Research Article

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Quality changes of durian pulp (*Durio ziberhinus* Murr.) in cold storage

https://doi.org/10.1515/chem-2024-0091
received June 8, 2024; accepted September 1, 2024

Abstract: In this study, the effects of four types of polystyrene (PS) plastic box with polyethylene terephthalate (PET) lid (PSPET), PS tray with polyethylene (PE) bag (PSPE), PS tray with a vacuumed PE bag (PSVPE), and PET box with a sealed lid (PET) on the quality of durian fruit during storage at 10°C were investigated. The analysis results showed that in all four types of packaging, the total aerobic bacteria count in the durian pulp ranged from 10^1 to 10^5 CFU/mL after storage. However, total yeast and mold count was not detected. During the same survey period, PET packaging for the product had the lowest weight loss of 0.58–3.07%. Next, the impact of temperature, at 0 and 10°C, on the quality stability of durian fruit during storage was also studied and evaluated. Durian pulp preserved in PET at two different cold temperatures did not show any significant difference in microbial content and phytochemical composition. Total aerobic bacteria count in the samples was recorded at about 10^4 CFU/g after storage; total yeast and mold count was not detected, and the weight loss reached 1.82 and 1.72% at temperatures of 0 and 10°C, respectively.

Keywords: Ri6, packaging, phytochemical composition

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1 Introduction

Durian (*Durio zibethinus* Murr.) is commonly found in the tropics, particularly in Southeast Asian countries, including Malaysia, Thailand, Indonesia, and the Philippines. Its scientific name is *Durio zibethinus* Murr. and its English name is durian. The nine edible Durio species are *D. lowianus*, *D. graveolens* Becc., *D. kutejensis* Becc., *D. oxleyanus* Griff., *D. testudinarum* Becc., *D. grandiflorus* (Mast.) *Kosterm. ET* Soeg., *D. dulcis* Becc., *Durio* sp., and *D. Zibethinus*. In contrast, only the *Durio zibethinus* species is commonly cultivated and harvested. Approximately the size of a coconut, durian fruit is round or oval in shape and green or yellowish-green in color. Each compartment of the durian's peel typically contains bright yellow fruit flesh (depending on the variety) and huge orangish-brown seeds. The durian peel also bears a number of sharp, stiff spines. The flavor comes from volatile sulfur compounds, and the flesh is soft, fatty, and aromatic. There are substantial changes in the composition of durians from different regions. A total of 26 volatile chemicals were discovered in durians from Singapore and Malaysia, including 12 aliphatic esters, 2 aldehydes, 4 alcohols, and 1 aromatic compound [1]. Ethyl 2-methylbutanoate was found to be the primary component of the distinctive scent among them. Numerous phenolic compounds with antioxidant, antiallergic, anticancer, anti-inflammatory, and antibacterial properties are present in durian and are used in a variety of pharmaceutical formulations. In Vietnam, several varieties of durian are widely circulated in the market, including Ri6, Monthong, Chuong Bo, Kho Qua, and Cai Mon. Particularly, Ri6 is widely cultivated and the most prevalent compared to other durian varieties. Due to its large planting area and its presence across all provinces of Vietnam, Ri6 became a readily available and accessible raw material, thereby contributing to the economic efficiency of the growers and related industries.

Minimally processed food is the application of straightforward methods to increase shelf life without the use of heat or chemicals to the point where it compromises the freshness of ingredients. Peeling, cutting, washing,

de-seeding, cutting, shaping, and packaging are typically required to minimize processing. Minimal processing method preserves the nutritional and sensory qualities of the fruit while protecting its structure and safety for all customers. Minimization of physical damage during processing can result in higher respiration rates and higher ethylene production in fruits with peak growth [2]. According to Rivera-López et al. temperature affects the material's respiration rate [3]. As a result, it is crucial to study the effect of temperature in order to determine how it influences the minimally processed durian. As mentioned above, the respiration rate of the raw materials affects the shelf life of minimally processed vegetables [3–6]. Meanwhile, different types of packaging have different moisture and heat transfer abilities. Boonthanakorn et al. demonstrated the effectiveness of polyethylene terephthalate (PET)/polyethylene (PE) packaging in preserving durian [7]. In the same year, Mphahlele et al. showed that lychee fruits were well-preserved using PET at low temperatures [8]. Consequently, PET became widely available in the market. Additionally, polystyrene (PS) and PE were also commonly used packaging materials for preserving agricultural products due to their cost-effectiveness. These three types of packaging share a common characteristic of excellent water resistance. As a result, they were widely applied in the food packaging industry and became ideal subjects for research to meet the diverse needs of the market. Therefore, the influence of the type of packaging on the phytochemical changes of preserved fruits and vegetables is urgently needed to be investigated.

2 Materials and methods

2.1 Materials

The primary raw material employed in this investigation was *Durio ziberhinus* Murr., variety Ri6. The durian barn, located at 410 To Ngoc Van, Linh Dong ward, Thu Duc City, Ho Chi Minh City, sells durian from the Tien Giang province. The durian fruit features a yellow pulp, a dry surface, an average of 4–5 segments per fruit, a light yellow peel, and a distinctive aroma. The chemicals used were gallic acid, Folin–Ciocalteu 99.5% (Sigma, USA), methanol 99.5%, Na_2CO_3 99.5%, NaOH 96%, phenolphthalein 1%, ethanol 99.5%, Na_2SO_4 99.5%, potassium sodium tartrate, and DNS (Xilong, China).

2.2 Minimally processed durian

The sample preparation procedure was referenced from the study of Boonthanakorn et al. and Tan et al. [9,10]. Through the process of experimentation and adjustment, the procedure for preserving durian fruit was developed and is presented in Figure 1. First, the durian fruit, after being transported to the laboratory, was washed on the surface and dried, and the durian segments were separated using a knife. Durian pulp was quickly packed with various types of packaging, including PSPET, PSPE, PSVPE, and PET. Sample preparation was carried out at room temperature (23–25°C). Each experimental unit was 1 pack, equivalent to a mass of 150–200 g. Durian fruit, after packaging, was stored in a refrigerator at different temperatures (10 and 0°C, RH 75%). During the storage period of 16 days, every 4 days, the change in total aerobic bacteria count, total yeast and mold count, weight loss, water content, total acid content (TA), pH, total soluble solid (TSS), color difference (ΔE) and b^*, total polyphenol content (TPC), and sensory characteristics of durian pulp were analyzed and evaluated.

2.3 Phytochemical analyses

2.3.1 Weight loss

The experimental samples, which included the durian pulp and packaging, were weighed before storage using a balance (PA 214, OHAUS, USA) (W_1). The experimental

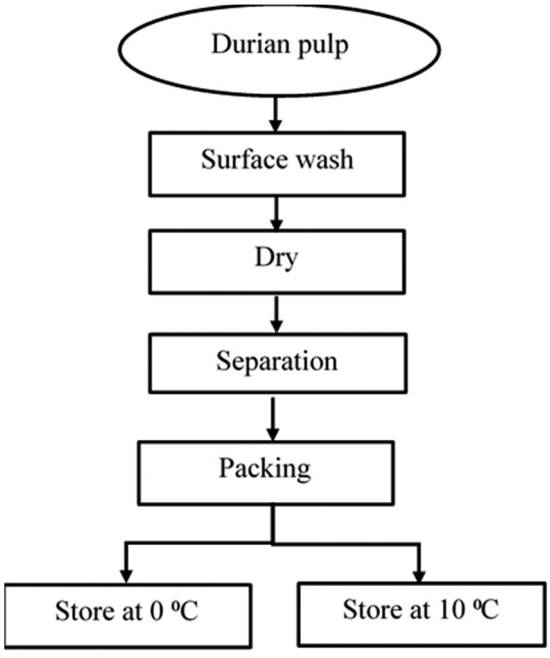


Figure 1: Graphical diagram for preservation of the durian pulp.

samples, which included durian pulp and packing, were evaluated following the storage period (W_2). The following formula was used to calculate the weight loss of samples of preserved duratian:

$$\text{Weight loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100,$$

where W_1 and W_2 represent the sample weight before and after storage.

2.3.2 TA content

The titratable acidity of durian was measured according to TCVN 5483-2007 standard. A total of 5 g of the pureed durian sample was made up to 50 mL with distilled water and filtered through filter paper 101. Next, 20 mL of the durian extract solution was added to a 100 mL conical flask; then, 2–3 drops of 1% phenolphthalein were added to the sample and mixed well. The sample for analysis was titrated with 0.1 N NaOH until the solution turned pink, which persisted for 30 s. The volume of 0.1 N NaOH used was recorded, and the amount of acid in the durian sample is expressed as a percentage of malic acid according to the following formula:

$$\text{TA(\%)} = \frac{V \times K \times V_2 \times 100}{V_1 \times m},$$

where TA (%) is the total acid present in the sample (converted to malic acid). V is the volume of 0.1 N NaOH (mL), V_1 is the sample extract volume (mL), V_2 is the volume of the volumetric flask (mL), K is the malic acid coefficient (0.0067), and m is the sample weight (g).

2.3.3 pH value

The pH value was determined using a pH meter (HI2211, Hanna, Romania). The pureed sample was combined 1:1 (g/g) with water. Prior to measurement, the sample was kept at room temperature. The electrode was cleaned with distilled water and then dried with fresh paper. Electrodes were then put into the analytical sample until the results on the electronic display stabilized. The meter was calibrated using 4.0 and 7.0 standard pH buffers before use.

2.3.4 TSS

A 1:9 (g/g) ratio of the pureed material to water was used in the mixture. To get a clear solution, the mixture was filtered through filter paper 101. Prior to measurements, the sample was kept at room temperature. The TSS of durian samples was determined using a handheld refractometer (PR-101 Alpha, Atago Japan). The prism surface was cleaned with distilled water and dried with fresh paper. After adding 2–3 drops of distilled water to the refractor glass to obtain the concentration to zero, 2–3 drops of diluted durian extract were added until the readings were displayed on the screen. TSS of the durian sample was calculated from the reading on the refractometer multiplied by the dilution of the sample.

2.3.5 Water content

The moisture content of the preserved durian samples was determined using an infrared moisture drying balance (MB90, OH, USA). A total of 0.5 ± 0.01 g of durian samples were weighed and dried at 105°C. The water content was displayed on the screen of a moisture-drying balance.

2.3.6 Total polyphenol content

The method was referenced according to Lim and Murtijaya [11]. A 0.3 mL of the extract and 1.5 mL of 10% Folin–Ciocalteu were mixed and shaken in a test tube. The mixture was allowed to stand for 5 min in the dark. Then, 1.2 mL of 7.5% Na_2CO_3 was added to the mixture and shaken well. The optical density of the sample was obtained at 765 nm after 30 min of reaction at room temperature (23–25°C) in the dark using a UV–Vis spectrophotometer (Evolution 60S, Thermo, USA). The total polyphenol content of the sample was obtained as milligrams of gallic acid equivalent per 100 g of dry matter.

$$\text{TPC} = \frac{(y - b) \times V \times \text{df} \times 100}{a \times m(100\% - \text{moisture\%}) \times 1{,}000},$$

where TPC is the total polyphenol content (mg GAE/100 g DM), y is the optical density value of the analyzed sample, a, b are coefficients in the gallic acid standard curve equation, V is the sample extract volume, df is the dilution factor, m is the weight of the sample, and 100/1,000 is the conversion factor (from μg/g to mg/100 g).

2.3.7 Total aerobic bacteria count and total yeast and mold count

The total number of aerobic bacteria was determined according to the standard TCVN 6406-2016. A total of 10 g of durian samples were weighed into a sterile 250 mL

Schott bottle containing 90 mL of sterile 0.85% saline and shaken well for 1 min. The suspension obtained had a 10^{-1} dilution. Furthermore, the next decimal dilution was prepared by aspirating 1 mL of this solution with a sterile micropipette into a test tube containing 9 mL of sterile 0.85% saline. The sample was vortexed to obtain a 10^{-2} dilution. The 10^{-3} dilution was performed similarly. First, three successive dilutions were selected so that the bacterial density present on the agar was 25–250 CFU/mL. Then, 1 mL of the sample with 10^{-1}, 10^{-2}, and 10^{-3} dilutions was transferred to sterile Petri dishes, respectively. Each dilution was inoculated into two Petri dishes. Next, the sterile PCA medium (plate count agar) at 45–50°C was placed in a Petri dish at the rate of 15–20 mL/plate. Immediately after that, the Petri dish was rotated clockwise 5–6 times and vice versa to help diffuse the sample solution into the medium. After the medium solidified, the plate was inverted and incubated at room temperature (29–31°C). After 48 h, the number of colonies appearing on the agar plate was recorded:

$$N = \frac{\Sigma C}{V \times (n_1 + 0.1 \times n_2) \times d},$$

where N is the density of total aerobic bacteria in 1 g of sample, C is the total number of colonies on the plates counted, n_1 is the number of plates counted at the first concentration, n_2 is the number of plates counted at the 2nd concentration, d is the dilution factor of the 1st concentration, and V is the volume of microbiological sample inoculated into the plate.

The procedure for preparing the samples for analysis and inoculation and the calculation formula was similar to the method for determining the total aerobic bacteria count. However, the preparation medium for determining total yeast and mold count was replaced with Dichloran Rose Bengal Chloramphenicol Agar (DRBC Agar).

3 Results and discussion

3.1 Effect of packaging type on the quality of durian pulp during cold storage

3.1.1 Total aerobic bacteria count, total yeast, and mold count

During the preservation process at a temperature of 10°C, the study observed an increase in the total amount of aerobic microorganisms. Aerobic microorganisms are a type of bacteria that thrive in oxygen environments. During the preservation of durian, aerobic microorganisms are often the main cause of rapid spoilage of the product, leading to cracking, softening, discoloration, and foul odors [12]. In the first 4 days of preservation, the total amount of aerobic bacteria was in the range of 2.0–9.5 × 10^1 CFU/g, but after 16 days of preservation, it increased by an additional 10^3 CFU/g. It is noteworthy that in the PSVPE, the total amount of aerobic microorganisms increased by 10^4 CFU/g after preservation. Gaseous compounds, including methane and hydrogen sulfide, are produced by bacteria and play a crucial role in their growth and development. As the storage time of durian increases, these gases are produced in greater quantities, promoting the growth of aerobic microorganisms [13]. Nutrients in durian include various types of sugars, amino acids, fats, and minerals such as potassium, magnesium, calcium, and iron, and antioxidants such as beta-carotene, vitamin C, vitamin E, and polyphenols that create a conducive environment for the growth of microorganisms, promoting their rapid development [14]. Overall, the experiment did not observe any growth in the total amount of yeast and mold, with a total amount of <10 CFU/g after 16 days of preservation (Table 1).

Table 1: Changes in aerobic microbial count and total yeast and mold content of durian segments stored at 10°C at different storage times

Evaluation criteria	Packaging type	Storage time (days)				
		0	4	8	12	16
Total aerobic bacteria count (CFU/g)	PSPET	2.0–3.0 × 10^1	3.0–6.5 × 10^1	1.3–2.8 × 10^3	6.0–6.2 × 10^3	2.7–3.1 × 10^4
	PSPE	2.0–3.0 × 10^1	4.5–7.0 × 10^1	2.2–2.8 × 10^3	0.7–1.1 × 10^4	2.6–3.2 × 10^4
	PSVPE	2.0–3.0 × 10^1	6.0–9.5 × 10^1	2.2–4.8 × 10^3	0.8–1.6 × 10^4	2.4–2.8 × 10^5
	PET	2.0–3.0 × 10^1	5.5–6.5 × 10^1	1.6–2.1 × 10^3	3.9–5.6 × 10^3	2.1–2.3 × 10^4
Total yeast and mold count (CFU/g)	PSPET	<10	<10	<10	<10	<10
	PSPE	<10	<10	<10	<10	<10
	PSVPE	<10	<10	<10	<10	5.0–7.5 × 10^1
	PET	<10	<10	<10	<10	<10

3.1.2 Weight loss and water content

The sample weight tended to decrease in all four types of packaging during the cold preservation process at 10°C (Figure 2a). The samples' weight decreased by 0.58, 1.45, 2.22, and 3.07% for PSVPE, PSPE, PSPET, and PET, respectively. The statistical analysis results showed that the type of packaging had a significant effect on weight loss at a 95% confidence level ($p < 0.05$). The LSD ranking test showed that the PSVPE packaging differed significantly from the

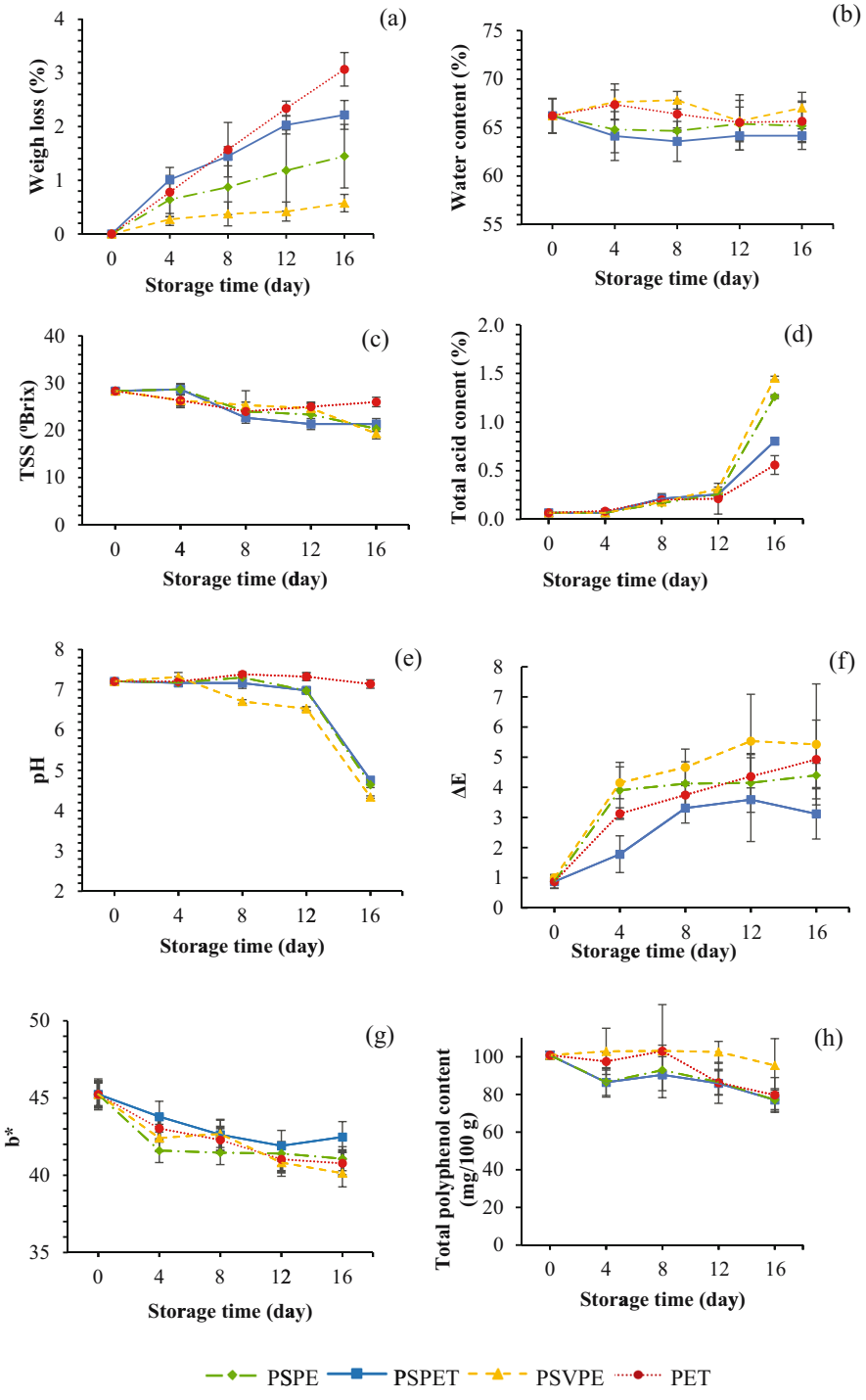


Figure 2: Variation of (a) weight loss, (b) water content, (c) TSS, (d) TA content, (e) pH, (f) color difference (Δ*E*), (g) *b**, and (h) polyphenol content of durian pulp stored in different packages.

PET, PSPE, and PSPET ($p < 0.05$). This phenomenon could be explained by water loss. After 16 days of preservation, the water content in the sample decreased from 65.22 g/100 g to 64.16 g/100 g (PSPET), 65.18 g/100 g (PSPE), 67.03 g/100 g (PSVPE), and 65.65 g/100 g (PET). Packaging materials such as PET and PE are waterproof. As such, they help prevent the evaporation of water from the product to the outside environment, helping to maintain the moisture inside the product. In addition, the PET box also has the best heat transfer ability, which helps protect the product from outside temperature changes.

3.1.3 TSS, TA, and pH

Figure 2c illustrates the type of packaging that affects the TSS of cold-preserved durian samples, which is statistically significant at a 95% confidence level ($p < 0.05$). After 16 days, the TSS of the sample stored in PET was 26 °Brix, while that of the sample stored in PSVPE was 19.33 °Brix. PET packaging has greatly reduced the exposure of the durian pulp to the outside air, thereby reducing the decomposition of organic matter in the durian pulp. Besides, PET packaging minimized decomposition and kept the TSS content of durians stable during storage, making the TSS content of durians at least 16 days of storage compared with other types of packaging. Unlike the slightly decreasing trend of TSS, the pH value decreased sharply after the preservation process (Figure 2d). In addition, the ANOVA results showed that the type of packaging had a statistically significant effect on the pH value of durian pulp samples at a 95% confidence level ($p < 0.05$). The LSD test showed that PSVPE had a significant difference compared to other types of packaging at a 95% confidence level. Specifically, on day 16, the pH values of durian pulp samples in PET, PSPET, PSVPE, and PSPE were 7.14, 4.76, 4.33, and 4.64, respectively. As predicted, Figure 2e shows that the TA of the durian pulp samples increased significantly during the preservation process. According to the statistical analysis results, the type of packaging had a statistically significant effect on the TA content at a 95% confidence level ($p < 0.05$) after 16 days of preservation. The highest and lowest TA values of durian pulp samples were achieved when preserved in PSVPE (1.45 g/100 g) and PET (0.56 g/100 g), respectively. The sharp increase in TA content of durian samples after 16 days of storage could be influenced by various factors, including the nature of the packaging, the degree of light exposure, the growth of bacteria and mold, and the natural aging process of durian fruit.

3.1.4 Color difference (ΔE) and b^*

Figure 2f and g illustrates the influence of storage time and packaging type on color change (ΔE) and b^* during storage. Across all packaging types, the study observed two distinct changes, where ΔE values increased from 1 to 5.43, and b^* values decreased from 45.24 to 40.13 during the investigated storage time. This suggests the decrease in the yellow color of the durian over time in storage. The yellow color of the durian fruit is mainly due to the presence of carotenoids, a pigment with antioxidant properties. When the durian pulp was stored in an environment with more oxygen, the carotenoids were oxidized, and resulted in color loss. In addition, enzymatic degradation may have caused discoloration due to colored reactants produced during this process. After storage, the difference in ΔE values between the two packaging types, namely PSVPE and PSPE, was 5.95 and 3.12, respectively, while for b^* values, it was 42.47 and 40.77, respectively. ANOVA results indicated that the packaging type did not significantly influence ΔE and b^* values during storage at a 95% confidence level ($p > 0.05$).

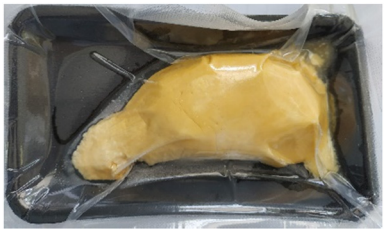
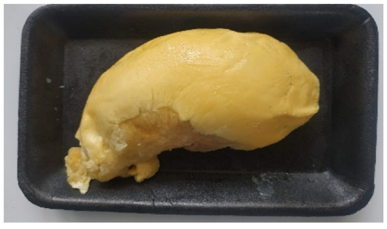
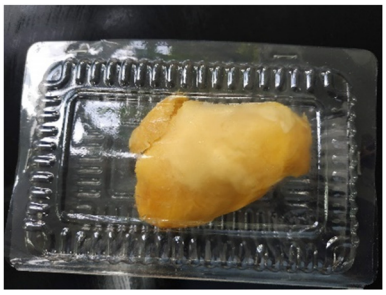
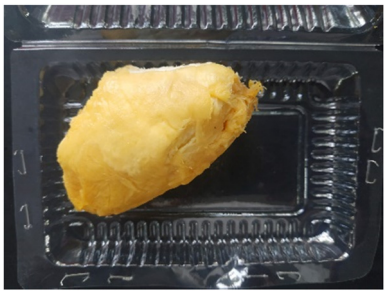
3.1.5 TPC

At the end of the preservation period, the total polyphenol content of the durian sample preserved in PSVPE reached the highest level at 95.39 mg/100 g dry material. This amount differed from those of the durian samples preserved in other types of packaging (77.04–77.09 mg/100 g dry material). In general, the polyphenol content represented by the graphs in Figure 2h tended to decrease over the preservation period from 95.39 (mg/100 g dry material) to 77.04 (mg/100 g dry material), corresponding to the preservation time from 0 to 16 days. Polyphenols are organic compounds with antioxidant properties and are widely found in fruits and vegetables. During storage, the durian pulp may have been exposed to oxygen, which caused oxidation and the breakdown of polyphenols into other substances. Besides, enzymatic degradation may also have caused the loss of polyphenols during storage.

3.1.6 Sensory characteristics

According to preliminary results of sensory, durian samples preserved in PET have a darker color than other preserved samples. However, the flavor of the fruit in this type

Table 2: Appearance of durian fruits after preservation in different types of packaging

Types of packaging	Before preservation	After preservation*
(A) PSPET		
(B) PSPE		
(C) PSVPE		
[D] PET		

*Images were recorded on the 16th day of storage.

of packaging still retained its characteristic taste. Meanwhile, the experimental samples in other types of packaging showed changes in flavor with some having a slightly sour taste and a strong odor. These results correspond to the changes in the pH value and TA presented above. Thus, it can be concluded that each type of packaging had different effects on the phytochemical and microbiological parameters of the durian pulp during preservation at a temperature of 10–12°C. The PET helped maintain values such as total aerobic bacteria, total yeast and mold count, TA, pH, and weight loss. Meanwhile, the PSVPE provided good results in terms of color stability and total polyphenol content. This phenomenon can be explained by the fact that under vacuum packaging (PSVPE), durian pulp was preserved under aerobic conditions to reduce the exposure of oxygen in the air to polyphenol compounds, limiting oxidation. However, under the influence of vacuum pressure, the durian pulp's structure was disrupted, and the flesh leaked (Table 2), creating conditions for the growth of microorganisms. The growth of microorganisms increased the TA content and decreased the pH value in the durian sample. For minimally processed products, fresh agricultural products continue to "live" and breathe and exchange moisture with the outside environment. This is one of the main reasons leading to the weight loss of the raw materials during post-harvest preservation. The moisture and gas transmission capabilities of different materials and packaging methods can lead to different levels of moisture loss in the durian during preservation. Through microbiological and phytochemical analysis, PET was selected as the optimal packaging material for further surveys. PET/PE

films were also selected for the Monthong durian preservation study [9]. Research on lychee fruit that had minimal processing also demonstrated that PET packing with 1.1 mm perforations could effectively preserve lychee fruit with denta E, TSS, TA, and pH values of 6.68, 17.88 °Brix, 0.19%, and 4.34, respectively [15]. However, multilayer nylon–poly packaging was chosen for the study on prolonging the shelf life of Butiá fruit when TSS, TA, pH, and L^* values for 11.13%, 1.25%, 3.30, and 69.09, respectively [16]. A study on the preservation of red cabbage demonstrated that polyvinylidene chloride (PVDC) packaging was capable of maintaining good phytochemical characteristics, such as phenolic content (296.35 mg kg^{-1}) and microbiological content (4.60 log CFU g^{-1}) [17].

3.2 Effect of storage temperature on the quality of durian pulp during cold storage

3.2.1 Total aerobic bacteria count, total yeasts, and mold count

Table 3 shows the changes in total aerobic microorganisms, total yeast, and mold count of durian pulp stored at 0 and 10°C at different storage times. The total aerobic microorganisms count in cold-stored durian samples was found to have an increase of 10^1 CFU/g after 8 days of storage. This count continued to increase and reached 10^4 CFU/g after 16 days of storage at 10°C. Cold temperatures reduced the growth rate and activity of aerobic microorganisms, especially bacteria, including *Pseudomonas* spp., *Aeromonas* spp., and *Bacillus* spp. When stored at a low temperature, they were unable to grow and develop quickly. When the storage time was increased, the product was exposed to the external environment and the microorganisms present in the product had consumed nutrients, decomposed organic matter and created decomposition products, substances, and gases such as methane, hydrogen sulfide, and ammonia.

3.2.2 Weight loss and water content

Sample mass tended to decrease at both storage temperatures (Figure 3a). The storage time lasted up to 16 days, and the weight losses of durian samples stored at 0 and 10°C were 1.82 and 1.72%, respectively. At this time, the water contents of the samples tested at 0 and 10°C were 67.82 g/100 g and 66.71 g/100 g, respectively (Figure 3b). Statistical processing results showed that storage temperature had no significant effect on both analytical parameters with a 95% confidence level ($p > 0.05$). When the product is stored for a long time, water in the product may have been evaporated or absorbed by the wrapping materials, which reduces the moisture content of the product and may have caused the product to become drier [18].

3.2.3 TSS, TA content, and pH

During storage, the TSS of durian samples at both temperatures tended to decrease, but there was no statistical significance at the 95% confidence level ($p > 0.05$). After the storage period, the TSSs of the two durian samples were 24.33 g/100 g and 23.67 g/100 g, corresponding to the storage temperatures of 0 and 10°C (Figure 3c). ANOVA results showed that storage temperature significantly affects the TA content at a 95% confidence level of durian samples ($p < 0.05$) after 16 days. The TA content was 0.09 g/100 g for the 0°C sample and 0.14 g/100 g for the 10°C sample (Figure 3d). In addition, storage temperature significantly affects the pH value of durian samples at the 95% confidence level ($p < 0.05$). These values are, as shown in Figure 3e, 7.1 for samples stored at 0°C and 6.87 for samples stored at 10°C. During the storage of the product, the molecules in the durian pulp may have come into contact with oxygen in the air, leading to an oxidation process that causes the fat molecules in the product to decompose into substances. Among them are organic acids such as acetic acid, butyric acid, propionic acid, and valeric acid. At the same time, oxidation also produced new substances called oxidizing

Table 3: Change in total aerobic bacteria count, total yeast, and mold count of durian pulp stored at 0 and 10°C at different storage times

Evaluation criteria	Temperature (°C)	Storage time (day)				
		0	4	8	12	16
Total aerobic bacteria count (CFU/g)	0	$1.0–2.5 \times 10^1$	$4.0–5.0 \times 10^1$	$1.4–2.3 \times 10^2$	$2.7–3.1 \times 10^2$	$2.6–4.0 \times 10^3$
	10	$1.0–2.5 \times 10^1$	$5.5–8.0 \times 10^1$	$2.1–3.2 \times 10^2$	$4.9–5.8 \times 10^2$	$0.6–1.0 \times 10^4$
Total yeast and mold count (CFU/g)	0	<10	<10	<10	<10	<10
	10	<10	<10	<10	<10	<10

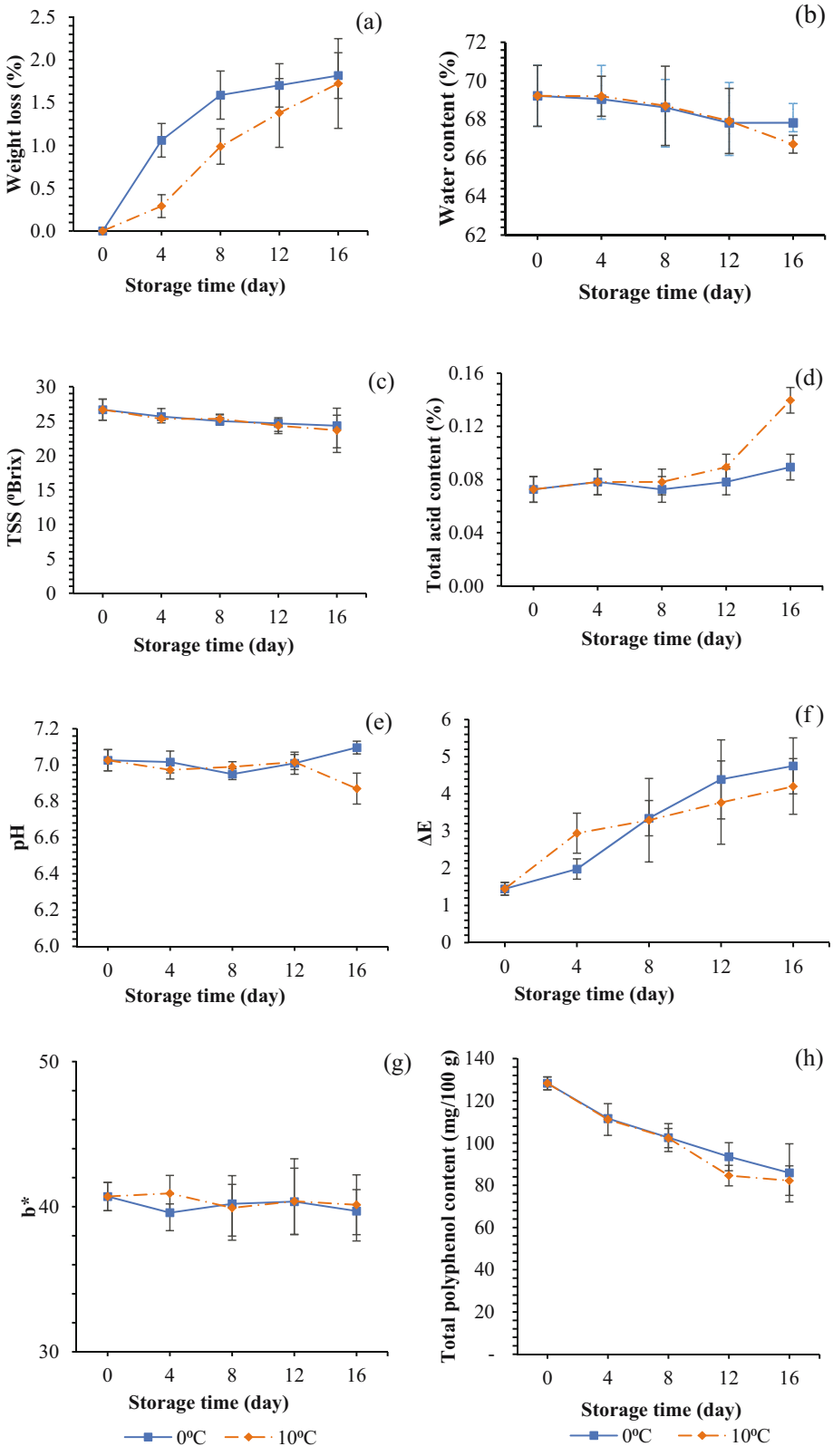


Figure 3: Variation in (a) weight loss, (b) water content, (c) TSS, (d) TA content, (e) pH, (f) color difference (Δ*E*), (g) *b**, and (h) total polyphenol content of the durian pulp stored at 0 and 10°C.

Table 4: Pearson correlation coefficients among the measured properties of durian pulp during cold storage

	Weight loss	Water content	TSS	TA	pH	Δ*E*	*b**	TPC	Aerobic bacteria count	Yeast and mold count
Weight loss	1.00									
Water content	−0.81*	1.00								
TSS	−0.87*	0.06	1.00							
TA	0.53	−0.1	−0.7*	1.00						
pH	−0.25	0	0.39	−0.64	1.00					
Delta *E*	0.8*	0.13	−0.92*	0.48	−0.16	1.00				
*b**	0.04	−0.96*	0.18	−0.12	0.13	−0.35	1.00			
TPC	−0.9*	0.07	0.97*	−0.61	0.24	−0.96*	0.17	1.00		
Aerobic bacteria count	0.56	−0.05	−0.66*	0.96	−0.55	0.51	−0.17	−0.61	1.00	
Yeast and mold count	0	0	0	0	0	0	0	0	0	1.00

*$p < 0.05$.

compounds, including aldehydes, ketones, alcohols, and hydroperoxides. This increased TA during storage at 10°C. However, at a temperature of 0°C, the TA value did not change significantly.

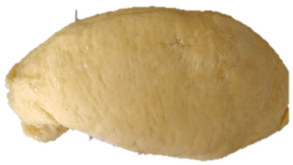
3.2.4 Color difference (Δ*E*) and *b**

Storage temperature did not significantly affect the color change Δ*E* (Figure 3f) and *b** (Figure 3g) of durian samples ($p > 0.05$) at the 95% confidence level. After 16 days of storage, the Δ*E* values of durian samples were 4.75 and 4.2, and the value stored at 0°C was higher than that at 10°C. In particular, durian samples stored at lower temperatures had higher *b** values. The difference in the *b** index between the two surveyed temperatures ranged from 39.7 to 40.13. Since the rate of chemical reactions was slower at lower temperatures, the separation and recombination of the product's various constituents was minimized. As a result, chemical processes in the product were slower under these conditions. Since then, aging and oxidation progressed more gradually, which helped to reduce the loss of yellow color at 0°C of the durian fruit during storage.

3.2.5 Total polyphenol content

Figure 3h shows that storage temperature has no significant effect on the total polyphenol content at a 95% confidence level ($p > 0.05$). At 10°C, this parameter decreased

Table 5: The appearance of durian pulp in PET after storage at different temperatures (0 and 10°C)

Temperature (°C)	Before preservation	After preservation
0		
10		

continuously with a storage time from 128.27 mg/100 g DM before storage to 82.19 mg/100 g DM after storage. The values were 85.88 mg/100 g DM at 0°C storage temperature and 82.19 mg/100 g DM at 10°C storage temperature. At a storage temperature of 0°C, the quality of durian samples was better maintained in most of the analytical parameters. However, not many parameters, such as water content, pH, TA content, and TSS content, had a statistically significant difference compared to the sample at a storage temperature of 10°C of the preserved durian samples. Under the same conditions, the lower storage temperature (0°C) increases the relative humidity content in the air, and the drainage capacity of durian samples is more limited. At the same time, the low temperature helps to limit the respiration and metabolic reactions of the raw materials. Besides, the temperature of 0°C helps minimize the growth of microorganisms present in durian samples.

3.2.6 Pearson correlation

There was a strong negative correlation between the weight loss–water content ($r = 0.81$, $p < 0.05$), weight loss–TSS ($r = 0.87$, $p < 0.05$), TSS–ΔE ($p = 0.92$, $p < 0.05$), and TPC–ΔE ($r = 0.96$, $p < 0.05$). In addition, the current study also showed a close positive correlation between the weight loss ($r = 0.80$, $p < 0.05$), TSS–TPC ($r = 0.97$, $p < 0.05$), and TA–total aerobic count ($r = 0.96$, $p < 0.05$). The reasons for these phenomena are explained previously (Table 4).

3.2.7 Sensory characteristics

According to the results of preliminary sensory characteristics, there were no obvious differences in color and taste between the two durian samples stored at two different temperatures. Table 5 shows the visual image of the durian fruit after 16 days of storage in PET. Based on the results of the phytochemical and microbiological analysis, as well as the applicability of the research results (energy saving, machine utilization capacity, and product cost reduction), the preservation temperature of 10°C was optimal. The obtained results were different from the study that evaluated the phytochemical properties of the minimally processed durian (*Durio zibethinus* cv. D24) at 4°C, which gave the values of L^*, TSS, pH, and the number of aerobic microorganisms of 74.68, 36.8%, 7.94, 0.07 g malic acid/100 g, and 1.65×10^4 CFU/g, respectively [19], and 5°C was selected for the study on minimally processed durian after 2 months for TSS values of three different varieties, including Duyaya, Nanam, Puyat of 26.67, 25.33, and 24.00 °Brix, respectively [20]. The weight loss of durian (*Durio kutejensis* (Hassk.) Becc.) was up to 48.21% when stored at 15°C for 12 days [21]. When durian was stored for 9 days at 8°C, the parameters, including weight loss, TSS, and L^* were 2.4%, 28.8 °Brix, and 7.9, respectively [22].

4 Conclusion

The phytochemical and microbiological parameters of the durian samples during cold storage were affected by the investigated factors, including cold temperature and various methods of packing. Physical and chemical characteristics (total dissolved solids, TA, total polyphenol, weight, and color), as well as aerobic microbial content, varied over the course of storage. The results indicated that PET packaging was the most effective material for preserving durian. Compared to the other three packaging types, PET packaging better maintained the color, flavor, pH value, and TA of durian during storage. Furthermore, after 16 days of storage, durian packaged in PET did not show any yeast or mold growth and had the lowest total count of aerobic microorganisms. Additionally, durian stored in PET packaging at 10°C yielded more optimal results compared to storage at 0°C. Both storage temperatures did not show significant differences in weight, TSS, color, flavor, and polyphenol content of durian. Therefore, storing durian at 10°C not only conserves energy and reduces operational costs but also enhances the economic efficiency of the product.

Acknowledgements: The authors would like to express their gratitude to the Department of Science and Technology of Tien Giang province, Vietnam, for their helpful assistance with this study.

Funding information: Authors state no funding involved.

Author contributions: Quang Binh Hoang, Hoang Phuc Le, Huu Quy Ha, Ba Hoang Truong, Thanh Viet Nguyen, Diep Ngoc Thi Duong, Chi Khang Van contributed to the experimental design. Quang Binh Hoang, Chi Khang Van carried out the data analysis, manuscript preparation, and data interpretation. All authors read and approved the final manuscript.

Conflict of interest: The authors report no financial or any other conflicts of interest in this work.

Ethical approval: This study does not involve experiments on animals or human subjects.

Data availability statement: All data generated and analyzed are included with this research article.

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