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Effect of thickness of polyethylene packaging and temperature on quality of solar-dried oyster mushroom (*Pleurotus sajor-caju*)

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Abstract

Pleurotus sajor-caju is evaluated as an edible fungi with high nutritional and medicinal value, but fresh mushrooms are easily damaged after harvest due to many reasons. Drying methods can be taken to maintain mushroom quality, reduce losses and prolong postharvest storage time. The objective of this study was to evaluate the effects of polyethylene (PE) packaging thickness (91.70 µm; 81.30 µm and 53.50 µm), temperature (28°C-30°C and 3°C-5°C) (with air humidity of 60-62% and 76-78% respectively), to the quality of oyster mushrooms dried by solar energy, during storage. During the storage period, the total sugar and protein contents of all treatments decreased. Besides, the colour (through the difference in lightness and darkness (ΔL) value) and firmness of the solar-dried oyster mushrooms also decreased, so, oyster mushrooms were darkened and softened. After 6 months, the lowest protein, total sugar and lipid loss was found in PE packaging of 91.70 µm thickness at storage temperature of 3 °C-5 °C. In addition, the water activity of dried mushrooms was lower (less than 0.7), so it ensures microbiological safety.

Keywords

Oyster mushrooms, quality, pakaging thickness, temperature, solar-dried

Introduction

Packaging has become a major technique in prolonging the shelf life of postharvest fruits and vegetables and atmosphere inside the package is one of the important factors in Modified Atmosphere in Packaging (MAP) technology. A type of packaging with exclusive air permeability that helps to create an environment where the composition of the air remains constant and respiration of fruit and vegetables is minimal to increase the shelf life. With advantages such as light weight, good transparency, exclusive air permeability etc, these are the characteristics that make plastic packaging materials are used in MAP (1). MAP can be classified into two basic types, such as active MAP (air composition is modified to the appropriate proportion and blown into the packaging) and passive MAP (the change of air composition is not achieved) (2). Either way, if the air permeability (CO_2, O_2) of the membrane is designed for the respiration of fruits and vegetables, it will prolong the storage life.

Pleurotus sajor-caju was said to contain unique nutritional and medicinal values, aroma as well as taste (3). Specifically, carbohydrates and

proteins are the main components, accounting for 70 to 90% of the dry weight of fruit and they are considered as polymers with high nutritional value and bioactive compounds, protecting the human gut microbiota (4). However, due to the high water content of oyster mushrooms (about 90%), it is susceptible to spoilage by microorganisms that grow with reactions that depend on water content (5). Therefore, oyster mushrooms can hardly be stored for more than 24 hrs at ambient temperature (6). Mushrooms after harvest lose weight, turn brown, wilt and spoil, which is mainly caused by respiration and transpiration. To reduce the postharvest loss and extend their life time, dried mushrooms should be applied. The solar drying gave the best mushroom quality. The use of solar drying method can be an economic method with low energy consumption and environmentally friendly in An Giang province (Vietnam) which reduce the postharvest losses and increase the consumption availability of products (7). However, dried oyster mushrooms have a firm texture that can break and lose some of the features of the packaging during storage. Polyethylene packaging is one of the packaging materials that can be used to pack mushrooms after harvest (8). Besides, the low temperature was applied in mushroom storage to retain the nutritional components and extend the shelf life of mushrooms for a rather long time (8, 9). Therefore, this study carried out to investigate the effects of storage temperature and packaging thickness to prolong the shelf life of dried oyster mushrooms.

Materials and Methods

Materials

Oyster mushrooms *(Pleurotus sajor-caju)* were harvested at the Experimental-practical Area of An Giang University, Vietnam National University Ho Chi Minh city (Vietnam), according to standard of with 12.5±0.5 cm of length, 6.6±3.5 cm and 1.4±0.5 cm of width and thickness of cap respectively and 10.48±4.32 g of weight; free of defects, injury or insects (10). Oyster mushrooms were washed with clean water and dried in a solar drying to an equilibrium moisture content, corresponding to 11.82±0.05% of moisture content and 0.532±0.002 of water activity.

PE packaging was purchased from Pham Gia packaging production Co, Ltd, Ho Chi Minh city, Vietnam.

Experiment Design

The experiment was conducted in completely randomized design (CRD) with 2 factors, including the thickness of polyethylene (PE) and storage temperature, 3 replications and 3 samples per replication.

100g of solar-dried oyster mushrooms for each sample were packed in polyethylene (PE) (28×20 cm^2) with thickness of 91.70 µm (PE_1), 81.30 µm (PE_2) and 53.50 µm (PE_3) and stored at 3°C-5°C (T_1) (9, 11, 12) and 28°C-30°C (T_2) (with air humidity of 60-62% and 76-78% respectively). Samples were carried out and analysed every month.

Determination of colour and hardness

The colour of solar-dried oyster mushrooms was measured using a Hunter L,a,b colorimeter (CR 400, Konica Minolta, Japan). The difference in lightness and darkness (ΔL) was calculated using equation 1 (13):

$$\Delta L = L^* - L_{ref} \quad \text{(Eqn. 1)}$$

Where L* is the colour parameter for lightness of sample; L_{ref} is the colour parameter for lightness reference colour; if ΔL is positive, the colour is lighter; if ΔL is negative, the colour is darker.

The hardness (g force) of samples was determined using a CT3 structure analyzer (Brookfield, USA) with a TA-SBA cutter (Trigger load of 500g and speed of 10 mm/s) and determined on the stem of oyster mushrooms. All samples were measured at 28°C-30°C.

Determination of water activity (aw)

The activity water (a_w) was measured using Aqualab (4TEV, USA). All samples were measured at 28°C-30°C.

Determination of protein content

The total protein content (g/100 g dry matter) was measured by the Lowry method (14) with some modifications. 1 g of sample and 10 ml of concentrated sulfuric acid were added to Kjeldahl tube and digested on digestion block until the solution of sample become clear. 0.1 ml of digested sample or standard was added with 0.1 ml of 2 N NaOH in the tube and placed in boiling water for 10 minutes. The tube was cooled to room temperature and then added with 1 ml of complex forming reagent (including 2% (w/v) Na_2CO_3, 1% (w/v) $CuSO_4.5H_2O$ and 2% (w/v) sodium potassium tartrate in the proportion of 100:1:1, respectively). Approximately 0.1 ml of Folin-Ciocalteu reagent was then added into the tube, vortexed and was left at room temperature for 30 minutes. The Lowry method is based on the reaction of Cu^+ with Folin-Ciocalteu reagent to react into an intense blue colour and measured with an absorbance of 750 nm. The concentration of total protein was based on the standard curve of protein, y = 0.0041x + 0.0118 (R^2 = 0.9999), where y is the absorbance and x is the concentration of the solution in the tube.

Determination of total sugar content

Total sugar (g/100 g dry matter) were measured by the DNS method (14) with some modifications. This method is based on the oxidation of the C=O group by 3,5-Dinitrosalicylic acid from yellow colour to orange-red in an alkaline medium. An aliquot (1 ml) of sample was put in a test tube and then added 2 ml of DNS reagent. The tubes of blank, solution of standard glucose and samples were put in boiling water for 10 minutes. Next, 7 ml distilled water was added. The solution was analysed at an absorption of 575 nm. The concentration of total sugar was based on a standard curve of glucose, y =23885x + 0.126 (R^2 = 0.9999), where y is the absorbance and x is the concentration of the solution in the tube.

Determination of lipid content

Total lipid was determined by the Soxhlet method (14). Samples were dried at 105°C to constant weight. 5g of dried sample was put in the thimble and 350 ml petroleum ether in the flask of a Soxhlet extractor and extracted for 6 hrs or longer. After the end of the extract, the sample was

removed from the thimble, evaporated the solvent and dried to constant weight. The lipid content was measured according to equation 2.

$$X = \frac{(a-b) \times 100}{a} \qquad \text{(Eqn. 2)}$$

With X is lipid content, %; a is weight of dried sample before extraction, g; b is weight of sample after extraction, g.

Results and Discussion

Changes in colour and hardness of solar-dried Pleurotus sajor-caju at different thickness of packaging and temperature during storage

The effect of thickness of packaging and temperature on the change in colour and hardness were shown in Fig. 1 and 2.

The thickness of PE packaging and temperature also had a statistically significant influence on the colour of solar-dried oyster mushrooms ($p<0.05$). The results also showed that the ΔL values decreased in all samples, that means, oyster mushrooms became darker. At 3°C-5°C, the ΔL values were higher than that of samples at 28 °C. Specifically, the initial ΔL value of stem of oyster mushrooms was -24.14 and after 6 months of storage, the ΔL value decreased to -31.86 and -40.42 in PE_1; -32.83 and -44.07 in PE_2; -34.16 and -49.88 in PE_3 when stored at 3°C-5°C and 28°C-30°C, respectively (Fig. 2a). The samples in PE_1 packaging stored at 3°C-5°C were less dark than others. The colour is the first and important quality factor for consumers to evaluate and accept (12, 15). The growth of brown colour is the first sign of spoilage and quality deterioration. During storage, the Maillard browning reaction was activated even when stored at 0°C and with an increase of every 10°C in storage temperature, the reaction rate increased 2-3 times (16). Oyster mushrooms contain sugars and amino acids, therefore, browning is inevitable when stored at >5°C (12, 15).

Besides, the result also showed that there was a significant difference in hardness of solar-dried oyster mushrooms in all thickness of packaging and temperature ($p<0.05$). In general, the hardness decreased at the end of storage. The samples packed in PE_1 still kept the highest hardness after 4 months, while the hardness of others decreased during storage at both 3°C-5°C and 28°C-30°C (Fig. 2b). The hardness is an important quality parameter related to acceptance of consumers (17). The change of structure may be due to the porosity of oyster mushrooms during storage, which is the natural state when oyster mushrooms contact to the external environment (12). In addition, postharvest aging is accompanied by the changes in the cell wall of mushrooms that lead to loss of swelling

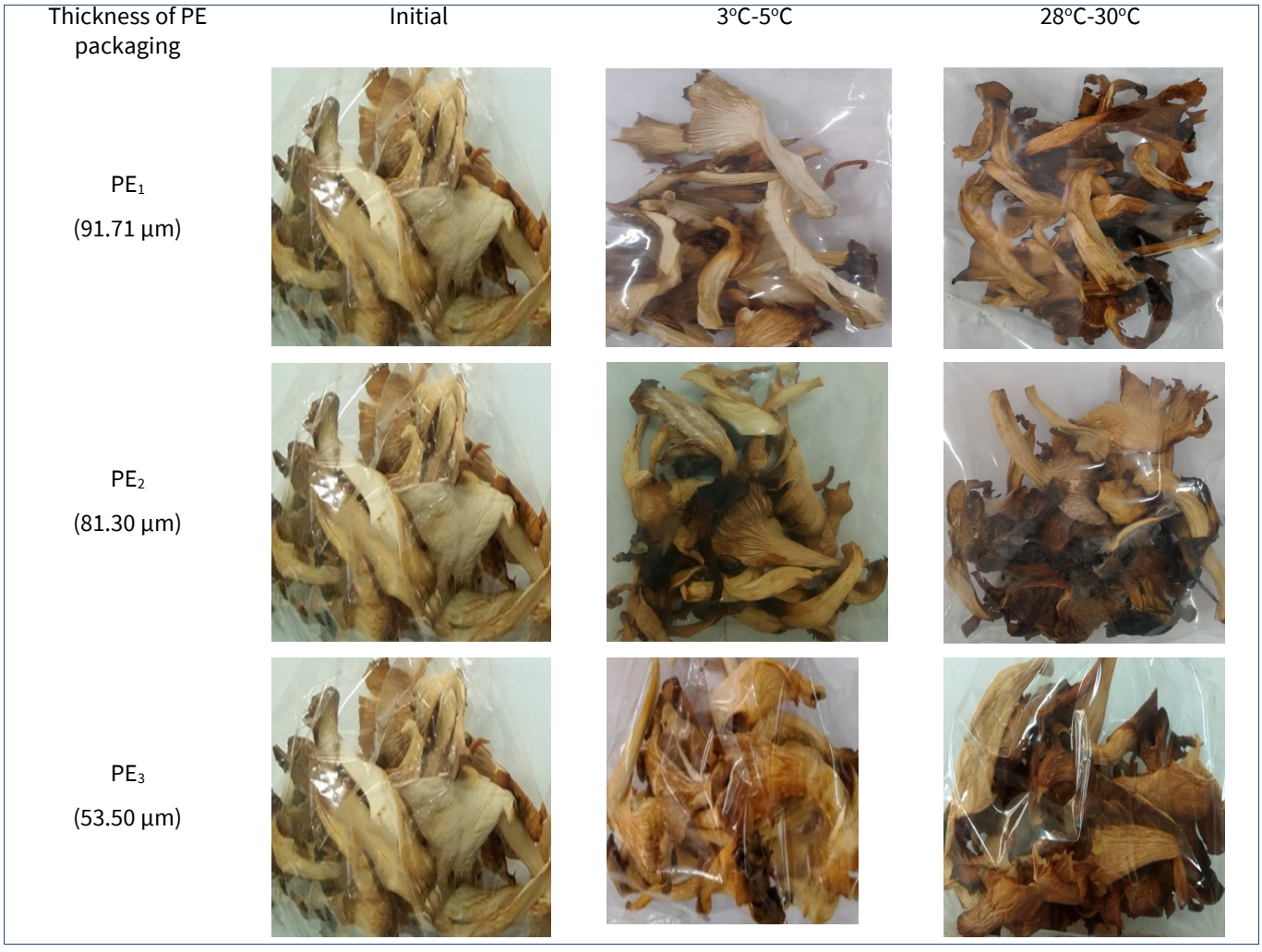

Fig. 1. Solar-dried oyster mushrooms at different thickness of PE packaging and temperatures after 6 months.

function, so that the cell wall becomes weakened, eventually leading to the loss of rigidity of mushrooms.

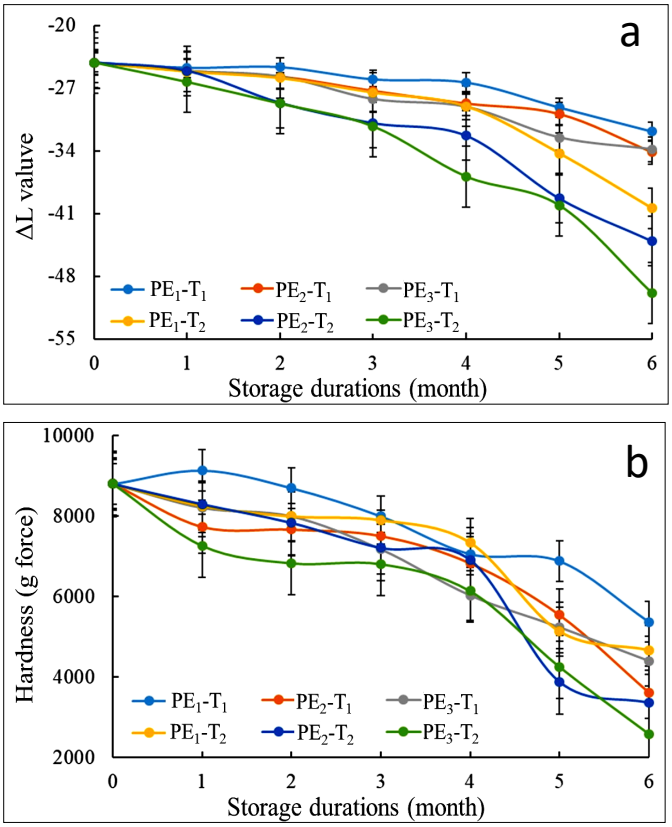

Fig. 2. Effect of thickness of PE packaging and temperature on the colour (through ΔL value) (**a**) and hardness (**b**) during storage.

Changes in chemical position of solar-dried Pleurotus sajor-caju at different thickness of packaging and temperature during storage

Effect of thickness of PE packaging and temperature on changes in water activity and chemical composition of solar-dried oyster mushrooms during storage time were shown in Fig. 3.

The results showed that the thickness of PE packaging and temperature differently affected the chemical composition of solar-dried oyster mushrooms. Protein and total sugar contents decreased with increasing storage time. In general, samples stored at 28°C-30°C lost protein and total sugar contents more than those of samples at 3°C-5°C. Specifically, the total sugar content of samples stored at 28°C-30°C was lost more than that of samples at 3°C-5°C (30.58-37.91% and 16.61-31.68%, respectively) (Fig. 3b). Initial total sugar content was 24.94 (g/100 g dry matter); which decreased evenly and the difference was statistically significant with increasing the storage time. After 3 months of storage, the total sugar content tended to slow down. The carbohydrate of oyster mushrooms includes various sugars such as monosaccharides, oligosaccharides and polysaccharides (glycan). During storage, mannitol and α-trehalose which are the main components of oligosaccharides decreased and so, the total sugar content of samples also decreased (18). In addition, when comparing the change in total sugar and hardness of dried oyster mushrooms during storage, the hardness was affected by the total sugar content (19).

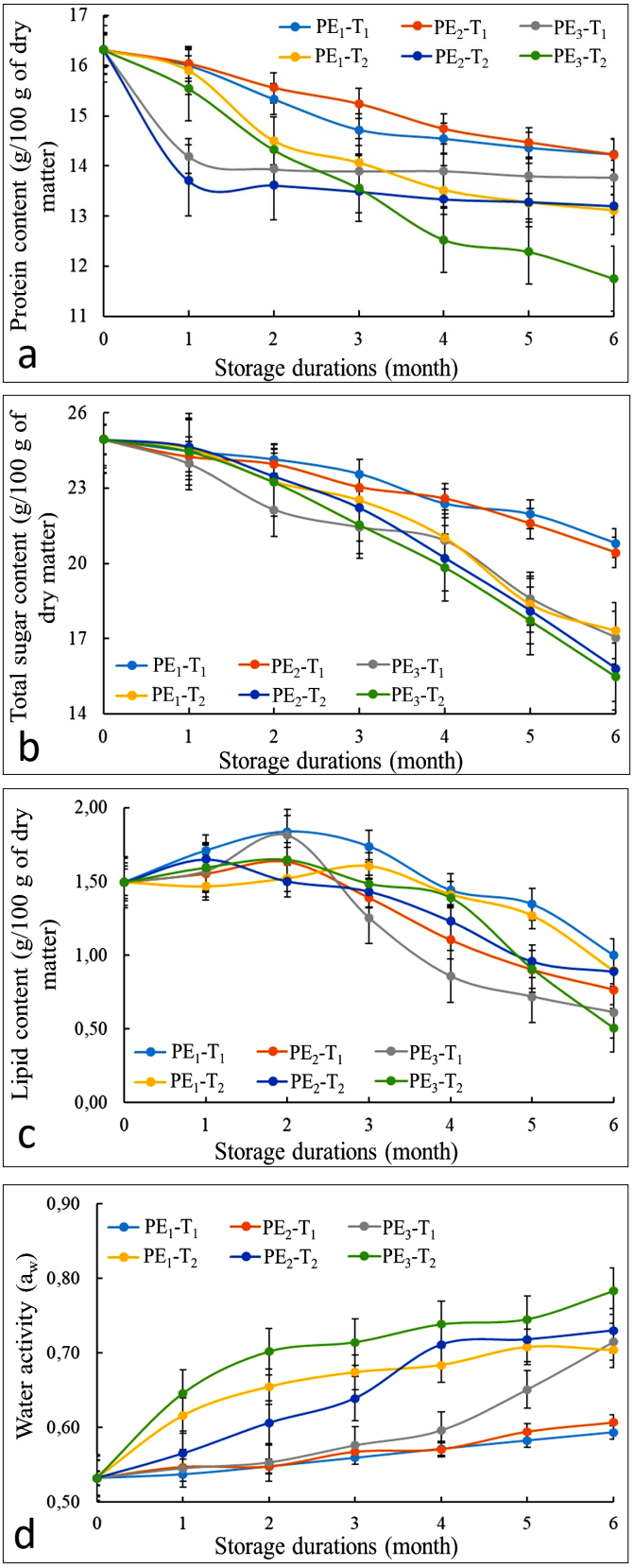

Fig. 3. Effect of thickness of PE packaging and temperature on protein (**a**); total sugar (**b**); lipid (**c**) and water activity (**d**) during storage.

Similar results for changes in protein content of solar-dried oyster mushrooms during storage. Protein content tended to decrease after 1 month of storage but it continued to decrease slowly with elapsing time of storage (Fig. 3a). Protein content of samples packed in PE_1 and PE_2 packaging decreased similarly and the most in PE_3 packaging (12.78-19.63%; 12.81-19.09% and 15.59-27.98%, respectively). At 3°C-5°C, protein content decreased slowly

after 6 months for samples packed in PE_1 and PE_2 packaging, in contrast, the content of protein decreased rapidly after 1 month and slowly in the following months. At 28°C-30°C, the protein content decreased rapidly during storage. The decrease in protein content is influenced by many factors, including the activity of tyrosinase (20). In addition, the protein of *Pleurotus sajor-caju* contains amino acids that are easily oxidized such as cysteine, lysine, histidine, methionine and tryptophan (21). Oxidative reactions can lead to protein degradation and loss of function (22). Besides, protein oxidation still takes place during cold storage (23). Moreover, the decrease in total protein content was also related to non-enzymatic browning (Maillard reaction) between amino acids and reducing sugars, causing the mushrooms to darken over time of storage. Furthermore, the relationship between the properties is carried out. The hardness was significant with high correlation coefficient (R^2) with protein and total sugar content (0.78 and 0.89 respectively). Similarly, the correlation between ΔL values with protein and total sugar contents was significant and high (0.71 and 0.92 respectively). This means that the decrement of total sugar and protein contents resulted in the decrement of the colour (through ΔL value) and hardness and solar-dried oyster mushrooms were darkened and softened.

The results in Fig. 3c showed that lipid content of solar-dried oyster mushrooms increased up to the 2nd month of the storage, however, decreased rapidly with increasing storage time. Specifically, per g/100 g of dry matter, the initial lipid content was 1.50; increased to 1.84; 1.64 and 1.81 in the 2nd month and decreased to 1.00; 0.76 and 0.61 in 6th month, respectively, when stored at 3°C-5°C. Similar results for changes in lipid content of samples stored at 28°C-30°C. The lipid content of samples packed in PE_1 packaging lost the least (33.11-40.20%) while that of samples in PE_3 packaging lost the highest (59.09-66.32%) when stored at 3°C-5°C and 28°C30°C During the storage of oyster mushrooms, the protein is hydrolyzed to free amino acids and these amino acids are further oxidized and converted to acetyl coenzymes which are further synthesized for fatty acids and then it is fat (24). The study of (11) also found an increase in the fat content in samples packaged with different types of food.

The results also showed that the a_w of all samples tended to increase during 6 months of storage. Water activity (a_w) of samples stored at 3°C-5°C changed slowly after 3 months and continued to increase with extension of storage time, however, a_w was still lower than 0.6 after 6 months, excepting for PE_3. Besides, a_w of samples stored at 28°C-30°C increased rapidly and more than 0.7 after 6 months of storage (Fig. 3a). This is explained by the difference between the relative humidity in the external environment and the aw of samples (25) and also due to gas-repellent properties of different thickness of packaging (26) Water activity (a_w) is considered the critical parameter for control of food preservation techniques. Each microorganism has a critical range a_w for different growth and most molds stop growing when a_w<0.7 (27). This proved that storage conditions affected the preservation of solar-dried oyster mushrooms and PE_1 packaging was more stable than others. Similar results are demonstrated in the study of (28, 29).

Conclusion

The thickness of packaging and storage temperature are significant in extending the shelf life of solar-dried oyster mushrooms. The shelf life of oyster mushrooms can be extended when packed in 91.70 µm of thickness of PE packaging and stored at 3°C-5°C with less decrement in the rate of physico-chemical changes.

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Authors contributions

NTNG designed, carried out the experiment, analysed data, wrote, reviewed and edited. TVK carried out the experiment and analysed data. NMT designed the experiment, wrote, reviewed and edited.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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