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Effect of different active packaging materials on storage of persimmon cv. Fuyu

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ABSTRACT

Persimmon is a high value climacteric fruit and deteriorate rapidly after harvest. Therefore, an investigation on extending storage life of persimmon fruits using active packaging technology was done with the following treatments *viz*., T1 (Control), T2 (Cloth bag + 3g activated charcoal), T3 (Non-woven pp bag + 3g Activated charcoal), T4 (Butter paper bag + 3g Activated charcoal), T5 (Polypropylene + 3g Activated charcoal), T6 (Cloth bag + 6g $KMnO_4$), T7 (Non-woven pp bag + 6g $KMnO_4$), T8 (Butter paper bag + 6g $KMnO_4$) and T9 (Polypropylene + 6g $KMnO_4$). These were stored at 4±1°C and 85-90% RH and analyzed for different physiochemical properties at 10-day intervals. Polypropylene packaging with 3g Activated charcoal or 6g $KMnO_4$ resulted in the longest shelf life and good quality fruits at more than 50 days of storage. Modified packaging with polypropylene + 3g Activated charcoal preserved fruit firmness, greater β-carotene content in pulp and lowest PLW (%), while fruits packed in Polypropylene + 6g $KMnO_4$ resulted in the highest pH, ascorbic acid, peel β-carotene and pectin content and lowest TSS, total and reducing sugar content. The highest BCR amongst various treatment combinations was found in fruits packaged in Polypropylene + 6g $KMnO_4$ on the 70th day of storage.

Key words*: Diospyros kaki*, Activated charcoal, BCR, Firmness, $KMnO_4$, Polypropylene bags.

INTRODUCTION

Diospyros kaki is a deciduous tree with over 500 different varieties, also known as Japanese persimmon, belonging to the Ebenaceae family. The persimmon fruit contains high natural phytochemicals, antioxidants, and nutrients, including sugars, carbohydrates, vitamins, carotenoids, sugars, polyphenols, dietary fibres, minerals, tannins, and triterpenoids. Fruit crops with a high content of bioactive chemicals (George and Redpath, 2) contribute to human health by supplying essential nutrients required by the body. Due to its distinct flavour and taste, this fruit is popular in Japan, China and Korea (Celik and Ercisli, 1; Luo *et al.*, 8; Suntudprom, 17).

Persimmon is a climacteric fruit with high perishability, especially when left out at room temperature, and could soon deteriorate physically and qualitatively (Zheng *et al*., 20). The fruit has a shorter shelf life even when stored in ideal conditions. At 0-2 °C, the fruits can be kept for two to three months (Singh *et al*., 15). Therefore, maintaining a low temperature is the best way to prevent fruit deterioration and slow ripening. Because of its appealing flavour, and appealing appearance, persimmon has good commercial acceptance.

"Active packaging technology" is a viable alternative for storing horticultural crops (Mujtaba *et al*., 10). Active packaging is defined as a system that aims to enhance the function of packaging by interacting with food and the environment (Lim, 7). Active packaging involves a beneficial action of materials used for packaging and the environment for enhancing storage life. The substances that absorb moisture, oxygen, ethylene, and balance carbon dioxide while maintaining the flavours and quality of the product are used along with packaging material to increase its efficiency. The anti-microbial agents with antioxidants and certain flavours are added to prevent off-taste while also extending post-harvest life by controlling the effect of fruit ripening due to ethylene action, thereby extending the fruit's marketability for a longer period (Glahan,3). The present paper explores the possibility of utilizing readily available packaging materials such as cloth bags, butter paper bags, and Non-woven polypropylene bags along with polypropylene bags to prolong the shelf life of persimmon fruits by making them available even in the off-season.

MATERIALS AND METHODS

The present study was conducted from May to December 2021, where uniform fruitlets were tagged from 11-year-old persimmon trees from the orchard of a progressive farmer in Pfutsero town located at

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a higher altitude, Phek district, Nagaland. Mature unripe fruits were harvested during the first week of September with the help of secateurs in the early morning hours. The harvested fruits were collected and kept in the shade to remove field heat and carefully packed in corrugated fibre board boxes with paper cushioning between layers to minimize any physical injury during transport. The fruits were immediately brought to the Laboratory, Department of Horticulture, Nagaland University: School of Agricultural Sciences, Medziphema, Nagaland, for further analysis.

Fruit samples were thoroughly washed in running water and dried with a clean cotton cloth to remove all moisture. Fruits of similar size and colour were weighed approximately two kg and placed under different treatments with three replications. The treatments were T1 (Control), T2 (Cloth bag + 3g activated charcoal), T3 (Non-woven polypropylene bag + 3g Activated charcoal), T4 (Butter paper bag + 3g Activated charcoal), T5 (Polypropylene + 3g Activated charcoal), T6 (Cloth bag + 6g $KMnO_4$), T7 (Non-woven polypropylene bag + 6g $KMnO_4$), T8 (Butter paper bag + 6g $KMnO_4$) and T9 (Polypropylene + 6g $KMnO_4$). The activated charcoal powder and potassium permanganate ($KMnO_4$) powder were packed in small sachets of non-woven polypropylene. These were then kept at a storage temperature of 4 ± 1 °C with relative humidity of 85-90%. Ten fruits under each treatment were kept separately to observe the physiological loss in weight (PLW) (%), recorded at 15-day intervals. Fruit firmness (N) was measured using a Hand Penetrometer (Model no. 46154). TSS of fruit pulp was determined with an ERMA hand Refractometer (0-32 °Brix). Titratable acidity (%) was determined using a known volume of filtered persimmon juice titrated with standard sodium hydroxide (0.1 mol L^{-1}) with phenolphthalein as an indicator (Ranganna, 11). The pH was recorded using a digital pH meter (HANA 825, Japan). Total and reducing sugar were determined by Lane and Eynon using Fehling's A and Fehling's B reagents with Methylene blue indicator. Determination of fruit ascorbic acid and β-carotene content of peel and pulp were determined following standard procedure as given by Ranganna (11). Pectin was determined by the addition of calcium chloride, which results in the precipitation of pectin. Calcium pectate was washed with water to make it free from chloride, dried and weighed as given by Ranganna (11) and pectin content calculated as

$$\text{Pectin \%} = \frac{\text{Weight of Ca pectate (g)} \times 100}{\text{Weight of sample (g)}}$$

The Benefit: Cost was calculated with the formula.

$$\text{BCR} = \frac{\text{Net return}}{\text{Total Cost}}$$

The data were statistically analyzed by the method analysis of variance method (Sukhatme and Panse, 16). The different sources of variation were estimated by error mean square using the Fisher Snedecor probability test at a 5 per cent significance level.

RESULTS AND DISCUSSIONS

The PLW (%) increased with an increase in storage time (Fig. 1). Fruits packed in polypropylene had the least PLW (%), possibly because polypropylene and scavenger retained fruit moisture and minimized the respiration rate. The firmness of fruit significantly decreased from 22.0 N at day 10 to 10.67 N at day 60 under control treatments with storage time, which followed a similar trend in all other treatments (Table 1). The firmness of the fruit is a parameter that can detect fruit ripening, which causes pulp tissue softening. Reduction in firmness may be due to microstructural changes in the flesh. It may also be due to a gradual decrease in swollen cells and an increase in deformed cells, causing intercellular adhesion loss leading to progressive degradation of parenchyma (Salvador *et al*., 12). Moisture loss due to greater transpiration and higher respiration may have resulted in lower fruit firmness than treated fruits. In general, there was no spoilage of fruits with the treatment of Polypropylene + 6g $KMnO_4$ on the last day of observation (day 70). By day 50, fruits under control treatment and cloth bags with 3g activated charcoal and 6g $KMnO_4$ had 100% spoilage, and on day 60, fruits in all treatments showed 100 % spoilage, baring those packaged in polypropylene with 3g activated charcoal or 6g $KMnO_4$ (Table 2). This may be due to the accumulation of moisture by cloth and non-

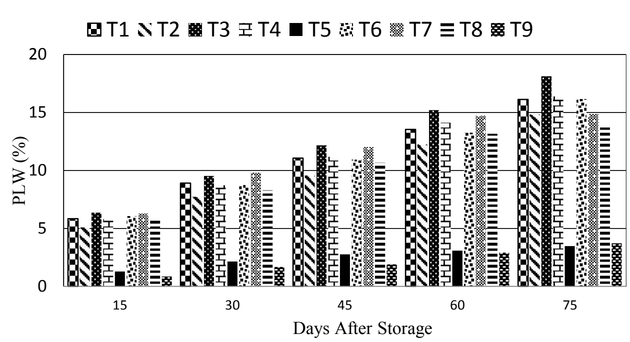

Fig. 1. Effect of packaging and scavenging treatments on physiological loss in weight (PLW %) during storage.

Table 1. Influence of different treatments on fruit firmness (N) of persimmon during storage.

Treatment	Days after storage						
	10	20	30	40	50	60	70
T_1	22.00	15.17	12.67	11.50	10.33	10.67	8.67
T_2	23.67	18.83	15.83	13.50	12.50	11.00	9.17
T_3	23.00	18.00	14.00	13.83	12.33	10.50	9.00
T_4	23.67	22.50	17.67	14.17	14.67	12.00	12.50
T_5	23.67	22.17	14.50	14.17	13.67	13.00	12.67
T_6	24.83	19.33	13.33	12.83	12.67	11.00	10.00
T_7	21.67	18.67	13.67	13.17	11.33	10.33	9.50
T_8	23.83	21.00	16.00	14.17	14.67	11.17	11.83
T_9	24.17	20.17	15.83	16.17	15.00	12.67	12.17
S Em ±	0.85	1.19	0.93	0.63	0.94	0.92	0.70
CD at 5%	NS	3.52	2.77	1.86	2.81	NS	2.09

T1 (Control), T2 (Cloth bag + 3g activated charcoal), T3 (Non-woven pp bag + 3g Activated charcoal), T4 (Butter paper bag + 3g Activated charcoal), T5 (Polypropylene + 3g Activated charcoal), T6 (Cloth bag + 6g $KMnO_4$), T7 (Non-woven pp bag + 6g $KMnO_4$), T8 (Butter paper bag + 6g $KMnO_4$) and T9 (Polypropylene + 6g $KMnO_4$).

Table 2. Persimmon fruit spoilage (%) during storage due to various packaging treatments.

Treatment	10	20	30	40	50	60	70
	days after storage						
T_1	0	33.3	53.3	93.3	100	-	-
T_2	0	26.7	46.7	80.0	100	-	-
T_3	0	13.3	40.0	73.3	86.7	100	-
T_4	0	0	6.7	13.3	60.0	100	-
T_5	0	0	0	0	0	0	13.3
T_6	0	20.0	40.0	60.0	100	-	-
T_7	0	13.3	33.3	53.3	66.7	100	-
T_8	0	0	6.7	6.7	46.7	93.3	100
T_9	0	0	0	0	0	0	0

T1 (Control), T2 (Cloth bag + 3g activated charcoal), T3 (Non-woven pp bag + 3g Activated charcoal), T4 (Butter paper bag + 3g Activated charcoal), T5 (Polypropylene + 3g Activated charcoal), T6 (Cloth bag + 6g $KMnO_4$), T7 (Non-woven pp bag + 6g $KMnO_4$), T8 (Butter paper bag + 6g $KMnO_4$) and T9 (Polypropylene + 6g $KMnO_4$).

woven polypropylene used as packaging material. The TSS-acid ratio was low at the initial stages of fruit growth due to low sugar content and high acidity in fruits (Fig. 2). There was a slow and gradual increase in the TSS-acid ratio in fruits packaged in polypropylene bags with 3g activated charcoal or 6g $KMnO_4$. There was degradation of reducing sugar, and the rapid hydrolysis of polysaccharides to monosaccharides could be the reason for the increase in fruit sugar content (Sharma *et al.,* 13).

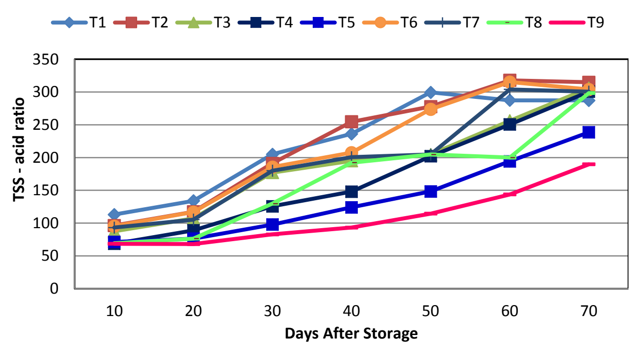

Fig. 2. Effect of packaging and scavenging treatments on TSS-acid ratio during storage. Days.

The decline in ascorbic acid content may be due to the utilization of organic acids during fruit acidity content and the increase in sugar content with the ripening of fruits with progress in storage time. The gradual decrease of acidity at the end of storage days may be due to their utilization in respiration and rapid metabolic transformation of organic acids into sugar (Kaur *et al.*, 5). There was a slow but gradual rise in pH value followed by a progressive decline after day 40, which contrasts with the report by Khan *et al.* (6), where the pH of the persimmon fruits gradually decreased (10 days) during storage and then a gradual increase in pH was observed for those packed in polyethene which were however found to be statistically at par (Table 3).

The total sugar and reducing sugar content of fruits increased with progress in storage days. Hydrolysis of polysaccharides by hydrolytic enzymes

Table 3. Qualitative characteristics of persimmon cv. Fuyu at 0 days and 60 days after storage.

Treatments	pH	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid (mg/ 100 g)	β carotene pulp (mg/ 100 g)	β carotene peel (mg/ 100 g)	Pectin (%)
Day 0								
	5.1	10.1	9.9	0.4	19.2	0.19	0.58	2.90
Day 60								
T1	5.1	21.4	19.8	1.3	7.7	0.49	0.59	0.75
T2	5.2	23.3	22.6	1.2	9.2	0.54	0.85	0.88
T3	5.2	22.6	22.3	1.7	8.7	0.49	0.90	0.47
T4	5.4	22.6	21.4	0.9	9.8	0.53	0.82	0.77
T5	5.6	22.3	20.8	1.3	10.3	0.64	0.93	1.08
T6	5.3	22.9	21.7	1.2	9.2	0.55	0.89	0.67
T7	5.1	23.3	21.4	1.0	9.2	0.50	0.84	1.09
T8	5.2	22.9	21.1	0.7	9.8	0.59	0.88	0.94
T9	5.5	22.3	20.3	0.8	10.8	0.59	0.93	1.44
S Em ±	0.03	0.34	0.47	0.37	0.45	0.01	0.02	0.04
CD at 5%	0.09	1.02	1.40	NS	1.35	0.04	0.06	0.11

T1 (Control), T2 (Cloth bag + 3g activated charcoal), T3 (Non-woven pp bag + 3g Activated charcoal), T4 (Butter paper bag + 3g Activated charcoal), T5 (Polypropylene + 3g Activated charcoal), T6 (Cloth bag + 6g $KMnO_4$), T7 (Non-woven pp bag + 6g $KMnO_4$), T8 (Butter paper bag + 6g $KMnO_4$) and T9 (Polypropylene + 6g $KMnO_4$)

could have led to sugar formation, resulting in increased content. The reduction in sugar percentage at the end of storage days in fruits may be due to complete hydrolysis. Inversion of non-reducing sugars to respiration or their conversion of sugars was also reported by Singh *et al*. (14) in Khasi mandarin.

The BCR of the various treatments was calculated as per the storage life of 100 kg of fruits. As the storage time increased, the fruits lost marketability under refrigerated conditions due to different physiological disorders and diseases and continued to generate negative gross income. Still, the fruits packed in polypropylene retained their marketability for up to 2 months, giving the highest BCR when stored and sold at higher prices during the off-season. Persimmon fruit tree yields about 160-200 kg of fruits/tree/year. In an area of 1 ha of land, a farmer can harvest about 50,000 kg of fruit per year under favourable conditions. In case of storing the fruits for up to 2 months in cold storage using packaging material of Polypropylene and scavenger $KMnO_4$, the buyer of wholesale fruit @ ₹200/kg can still preserve all the fruits at marketable condition and sell the fruits @ up to ₹400 to 500/kg after main fruiting season is over. Thereby, generating a gross income of ₹2,00,00,000 to 2,50,00,000 and net return of ₹1,45,08,950 (Table 4).

It could be concluded that all packaging materials and scavengers used in the present study effectively reduced the deterioration of the physio-chemical properties of persimmon. However, amongst all the treatments, using Polypropylene (80μm) combined with a $KMnO_4$ at 4 ± 1°C was the most effective in showing better keeping quality. The per cent increment in storage life of treatments was much higher than that of control, with T9 recording 100% marketable fruit till 70 days, thus showing the highest BCR. Other treatments like T4 and T8 also showed good potential as packaging material concerning persimmon's quality and shelf life. Further studies may be conducted to evaluate the shelf life after extending the storage life of persimmon fruits under such refrigerated conditions to obtain more economic return.

AUTHORS' CONTRIBUTION

Conceptualization of research (PA, GIY), Designing (PA, NP, CSM) and Execution of experiment (LC, PA), Contribution in data analysis (CSM, LC) and preparation of manuscript (LC, PA)

DECLARATION

The authors declare no conflict of interest concerning this manuscript.

Table 4. BCR of persimmon fruit based on local fruit market.

Treatment	BCR on Day 10				BCR at Day 50			
	Total cost	Gross return (@ ₹250/kg)	Net return (₹)	BCR	Total cost	Gross return (@ ₹400/ kg)	Net return (₹)	BCR
T_1	20488	25000	4512	0.22	20560	0	0	-
T_2	22206.8	25000	2793.2	0.12	22278.8	0	0	-
T_3	21569.8	25000	3430.2	0.15	21641.8	8000	- 13641.8	- 0.63
T_4	21106.8	25000	3893.2	0.18	21178.8	16000	- 5178.8	- 0.24
T_5	21306.8	25000	3693.2	0.17	21378.8	40000	18621.2	0.87
T_6	22344.8	25000	2655.2	0.12	22416.8	0	0	-
T_7	21644.8	25000	3355.2	0.16	21716.8	8000	- 13716.8	- 0.63
T_8	21144.8	25000	3855.2	0.18	21216.8	16000	- 5216.8	- 0.25
T_9	21444.8	25000	3555.2	0.17	21516.8	40000	18483.2	0.86

T1 (Control), T2 (Cloth bag + 3g activated charcoal), T3 (Non-woven pp bag + 3g Activated charcoal), T4 (Butter paper bag + 3g Activated charcoal), T5 (Polypropylene + 3g Activated charcoal), T6 (Cloth bag + 6g $KMnO_4$), T7 (Non-woven pp bag + 6g $KMnO_4$), T8 (Butter paper bag + 6g $KMnO_4$) and T9 (Polypropylene + 6g $KMnO_4$)

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