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RESEARCH ARTICLE

Shelf Life Extension of Cashew Apple by Modified Atmospheric Packaging

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ABSTRACT

Cashew apples are highly perishable fruits and cannot be stored in ambient conditions for more than one day. The study of modified atmospheric packaging of cashew apple was aimed to extend the shelf life. Cashew apple (variety: VRI 3) was subjected to passive MAP of O_2 – 21%, CO_2- 0.03 %, and N_2 78%. PP 60 µm film showed the lowest permeability of O_2 and CO_2 was 1999 mL/m^2/day and 2935 mL/m^2/day. The cashew apple packed with PP 60 µm had the lowest mass loss of 1.356 %, maximum retention of color 56.02 ('L'), 36.96 ('a'), 41.14('b'), firmness of 3.423 N, pH 0.259, and vitamin C of 404.35 mg/100g on the 9th day of storage under refrigerated condition. Fungal growth was also better controlled in PP 60 µm under refrigerated conditions and fungal growth was 9.73 x 10^{4}cfu/g on the 9th day. This study revealed that passive MAP of Cashew apple can extend the shelf life up to 9 days of storage.

Keywords: *Modified atmospheric packaging; Cashew apple; Passive MAP; Shelf life extension*

INTRODUCTION

Cashew fruit (*Anacardium Occidentale L.)* is considered the main crop in America and rare in Asia, Africa and belongs to the Anacardiaceae family (Das and Arora, 2017). The cashew apple is a pear-shaped fruit that is about 40-80 g obtained as a by-product from cashew nut, which is attached to it (Talasila and Shaik, 2015).The ripened fruit is juicy and rich in Vitamin C, sugar content, flavor, and astringent (Adou *et al.,* 2011). Cashew apple contains significant amount of polyphenols (Honorato and Rodrigues, 2010) and minerals (Marc *et al.,* 2011).

During 2017-2018, Cashew cultivation in India was 1040890 hectares and production was 8,17,045 M.T. The total export of cashew kernels from India was 84352 M.T and cashew nut was 8325 M.T according to a report of Cashew Export and Promotion Council of India (CEPCI). India is the world's largest producer, processor, and exporter of cashew kernels (CEPCI). About 10-15 tonnes of cashew apples are produced for every tonne of cashew nut. The cashew apple is highly perishable and has a limited shelf life of about 1-2 days. This gets wasted due to improper packaging and handling techniques and lack of awareness about its nutrient content. It is a rich source of total polyphenols, volatile compounds, vitamin C, Minerals, flavonols, sugars, dietary fibre and amino acids (Queiroz *et al.,* 2011)

Some of the methods available to increase the shelf-life of cashew apples are refrigeration, pretreatment with chemicals, and modified atmosphere packaging. Pretreatment with calcium chloride, potassium metabisulphite, sodium benzoate, or hydrogen peroxide did not improve the storability of cashew apples (Kutty, 2000). Refrigeration along with modified atmosphere has been shown to increase the shelf-life of fruits by slowing down the respiration rate (Costa *et al.,* 2011; Mangaraj *et al.,* 2012). Modified atmosphere packaging can be a probable solution to overcome the above-mentioned constraints. Active and passive modified atmospheric packagings are the two systems generally recognized for the packaging of fruits. Active modification occurs by the displacement of gases in the package, which is then replaced by a desired mixture of gases. At the same time, passive modification occurs when the product is packaged using a selected film type, and the desired atmosphere develops naturally as a consequence of products respiration and the diffusion of gases through the film (Kitinoja and Gorny, 1998; Preetha *et al.,* 2017).

Modified atmosphere packaging of cashew apples can reduce the respiration rate and thereby increase the shelf-life and reduce the physical damage to the product and help in transportation. Thus the study was taken up to optimum modified

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atmosphere storage conditions of cashew apples, namely CO_2 gas concentration, O_2 gas concentration, and temperature for extending shelf life.

MATERIALS AND METHODS

Raw material

Cashew apples required for the study were collected from Regional Research Station, Vriddachalam, Tamil Nadu Agricultural University. Cashew apples of the cultivar VRI3 and CW (H1) were used for the study. Ripe and firm cashew apples without blemishes and uniform size were plucked from the tree and collected from the field for the study.

Preparation and packaging of cashew apples

Two varieties of cashew apples, namely VRI 3 and CW(H_1) were chosen for the study. Cashew apples were taken for the study without removing the kernels since removing the kernels caused juice leakage. About 300 g cashew apples were packed under passive MAP (O_2 21 %, CO_2 0.03 % , N_2 78%) in LDPE and PP pouches and sealed using a heat sealer. The desired atmosphere develops naturally inside the package due to the respiration of products and the diffusion of gases through the film. The gas was analyzed using a gas analyzer (PBI Dansensor).

Head space gas analysis

The selected polymeric films (LDPE and PP) were made into pouch of size 20.5 cm in length and 15.5 cm breadth. The silicon septum was pasted on the surface of the pouch for drawing the gas samples. The cashew apples of approximately 300 g were taken in the pouch and it was sealed for passive atmosphere and sealed. The gas was measured in the package using a gas analyser analyzer (PBI Dansensor) at a particular interval.

Physicochemical Chemical characteristics

Mass loss, Vitamin C, Titrable acidity, TSS, Microbial analysis was analysed as per the procedure followed by (Preetha *et al.,* 2015). Cashew apple (10 g) was homogenized with deionized water (100 mL) and the pH of the solution was measured using a pH meter.

Firmness

The texture of cashew apples was determined using the texture analyzer (Stable Micro System and TA-HDi Analyzer Model, UK. Tests for finding out the force required for penetration at a set depth of 15 mm were conducted for the cashew apples. Type of probe used is penetration rig (4 mm cylinder probe). After running the test, the compression force required to penetrate the sample was directly obtained from the data logger (personnel computer) connected to the texture analyzer

Color value

Colour flex meter (Hunter Lab45°/0°Model, USA) was used for the measurement of color. It provides reading in terms of ‘L’, ‘a’, and ‘b’ where ‘L’ coordinate measures the luminance of colour and ranges from black at 0 and white at 100. Thus ‘L’ value measures the lightness of color and the chromatic portion of the solids is defined by: ‘a’ (red), ‘-a’ (green), ‘b’ (yellow), and ‘-b’ (blue).

Statistical analysis

All the analysis was carried out in four. Statistical analysis was carried out to study the effect of different parameters on all the dependent variables. Analysis of variance (ANOVA) was conducted with Simple Completely Randomized Block Design (CRD) using the software AGRES version 7.01.

RESULTS AND DISCUSSION

Modified atmosphere packaging of cashew apples

Cashew apples VRI 3 were chosen for the present study due to their commercial acceptance. The VRI 3 variety cashew apples were packed in four types of packaging films, namely LDPE 90 µm, LDPE 50 µm, PP 60 µm, and PP 30 µm. Then cashew apples were stored under ambient conditions of 24-33 °C and 50-70% rh and refrigerated conditions of 15-17 °C and 85-95 % rh in passive MAP until the samples got spoiled. Analysis was done for every three days interval. All the cashew apple samples stored under ambient conditions spoiled on the first day itself as per the visual observation and so they were not considered for further analysis. Similarly, control samples, kept at the refrigerated condition of 15-17 °C and 85-95 % rh without packaging, spoiled on the first day and were also not considered for further analysis.

Head space analysis in MAP storage

Head space gas analysis was done in four packaging films namely LDPE 90 µm (T2), LDPE 50 µm (T4), PP 60 µm (T6) and PP 30 µm (T8) under ambient condition and refrigerated conditions. At ambient condition, Cashew apples spoiled on the third day, which was clear from visual observations, so further measurement of gas concentration was not required. The gas concentration at refrigerated conditions was measured in three days interval.

The effect of gas concentration on the headspace of the pouches containing VRI 3 variety cashew apples stored at refrigerated condition is shown in Fig.1 & 2. As the storage time increased, the oxygen concentration decreased and carbon dioxide concentration increased. This could be due to the intake of oxygen for the respiration of fruit and the release of carbon dioxide as a by-product of respiration. It can be observed that O_2 concentration decreased below 1 % and CO_2 concentration increased above 15 % on the 9th d of storage. Kader *et al.* (1989) reported that a decrease in O_2 below 1 % and CO_2 above 15 % is an indication of anaerobic respiration. The temperature had a significant impact on the respiration rate. At ambient conditions the samples got spoiled within 24 h whereas, in refrigeration, the samples were in good condition up to 9 d, since O_2 consumption and CO_2 production were less due to low metabolic activity. Fonseca *et al.* (2002) also reported that at a lower temperature the oxygen consumption and carbon dioxide generation were less.

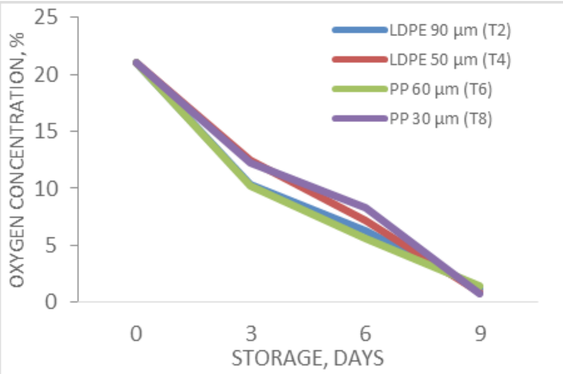

Fig 1. **Oxygen concentration of VRI 3 cashew apples in permeable system under refrigerated conditions**

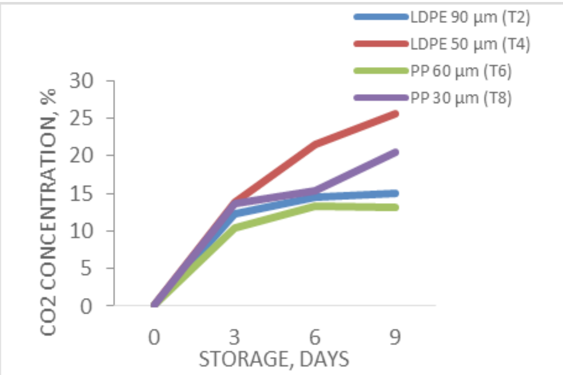

Fig 2. **Carbon dioxide concentration of VRI 3 cashew apples in permeable system under refrigerated conditions**

Mass loss

The effect of storage period on mass loss for VRI 3 variety cashew apples is shown in Fig.3. VRI 3 variety cashew apples stored under ambient conditions irrespective of the type of packaging films spoiled on the first day. In refrigerated conditions, weight loss occurred in all packages and the weight loss varied from 0.31 to 1.9 % on at the end of the 9th d of storage. The lowest weight loss was observed in PP 60 µm pouches packaged in refrigerated condition. T6 pouches had shown significantly lower weight difference ($P \leq 0.01$) from other packaging films. Wills *et al.*(1989) reported that respiration and the transpiration of water from the product attributed to physiological loss of weight of the samples.

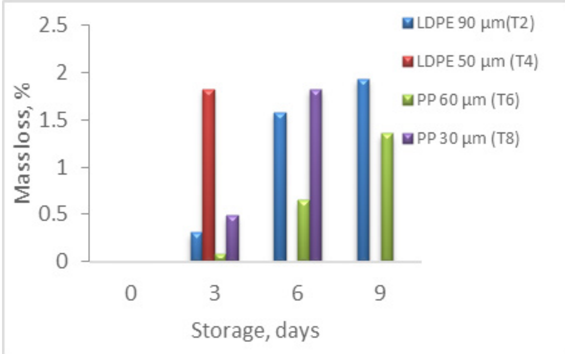

Fig 3. **Effect of MAP on mass loss of VRI 3 cashew apples under refrigerated conditions**

Color value of cashew apples

The change in the lightness of VRI 3 variety cashew apples is presented in Fig.4. In VRI 3 variety the change in the lightness of fruits during storage was very less in all four types of packaging under refrigerated conditions. This maybe due to the non-climacteric nature of the fruit. In VRI 3 variety cashew apples packaging films did not influence the lightness ($P>0.01$) and this prevailed all along with the storage. Neilsen and Anders (2008) reported that Honeoye strawberries packaged in antimist coated oriented polypropylene packaging films had retained the lightness throughout the storage period

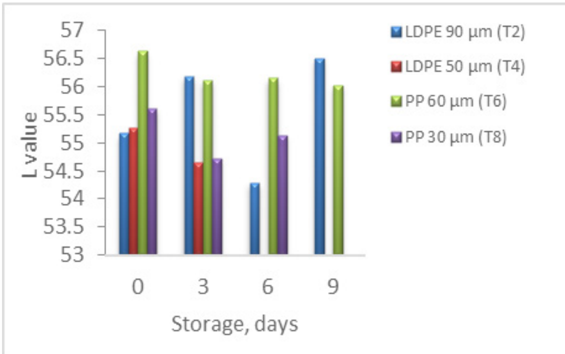

Fig 4. **Effect of MAP on 'L' value of VRI 3 variety cashew apples refrigerated conditions**

The change in redness of VRI 3 during passive MAP has been shown in Fig. 5. The initial 'a' value of VRI3 cashew apple was 26 ± 0.5. In VRI 3 variety cashew apples increase in redness was observed with an increase in storage time under refrigerated conditions. T6 pouches showed a steady increase in redness until the 9th d of storage. Statistical analysis showed that T6 had a significant effect on the redness ($P \leq 0.01$) of cashew apples.

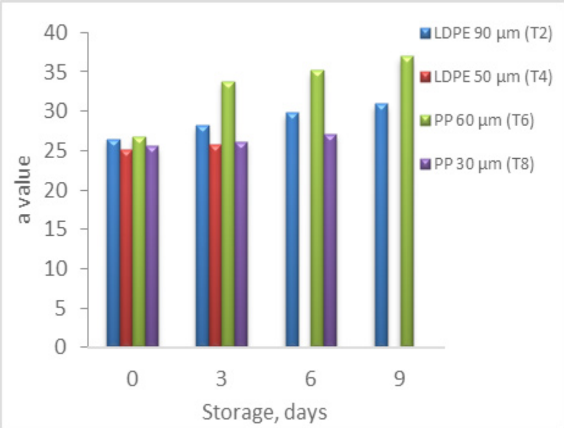

Fig 5. Effect of MAP on 'a' value of VRI3 variety cashew apples refrigerated conditions

The change in 'b' value of VRI 3 variety under passive MAP is presented in Fig 6. The initial yellowness of VRI 3 cashew apples was 35.25± 0.25. A gradual increase in yellowness was observed with storage time under refrigerated conditions. Statistical analysis showed that T6 had a significant effect on yellowness (P≤ 0.01) of cashew apples.

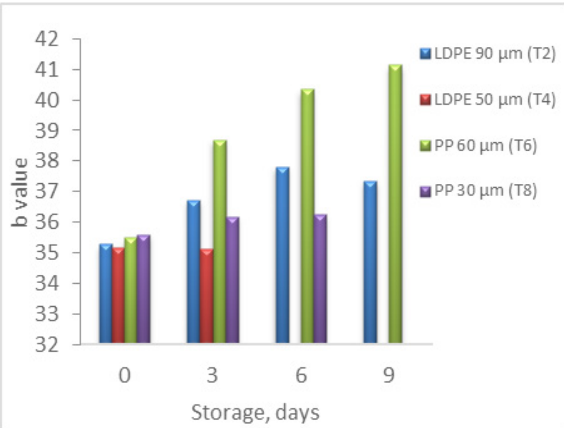

Fig 6. Effect of MAP on 'b' value of VRI 3 variety cashew apples under refrigerated conditions

Firmness

The effect of MAP on the firmness of VRI 3 cashew apples in a permeable system is shown in Fig. 7. The initial firmness measured at the start of the experiment was 4.1± 0.1 N. VRI 3 variety cashew apples stored in ambient conditions spoiled on the 1st d. Cashew apples stored in a refrigerated condition also had a loss of firmness. Firmness loss was minimum in cashew apples stored in T6 pouches. On the 9th day, cashew apples stored in T6 had the firmness of 3.42 N. This could be due to the low respiration rate of cashew apples in T6 pouches. Cashew apples stored in T2 showed a rapid decrease of firmness on day 3. A clear increase in softening was observed in cashew apples with an increase in storage period. According to Figueiredo *et al.* (2002) the increase in softening could be due to starch degradation and consequent increase in soluble sugar content as well as the action of pectolytic enzymes.

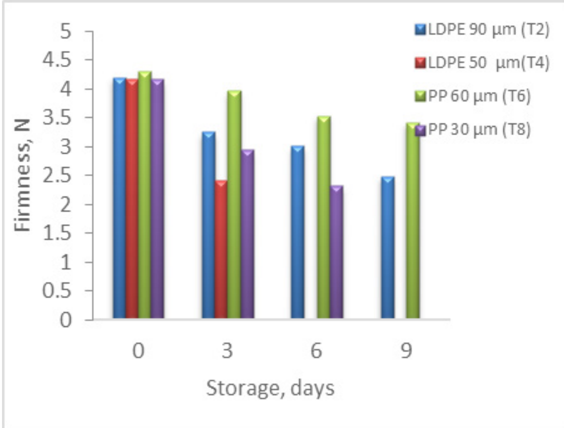

Fig 7. Effect of MAP on the firmness of VRI 3 variety cashew apples under refrigerated conditions

Titrable acidity

The change in titrable acidity of VRI 3 variety under passive MAP is presented in Fig.8. The acidity values decreased in all packaging films with an increase in storage time during the refrigerated condition. Filgueiras *et al*. (1999) reported that when cashew apple ripens their acidity decreases. The initial acidity value was 0.280 for all treatments. The decrease in acidity in T6 samples was very less till 9th day and on 9th day the titrable acidity in T6 was 0.267. T2 samples had a sudden decrease in acidity on 3rd day but the decrease was less on 6th day and 9th day. Throughout the storage period, T6 samples had retained higher acidity values and had a significant difference (P≤ 0.01) than other samples.

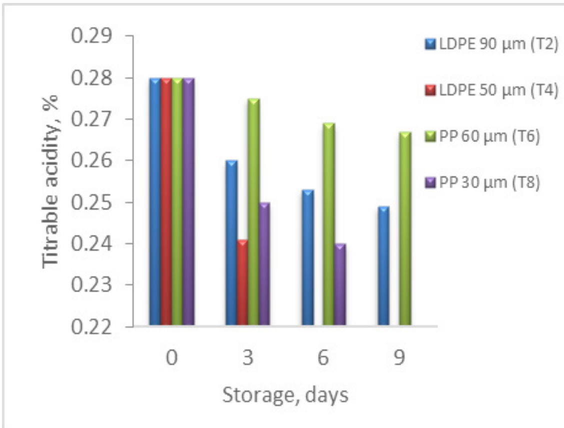

Fig 8. Effect of MAP on the acidity of VRI 3 variety cashew apples under refrigerated conditions

pH

The change in pH of VRI 3 variety under passive MAP is presented in Fig.9. The initial pH of VRI 3 variety was 3.70 ± 0.05. Decrease in pH was observed in all four treatments with an increase in storage period. The pH of T2, T4 and T8 reduced below 3.00 at the end of their respective storage periods. This could be due to the anaerobic respiration of cashew apples. Treatment T6 was better in retaining the pH till 9th day of storage and pH on the 9th day was 3.22. Statistical analysis also showed that T6 could retain the pH($P \leq 0.01$) better than other treatments.

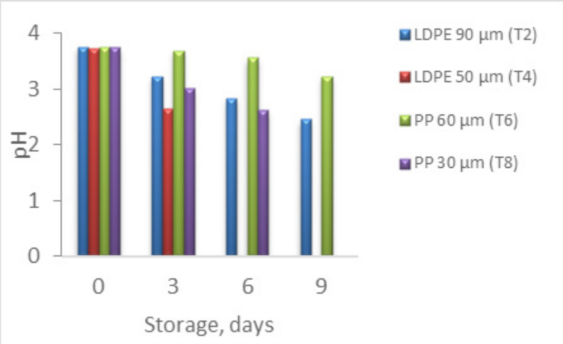

Fig 9. Effect of MAP on pH of VRI 3 variety cashew apples under refrigerated conditions

Total soluble solids

The change in total soluble solids of VRI 3 variety under passive MAP is presented in Fig. 10. The initial TSS of VRI 3 variety was 13.80± 0.1. TSS decrease was observed in all types of packages with an increase in storage period. The steady decrease in TSS was observed in T2 and T8 with an increase in storage period. There was no change in TSS in T6 samples till 3rd day but after 3rd day a gradual decrease in TSS was observed till day 9. On 9th day the TSS content in T6 samples was 12.35 whereas the TSS content of T2 was 9.7. It can be concluded from the above discussion that T6 is better in retaining TSS content of cashew apples than other treatments. Statistical analysis showed that T6 had a significant effect on retaining the TSS content of cashew apples.

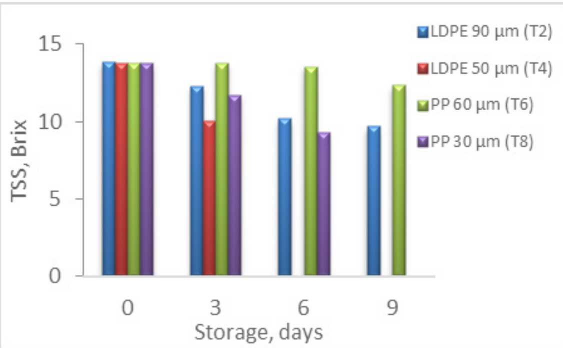

Fig 10. Effect of MAP on TSS of VRI variety cashew apples under refrigerated conditions

Ascorbic acid content

The change in ascorbic acid content of vitamin C of VRI 3 variety under passive MAP is presented in Fig.11. The initial ascorbic acid content of VRI 3 variety was 411.71 ±0.05 mg/100g. A decrease in ascorbic acid content was observed in all packages selected. Vitamin C content was constant in T6 samples until the 3rd day and decreased from the 6th day onwards. In T2 samples there was a steady decrease in ascorbic acid content till the 9th day. The vitamin C content of T6 was 404.39 mg/100g on the 9th day. On the other hand, the vitamin C content of T2 was 380.53 mg/100 g. Filgueras *et al.* (1999) reported that the Vitamin C content of cashew apples could be in the range of 139-387 mg/100 g. Statistical analysis showed that T6 had a significant effect on vitamin C content ($P \leq 0.01$) of VRI 3 cashew apples.

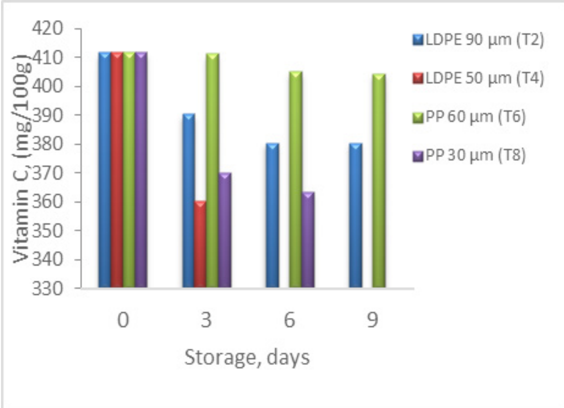

Fig 11. Effect of MAP on vitamin C content of VRI 3 cashew apples under refrigerated conditions

Microbial growth

Microbial growth in VRI 3 variety cashew apples stored under passive MAP is presented in Fig.12. Jay (2000) reported that fruits have low pH and are acidic in nature and so it does not have the presence of bacteria. Thus fungal growth was analyzed. The initial fungal population was 4.44×10^4cfu/g in all treatments. In T6 there was gradual microbial growth compared to other treatments. On 9th d the fungal growth was 9.73×10^4cfu/g in T6, whereas in T2, it was13.20 $\times 10^4$cfu/g. In T4, the growth was very high on the 3rd day itself and spoiled on 6th d. Statistical analyses have shown that the T6 had the lowest ($P \leq 0.01$) microbial growth.

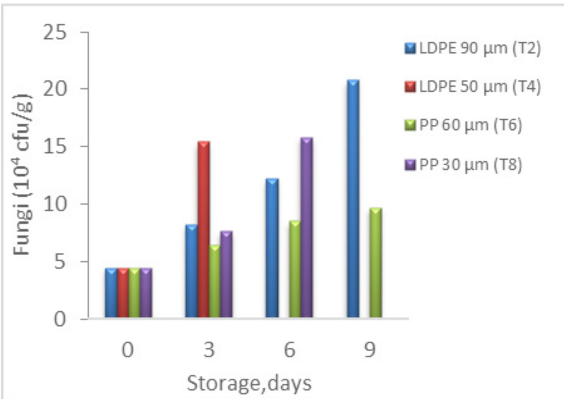

Fig 12. Effect of MAP on fungal growth content of VRI 3 variety cashew apples refrigerated condition

CONCLUSION

Modified atmosphere packaging of cashew apples was carried out to increase the shelf life of cashew apples. It was observed that PP 60 µm had the lowest permeability O_2 and CO_2 i.e., 1999 mL/m^2/day and 2935 mL/m^2/day, respectively, which was followed by LDPE 90 µm whose film permeability to O_2 was 2190 mL/m^2/day and CO_2 permeability was 5523 mL/m^2/day. The cashew apple was stored for up to 9 days. On the 9^{th} day, PP 60 µm had the lowest mass loss of 1.356 %, 'L' value of 56.02, 'a' value of 36.96 and 'b' value of 41.14, firmness of 3.423 N, pH 0.259, and vitamin C of 404.35 mg/100g. Fungal growth was better controlled in PP 60 µm under refrigerated condition and on 9^{th} d fungal growth was 9.73 x 10^4cfu/g.

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