Completely

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Randomized Design (CRD) Factorial experimental method which has two treatments, namely the provision of different concentrations of edible coating of breadfruit starch with the addition of red galangal extract and storage temperature. The difference in the concentration of breadfruit starch in edible coating consists of three levels of concentration and two levels of temperature with 3 replications with factors A and B can be seen in Table 1.

Table 1. Treatment combination.

Factor A (Storage Temperature)	Factor B (Concentration edible coating red galangal extract)			
Room temperature (A0)	A0B0	A0B1	A0B2	A0B3
Cold temperature 8°C (A1)	A1B0	A1B1	A1B2	A1B3

A0B0: control (without coating) at room temperature, A0B1: 1% concentration at room temperature, A0B2: 2% concentration at room temperature, A0B3: 3% concentration at room temperature, A1B0: control (without coating) at cold temperature, A1B1: 1% concentration at cold temperature, A1B2: 2% concentration at cold temperature and A1B3: 3% concentration at cold temperature.

2.2.1 Preparation of breadfruit starch

The breadfruit starch extraction process utilizes the method developed by Aliyah *et al*. (2021), which involves cleaning, peeling and chopping breadfruit into small pieces (sizing down). Then, sodium metabisulfite solution was utilized in the soaking procedure (5 g of sodium metabisulfite is dissolved in 1000 mL of distilled water). The breadfruit was subsequently soaked for 30 mins. Next, the mixture was crushed in a blender and filtered by squeezing it through a filter cloth. The starch solution obtained was then precipitated for 24 hrs to separate the starch from the water. The starch precipitate was dried in an oven at 50°C for five hours and then sieved through a mesh size of 80.

2.2.2 Preparation of red galangal extract

The red galangal rhizome used has a pink hue, smooth, shiny skin, was undamaged and was perforated. The galangal rhizomes are washed in running water so that foreign (unwanted) particles do not become entrained. Then, the galangal rhizomes were dried using the aeration method, after which the skin was removed and the rhizomes were ground in a blender. Using a filter cloth to remove sediment, the extracted galangal was then separated.

2.2.3 Production of edible coating

The edible coating is composed of breadfruit starch and red galangal extract. The breadfruit starch (10 g, 20 g and 30 g) was homogenized in 1000 mL of distilled water and then heated until it reached gelatinization temperature (Sulistyana and Handayani, 2021). The gelatinization temperature of breadfruit starch was 70 to 75°C (Widowati, 2016). After the temperature of gelatinization had been reached, 7% red galangal extract was added (Ayu *et al*., 2020). Stirring was used to incorporate red galangal extract until the solution was homogenous. Whole sapodilla fruit was dipped for 30 s in a homogenous edible coating solution and then drained for 10 minutes at room temperature on a perforated tray. After the sapodilla was completely dried, it was stored at cold temperatures.

2.2.4 Physicochemcial analysis

2.2.4.1 Moisture content

The moisture content was conducted following (Sudarmaji *et al*., 2021). Observation of sapodilla water content was carried out using the oven method. The container (aluminum foil) was weighed, and the thin slice sample was placed on the aluminium foil and weighed up to 10 g using a digital scale. The sample was dried in an oven at 105°C for 6 hrs or until the weight did not change significantly anymore. The samples were removed from the oven and were weighed to calculate the water content. Water content during storage can be calculated using the following formula:

$$\mathrm{KA}\ (\%) = \frac{b-c}{b-a} \times 100\% \qquad (1)$$

Where KA = Water content (%), a = Weight of container/aluminum foil, b = Weight of container + sample before oven (g) and c = Weight of container + sample after oven (g).

2.2.4.2 Weight loss

Weight loss is a decrease or loss in the weight of a commodity. Weight loss of sapodilla during storage was calculated using the following formula:

$$\text{Weight loss}\ (\%) = \frac{W_o - W_n}{W_o} \times 100\% \qquad (2)$$

Where W_o = initial weight of sapodilla (g) and W_n = sapodilla weight on nth day (g).

2.2.4.3 Total dissolved solids

Total dissolved solids were measured using a refractometer. The liquid from the material to be tested was dropped on the refractometer glass. The value obtained on the refractometer was in °Brix units.

2.2.4.4 Vitamin C test

Vitamin C levels refer to the iodine titration method. A total of 10 g of sample was weighed, crushed, then put into a 250 mL measuring flask and distilled water was added up to the tera mark. The solution was filtered using filter paper and 25 mL of the filtrate obtained was

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put into a 125 mL Erlenmeyer flask and 2 mL of 1% starch solution was added as an indicator. The solution was titrated with a standard 0.01 N iodine solution. The calculation of vitamin C levels was based on the following formula:

$$C = \frac{V \times F \times P \times 100}{B} \quad (3)$$

Where C = vitamin C content (mg/100 g sample), V = amount of 0.01 N iodine solution titrated (mL), P = dilution factor, F = mg vitamin C/mL dye solution and B = sample weight (g).

2.2.5 Total Microbial Count

The total microbial count was conducted following (Kurnia, 2021). Total microbial count test analysis is carried out using the dilution method. A total of 10 g of sample was weighed and mixed with 90 mL of physiological NaCl and then homogenized. A serial dilution by using the physiological saline was done up to 10^{-5}. One mL of each dilution was placed in a sterile petri dish. PCA media was added, then homogenized by swirling gently and incubated for 48 hours. The number of microorganisms was calculated using the following formula:

$$A = B \times \frac{1}{C} \quad (4)$$

Where A = number of colonies per mL or per gram, B = number of colonies per plate and C = dilution factor.

3. Results and discussion

3.1 Moisture content

Moisture content refers to the amount of water present in a fruit or other product. The moisture content of sapodilla fruit coated with edible breadfruit starch and red galangal extract serves as a criterion for evaluating the fruit's quality. The results of observing the water content of sapodilla fruit treated with edible coating at varying concentrations with the addition of red galangal extract are depicted in Figure 1.

During the storage period, the water content of each treatment increased daily, as shown in Figure 1. With a water content value of 77.5478%, A1B2 was the most effective treatment. This indicates that the 2% concentration treatment was more effective than other treatments at preserving the water content and quality of sapodilla fruit. During the storage period, the moisture content of the sapodilla fruit in this study varied between 70 and 77.5%. According to Alrashood *et al*. (2020) the water content of sapodilla manila ranges between 69 and 75.7%. The average water content of sapodilla fruit without a coating was greater than that of sapodilla fruit with a coating (Ringo e*t al*., 2021). This demonstrates that the edible breadfruit starch coating can inhibit the respiration process in sapodilla fruit, thereby reducing evaporation.

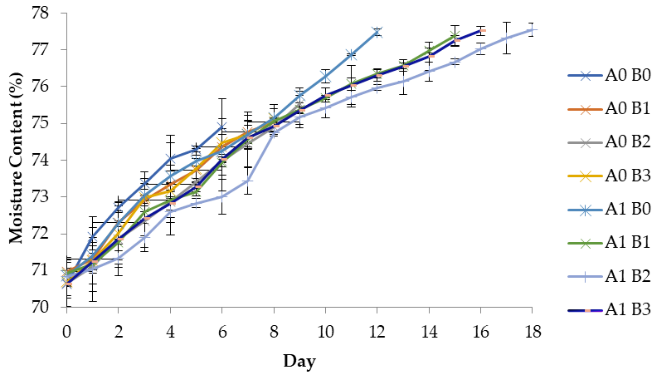

Figure 1. Analysis of moisture content of sapodilla fruit during storage. Description of the legend refer to Table 1.

The water content of sapodilla fruit was affected by the cold temperature and room temperature during storage because the colder the storage temperature, the more effective it was at inhibiting the process of water evaporation from the fruit, thereby maintaining the fruit's water content. Cooling to the ideal temperature has been shown to effectively slow respiration, thereby impeding aging, maturation and heat dissipation (Alabi *et al*., 2021). The main factors that cause horticultural products to lose water are temperature and humidity. In this study, cold temperature treatment was able to preserve the quality of the sapodilla fruit without causing it to ripen.

3.2 Weight Loss

Weight loss is one of the measured observation parameters that was used as a reference for determining the effect of the treatment administered in this study to determine the quality of sapodilla fruit. The results of observing the weight loss of sapodilla fruit treated with an edible coating at varying concentrations and red galangal extract are depicted in Figure 2.

Figure 2 shows that over the course of the storage period, each treatment's weight loss value increased daily. With a weight loss value of 11%, a smaller decline than other treatments, and the capacity to preserve sapodilla quality for a longer period of time than other treatments, A1B2 was the most effective weight loss strategy. This indicates that when stored at room temperature or in a cold environment, respectively, the edible coating concentration of 2% inhibits water evaporation more effectively than the control, concentrations of 1% and 3%. Sapodilla fruit treated with a concentration of 2% and stored at cold temperatures retained its quality for 18 days. The A0B0 treatment resulted in the greatest weight loss, indicating that the untreated fruit could not maintain the weight loss because there was no additional resistance to the continuous water vapor process. The A0B0 treatment could only maintain the quality of sapodilla at room temperature for six days. Kanani *et al*. (2018) determined that the cassava peel edible coating was able to significantly reduce the weight loss of sapodilla fruit compared to sapodilla fruit that was not coated with cassava peel. Loss of water during the storage process not only reduces fruit weight loss but also reduces fruit quality and causes damage. Weight loss occurs due to the breakdown of complex compounds into simple compounds, loss of water in large quantities can cause fruit to wither and wrinkle (Suriati, 2022). The loss of water in the fruit is closely related to the rate of respiration and transpiration in the fruit skin.

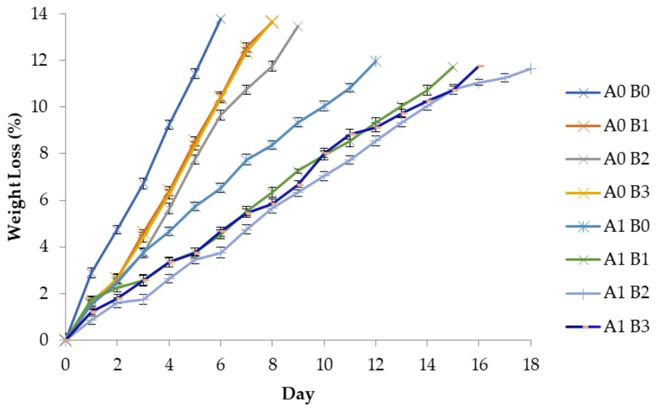

Figure 2. Analysis of sapodilla fruit weight loss during storage. Description of the legend refer to Table 1.

The application of an edible coating to sapodilla fruit influences weight loss because it can reduce the daily percentage increase in weight loss of sapodilla fruit during storage. The fruit's condition was preserved and water vapor was retained due to the edible coating's ability to slow down respiration and water vapor transmission. Furthermore, it has been demonstrated that low temperatures slow down the evaporation process, which results in a negligible weight loss percentage value during storage. This means that temperature also affects the weight loss value of sapodilla fruit. Jurić *et al*. (2023) reported that storing goods at low temperatures can also prevent the process of water evaporation by reducing respiration more effectively than storing them at room temperature. Cold storage was the most effective way to maintain the freshness of horticultural products.

3.3 Total dissolved solids

Total dissolved solids are the total amount of sugar in a product. Total dissolved solids are one of the parameters used to determine the storage quality of sapodilla fruit. Figure 3 displays the results of observations of the total dissolved solids of sapodilla fruit treated with an edible coating at varying concentrations with the addition of red galangal extract.

Figure 3 demonstrates that the value of total dissolved solids has increased and decreased for each treatment. With a total dissolved solids value of 23.5° Brix, A0B2 was the most effective treatment. Depending on the length of storage, the sap content of sapodilla fruit tends to decrease. The sweetness of a fruit is proportional to its total dissolved solids. This is because the longer a fruit ripens, the more complex compounds such as starch are converted into simple sugars, resulting in a sweeter flavor (Chettri *et al*., 2023). The presence of an edible coating and cold temperature storage has an effect on the value of total dissolved solids in sapodilla fruit because they can inhibit the respiration process of sapodilla fruit and preserve total dissolved solids (sugar content) in sapodilla fruit. The inhibition of respiration and the activity of enzymes that cause ripening can maintain the sugar content and prevent the acid content from decreasing in sapodilla fruit (Khaliq *et al*., 2019) During the ripening process, non-climacteric fruits store sugar, whereas climacteric fruits store carbohydrates in the form of flour (starch). The flour will be transformed into sugar as the fruit ripens (Aini *et al*., 2019).

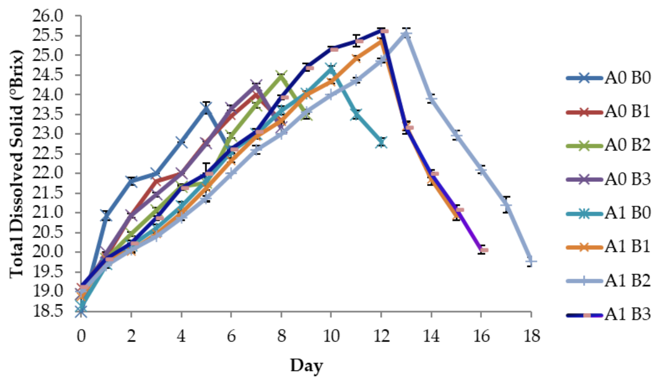

Figure 3. Analysis of total dissolved solids of sapodilla fruit during storage. Description of the legend refer to Table 1.

3.4 Vitamin C test

In determining the quality of sapodilla fruit, the vitamin C test is one of the measuring criteria. Vitamin C is a water-soluble vitamin. Figure 4 depicts the observational results of vitamin C levels in sapodilla fruit treated with edible coatings of varying concentrations and red galangal extract. The levels of vitamin C in each treatment decreased during the storage period, as shown in Figure 4. The best treatment was vitamin C A0B3 with a concentration of 0.0542 mg/100 g. Several factors, including the effect of temperature, the effect of air oxidation, the effect of storage time and the effect of freezing, reduced the vitamin C content of sapodilla fruit during storage. Vitamin C levels decrease more rapidly at room temperature than at cold temperatures because the fruit ripening process is more complete at room

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temperature, causing wilting due to respiration and oxidation processes and the longer the fruit's shelf life, the lower the vitamin C level (Fitriani *et al.*, 2020). This was in agreement with research conducted by Maharsih *et al.* (2022), who reported that the coating treatment on pineapples had a greater effect on reducing the levels of lost vitamin C. This phenomenon was caused by oxidation carried out by oxygen on the levels of vitamin C contained. In general, pineapples that were given an edible coating had a smaller decrease in vitamin C than those that were not given an edible coating.

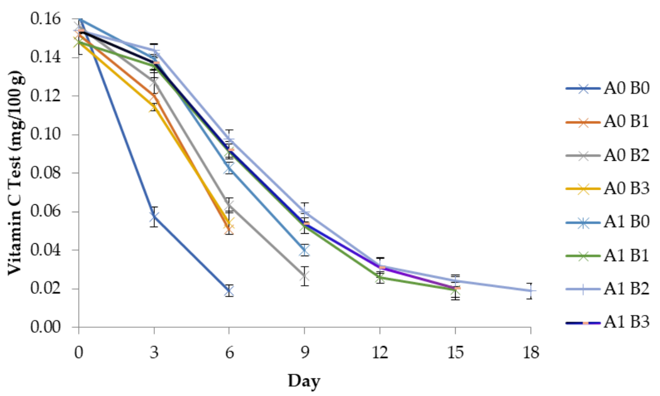

Figure 4. Analysis of vitamin C of sapodilla fruit during storage. Description of the legend refer to Table 1.

Edible coatings are capable of slowing down respiration and inhibiting rapid oxidation. Vitamin C content in fruit decreases as its maturity level increases (Wojdyla *et al.*, 2008). Due to the antimicrobial properties of red galangal, the addition of red galangal extract as an antimicrobial companion material was also able to maintain vitamin C levels in sapodilla fruit without causing stress to the fruit. The greater the number of microorganisms that grow on fruit, the greater its impact on vitamin C levels. As an antimicrobial, essential oil inhibits microbial activity, preventing the fruit from becoming stressed. The treatment of vitamin C levels in sapodilla fruit with temperature was also highly influential; the lower the storage temperature, the greater the respiration and oxidation, thereby delaying the loss of vitamin C levels in sapodilla fruit.

3.5 Total microbial count

Using the plate count agar (PCA) method, which is one of the measuring parameters for determining the quality of sapodilla fruit during storage, total microbes or microbial tests were conducted. Figure 5 depicts the results of total microbial observations of sapodilla fruit treated with an edible coating at various concentrations and red galangal extract. Figure 5 demonstrates that the total number of microbial count in each treatment increased over time. With a microbial value of 1.22E+7 CFU/g, total microbial A1B2 was the best treatment. This demonstrates that the 2% treatment was more effective than the other treatments at inhibiting the microbial development of sapodilla fruit because it contained the fewest colonies. As per the Maringgal *et al.* (2020), the number of colonies found in this study was still edible since the maximum contamination limit for fruit was 4.2E+8 CFU/5 g. Red galangal was used in edible coatings to inhibit the growth of microorganisms. This aligns with the findings of Ayu *et al.* (2020) study, which indicated that the sapodilla treated with edible coating but without red galangal extract had more microbes than the coating treatment that included red galangal extract. It demonstrated how the antimicrobial qualities of red galangal may help tomatoes last longer on the shelf. Furthermore, it highlighted the benefit of extending shelf life when anti-microbial active ingredients are added to edible coatings. Compared to the use of synthetic antimicrobials, the barrier qualities of the film layer reinforced by anti-microbial active ingredients can inhibit spoilage bacteria. Colder storage can also prevent microbial growth in comparison to room temperature storage, as microbes grow more quickly and are more active at room temperature than they are in colder environments. Most microorganisms cannot grow properly in low gas conditions. Furthermore, temperature has a significant impact because low temperatures help food products retain their shelf life, which can slow down metabolic processes (Anita *et al.*, 2023).

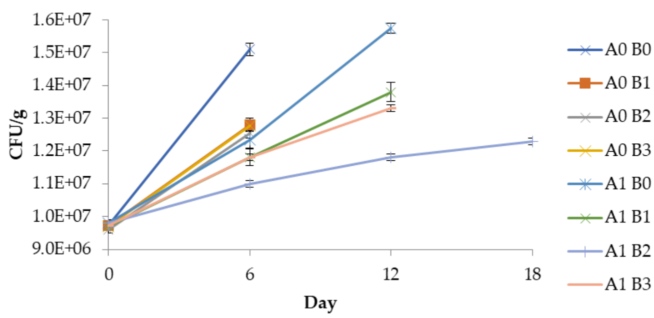

Figure 5. Total microbial analysis of sapodilla fruit during storage. Description of the legend refer to Table 1.

4. Conclusion

Based on the data obtained in this study, breadfruit starch treated with an edible coating at a concentration of 2% during cold storage was the most preferred. This has a significant impact on the weight loss parameter, which has a value of 11%, and total microbes, which has a value of 1.22E+7 CFU/g. However, the water content parameter was not significantly affected.

Conflict of interest

The authors declare no conflict of interest.

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