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Goldie Konthoujam
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Vijaya Rawat
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

AB Waheed Wani
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Sanjeev Kumar
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Vijaya Rawat
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Effect of different packaging materials on shelf life of banana (cv. Cavendish)

Goldie Konthoujam, Vijaya Rawat, AB Waheed Wani and Sanjeev Kumar

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Abstract
This present investigation entitled "Effect of different packaging materials on shelf life of banana (cv. Cavendish)" was designed at the School of Agriculture, Lovely Professional University, Phagwara, Punjab. The experiment was conducted in a completely randomized design with eight treatments with three replications. The experimental treatments were different packaging materials (Control, Plastic container with cover, Brown Paper Bag, CFB (Newspaper), CFB (Straw), Wooden crates, Low Density Polyethylene Bag (LDPE), High Density Polyethylene Bag (HDPE). The data was collected between 3 days interval from each of the packaging materials and the banana samples in each treatment were taken to analyze the shelf life, decay percentage, reducing sugar, non- reducing sugar, vitamin C, total phenol content, total flavonoids content, mineral K content. The banana fruits that have been packaged in different packaging materials were kept at room temperature for 12 days. The findings indicated that banana fruits packaged in high density polyethylene bag exhibited the lowest physiological weight also indicated that longest shelf, highest total soluble solids, titratable acidity, total sugar. Conversely, unpackaged (Control) banana fruits displayed the highest fruit loss as well as lowest values for all the mentioned parameters. The results demonstrated that the packaging of banana fruits using high density polyethylene bag could potentially decrease the postharvest losses of banana and detrimental health risk. The resistant accessions identified here can be suggested as novel approach so as to improve their marketing shelf life and quality and also decrease the chemical usage in postharvest treatments. Finally, it is recommended that high density polyethylene bag increases the shelf life and quality.

Keywords: Banana, packaging materials, postharvest, shelf life

Introduction

Banana (*Musa spp.)* belongs to the family Musaceae and found in South East Asia. It is one of the staple foods for both rural and urban areas mostly cultivated by small land holding farmers. The name of this very fruit banana is taken from the Arabic word "banan" meaning finger. Banana fruit is perennial herb that makes the trunk like pseudostem (Hailu *et al.*, 2014) [8]. The banana plants are also contemplated as a symbol of "Prosperity and Fertility". The banana fruits are economically important fruits in wide world that undergo physiological deterioration after harvesting (Duan *et al*., 2007) [7]. After rice, wheat and maize, banana is the fourth most important crop globally. Banana plans have huge impact for the people of tropical as well as sub-tropical regions due to its outstanding health benefits. They bagged good amount of income for the farmers (Prasad *et al*., 2015) [20]. Banana is a well known fruit in the world because of the nutrition present in it and also due to lower price. It is eaten raw as well as cooked and it is also a good source of Carbohydrate, Vitamin B, Potassium, Sodium, Phosphorus, Calcium and Magnesium (Rahman *et al.,* 2020) [21]. Banana lessens the problems of heart when consumed continuously and also suggested to the people who are undergoing kidney problem and high blood pressure. It also helps in curing joint paint, ulcer and gastroenteritis (Gogoi *et al.,* 2015) [9].

Various processed products like juice, wine, chips, jam, Banana puree can be produced from banana. In India, banana is prominent and popular among people since they are enjoyed and eaten by almost all the people. Looking into the nutrition and organic product of banana, it is also known as 'Apple of Paradise/Adam's Fig/Tree of Wisdom' (Bockel *et al*., 2018) [5]. India is the largest producer of banana in a space of 83lakhs hectare with more than 2.9 million tons (Prasad *et al*., 2015) [20].

The research for banana fruit is concentrated on selection of disease resistant variety, clump practices and fertilizers trial but it is also required to combine pre-harvest and post-harvest management since the main problem is in post-harvest losses (Workneh *et al.,* 2011a, 2011b) [27, 28]. The standard of fresh banana fruit and processed banana products are dependent on the post-harvest management while storing, transporting, so it is required to examine effectually to maintain the premium quality of fruit during harvest. Due to absence of storage potential, restricted access of transportation and chance of losses, farmers are enforced to discard the produce within short time (Melado *et al*., 2021) [18]. The area of global banana cultivation is 4.80 million hectares and the productivity is 20.8 million tonnes per hectare. India was considered as the largest consumer of banana as well as chief in the area of banana which is 0.88 million hectares while production is 30.808 million metric tonnes which is followed by Mexico in case of area of banana. In India, Tamil Nadu is the leading producer of banana followed by Andhra Pradesh, Gujarat, Maharashtra, Uttar Pradesh and Karnataka.

Quality is a significant element in the advertising of banana, particularly when planned for new utilization. Banana physical and substance qualities are affected by a few variables, for example, evaluating the nature of advertised foods grown from the ground these are inside the guidelines needed by buyers, is vital that the main credits of the organic products, as per the shopper inclinations at buying banana, are the flavor, time span of usability and appearance (length, breadth and shading) (Singh *et al.,* 2021) [23].

Frequently, conventional methods of packaging for banana give great results where straw and dried banana leaf are utilized even though the productiveness of these two packaging materials has not been scrutinized. It is also discovered that Modified Atmospheric Packaging (MAP) enhances the shelf life of banana. It is advisable to create low atmosphere in oxygen and high atmosphere in carbon dioxide to impact the metabolism while packaged or to expand the shelf life. Packaging separate the fresh fruits or processed products of banana from outer atmospheric condition and assist suitable conditions (Beaudry, 2000) [3].

The post-harvest losses of banana account for 30-40% because of poor handling, improper storage facilities as well as abrasion, browning, decay, skin discoloration and so on and also bananas are susceptible to mechanical damages. The fruit is hardly unanimous with other fruits in mixed load while storing or transporting since it produces high amount of ethylene and also susceptible to chilling injury (Kumari *et al*., 2017) [11]. The quality of banana is reduced and huge amount of it is shriveled, from the time of harvesting to consumption. The quality loss of banana can be minimized by upgrading the post- harvest techniques by using different packaging materials. The fruits of banana ripen fast at higher temperature and shorten their shelf life. Therefore, it is required to make few methods in order to delay the ripening of fruits and expanding the shelf life under certain condition while the eating qualities of fruits are not being affected. The banana fruits are not able to store for long period of time since it is perishable in nature. Because of the short shelf life of the fruits, it is difficult to transport in far places and hence, sold only in local market. The reason behind the spoilage of fruit is the harvesting of fruit at improper stage, physical damage while transporting, fungal infections, fungal breakdown followed by senescence. When the banana fruits reach its maturity, they release ethylene that enhances the ripening of fruits. Destruction of chlorophyll is one of the damages caused by ethylene. Hence, ethylene plays a major role in ripening of climacteric fruit. Since banana is a climacteric fruit, controlling the ethylene will be able to solve various problems. Utilization of ethylene absorbent at such temporary storage will postpone the untimely climacteric process. Ethylene absorbent acts as oxidizing agent, which oxidized ethylene to acetaldehyde (CH3CHO), which in turn is oxidized to acetic acid (CH3COOH). Acetic acid is then oxidized to carbon dioxide (CO2) and water (H2O). This loss can be kept at minimum by improving postharvest handling techniques by the utilization of packaging materials or through improving traditional packaging practices. Use of ethylene absorbent during transport will retard the chances of untimely ripening while transporting (Singh *et al*. 2009) [24].

The utilization of post- harvest treatments so as to increase the shelf life of banana is an enhanced technique that aids in the production of quality for farmers as well as cultivators of banana. Therefore, packaging has become a fundamental and decisive component for the industrial as well as commercial chain of food supply. The latest technique is the modified atmosphere packaging. It has also found out that the thickness of polyethylene has great impact on the shelf life of banana (Pamungkas *et al*., 2023) [19]. In this terms, bananas packed in LDPE (which is also a kind of modified atmospheric packaging), plastic boxes, gunny bags, aluminium foils, etc. increase the shelf life. Because of their elevated respiratory activity and production of ethylene during the stage of maturation, bananas are exceptionally perishable as well as climacteric in nature. After the harvesting of banana fruits, they endure fresh for about seven to eight days under normal temperature. The shelf life of fruits can be increased by different methods and packaging materials plays one of the major roles in increasing shelf life of fruits (Manikpuri *et al*., 2023) [15]. So as to meet the customers in appropriate state, the fresh bananas should be properly sold considering the application of the most suitable temperature as well as humidity and also proper handling and packaging techniques. Proper packaging of bananas not only enhances the quality of fruits but also gains the preferences of consumers (Marpaung *et al*., 2019) [16]. Handling the fruits properly during the time of harvesting decreases the mechanical loss as well as decreases wastes which is caused by microorganism contamination (Marpaung *et al*., 2020) [17].

Materials and Methods

Description of the study area

The experimental study was carried out in 2023 at the Horticulture laboratory, School of Agriculture, Lovely Professional University, Punjab to evaluate the effect of different packaging materials on shelf life and quality of banana fruits. The experimental laboratory is located in Phagwara, Punjab also located about 31.1471 ºN latitude and 75.3412 ºE longitude. The location comprises an altitude of 300 meters above mean sea level. The mean annual temperature ranges from 2- 40 ºC with an average of 21 ºC. The rainfall in this location ranges from 273 to 676 mm.

Experimental materials

Different packaging materials were utilized in this experiment. Collected green, physiologically matured banana fruit (cv. Cavendish) was used as experimental material. Additionally, different packaging materials: T_0: Control, T_1: Plastic container with cover, T_2: Brown Paper Bag, T_3: CFB (Newspaper), T_4: CFB (Straw), T_5: Wooden crates, T_6: Low Density Polyethylene Bag (LDPE), T_7: High Density Polyethylene Bag (HDPE)]

Treatments and experimental design

The treatments were consisted of eight different packaging materials [Control, Plastic container with cover, Brown Paper Bag, CFB (Newspaper), CFB (Straw), Wooden crates, Low Density Polyethylene Bag (LDPE), High Density Polyethylene Bag (HDPE)]. The experiment was laid out in a completely randomized design (CRD) with three replications.

Experimental procedure

The experiment was investigated in laboratory condition. Physiologically sound green mature bananas (cv. Cavendish) were collected from local market. Transportation was done during morning time and fruits were covered with newspaper so as to avoid light and heat damage. Fruits were washed with using tap water to discard the soil particles on the surface and to decrease the microbial population. The banana fruits were packed by using different packaging materials and arranged in the storage room with three replications. Six fruits were packed in each treatment and forty- eight banana fruits per replications. A total of 144 banana fruits were used for all eight packaging materials and three replications.

Data collection

The data were collected from banana fruits of different packaging materials on three days interval. The sample of banana fruit in each treatment was randomly taken for assessment. Data was recorded at three days interval over the storage duration.

Physical parameters

Shelf life: Shelf life: Shelf life as determined by various packaging materials was evaluated by counting the days which is essential for fully ripening so as to acquire eating and optimum marketing qualities. The shelf life of the banana fruit was influenced by the long lasting of the fruit.

Physiological weight loss (PLW)

The initial weights of the banana fruits were taken by using electronic balance before storing. Then the weights were again recorded with three days intervals during the period of storage (Krishnakumar and Thirupathi, 2014) [12] and the physiological weight loss was estimated with formula.

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Decay percentage (%)

The decay percentage was estimated by total percentage of decayed fruits at the end of stAorage and was expressed in percentage (Krishnakumar and Thirupathi, 2014) [12]. The values for decay percentage were calculated by using the following formula:

$$\text{Decay percentage (\%)} = \frac{\text{Number of decayed fruits}}{\text{Total number of fruits}} \times 100$$

Bio-chemical Parameters

Total Soluble Solids (TSS) (ºBrix): Total Soluble Solids (TSS) of banana was calculated using the method which is followed by (Li J *et al*., 2019) [13] along with some changes. The pulp of banana was mashed uniformly by the help of a mixer so as to calculate the TSS of the sample. A drop of banana pulp was put on the digital refractometer and noted the readings.

Vitamin C: Vitamin C was estimated by visual titrimetric method by using 2, 6- dichlorophenol- indophenol dye. The dye is blue in alkaline solution while red in acidic solution and is reduced by ascorbic acid to colorless form (Rangnna, 2007) [22].

Required reagents

1. **3% Metaphosphoric acid (HPO3):** 3gm of HPO3 was dissolved in 100 ml distilled water.
2. **Ascorbic acid standard:** 100 mg of ascorbic acid was dissolved in 100 ml of HPO3 and then diluted 10 times with 3% HPO3.
3. **Dye solution:** 50 mg of sodium salt of 2,6-dichlorophenol- indophenols dye was then dissolved in 150 ml hot distilled water which contains 42 mg of sodium bicarbonate. Dye solution was then stored in refrigerator and standardized regularly.

Standardization of dye: 5 ml of standard ascorbic acid along with 5 ml of HPO3 were mixed and titrated against dye till it appears pink and should persist for 15 seconds. Dye factor was estimated by following formula.

Dye factor = 0.5/ Titrated value.

Procedure

- 5 gm of banana fruit sample was homogenized by using mortar and pestle in 100 ml of 3% HPO3.
- Then samples were filtered with Whatman No. 1 filter paper and 10 ml of aliquot was taken from the sample in a conical flask then titrated with 2,6- dichlorophenol-indophenols dye until pink color appears and persist for 15 seconds.
- The observations were and expressed in mg.

$$\text{Vitamin C} = \frac{\text{Titre value x dye factor x volume made up}}{\text{Aliquot (ml) x weight or volume of sample (g)}} \times 100$$

Total Phenol Content (mg/GAE/100g): The Total Phenol Content was estimated by using the reagent Folin-ciocalteu with little changes.In 100 µl of sample extract (in 80%l ethanol), 2.9 ml distilled water, 0.5ml Folin- Ciocalteau reagaent and 2 ml of 20% Sodium carbonate (Na2CO3) solutions were added. Then the mixture was made to stand for 90 minutes and the absorbance was recorded at 765nm wavelength by using spectrophotometer. The Total Phenolic Content was expressed as micrograms (mg) of Gallic acid equivalent per gram of fresh weight (mg/GAE/100g) (Silva *et al*., 2011) [6].

$$\text{Total Phenol Content} = \frac{\text{OD 765 X Volume made (with 80\% ethanol)}}{\text{Aliquot taken x weight of sample x 1000}} \times 100$$

Total flavonoids content (%): To estimate the Total Flavonoids Content, a colorimeter assay was used. 1 ml of extract was mixed with 4ml distilled water in 10 ml volumetric flask. And to this mixture, 0.3 ml of 5% NaNO2 was added and made it stand for 5 minutes at room temperature. After that 0.3 ml of 10% AlCl3.6H20 was added then again mixture was made to stand for about 6 minutes at room temperature. Later that, 2 ml of 1N NaOH was added and then the solution was diluted to final volume of 10 ml with distilled water. The absorbance of the solution and blank were recorded 510 nm wavelength. The concentration of the total flavonoids content was expressed as catechin equivalents (CE) by using a standard curve prepared from authentic catechin. The standard curve was recorded by plotting the absorbance and concentration of catechin. The total flavonoids content was estimated by the following formula (Silva *et al*., 2011) [6].

$$\text{Total Flavonoids Content} = \frac{\text{OD510 x volume made up (with 80\% ethanol)}}{\text{Aliquot taken x weight of sample x 100}} \times 100$$

Results and Discussion

The analysis of variance (ANOVA) for all the recorded parameters of physiological weight loss, total soluble solids, titratable acidity and total sugars were shown highly significantly ($p \leq 0.05$) difference by different packaging materials.

Shelf life

The shelf is the period from the time of harvesting till the last edible stage (Bantayehu *et al*., 2017) [2]. The shelf life of any product is dependent on the initial quality of the product, how much quality change can be permitted, prevailing environmental conditions and decelerates properties of the packaging materials and compatibility amongst the food products and packaging (Tsegaye *et al*., 2020) [26]. Remarkable variations were observed within the treatment combinations in case of extension of banana. The bananas which were packed in high density polyethylene and low density polyethylene have shown to have the longest shelf life. The lowest shelf of banana fruits was observed under unpacked fruits (Control).

Physiological weight loss

The effect of different packaging materials at ambient temperature on the rate of changes of physiological weight loss is presented in Table 1 and Fig. 2. The physiological weight loss of fruits was found to be increasing with the storage period irrespective of treatments. At 1st day of storage the highest physiological weight loss was recorded with T_0 (2.85) and lowest was recorded with T_7 (1.68). At 3rd day, the highest physiological weight loss was recorded with T_0 (6.04) while the lowest was recorded with T_7 (3.26). On 6th day, the highest physiological weight loss was recorded with T_0 (10.31) and the lowest was recorded with T_7 (5.33). At 9th day, the highest physiological weight loss was recorded with T_0 (15.37) and the lowest was recorded with T_7 (7.6). And on the 12th day of storage, the highest physiological weight loss was recorded with T_0 (19.98) while the lowest was recorded with T_7 (9.41).

The fruits lose weight physiologically, which decreases the quality of the fruits as the ripening process progresses. Because of the constant evaporation from the fruits, the physiological weight loss increased in all treatments as storage duration continued. The mechanism underlying the positive effects of high density polyethylene is that respiration causes loss in weight since a carbon atom is being lost from the fruit, every time a carbon- dioxide molecule is built from an absorbed oxygen molecule and developed into atmosphere (Singh *et al*., 2021) [23].

Decay percentage (%)

The effect of different packaging materials at ambient temperature on the rate of changes decay loss percentage of banana is presented in Table 1 and Fig. 1. With the increasing period of storage duration, the fruits tend to loss their marketability properties and increase their decay loss percentage. The decay loss percentage was estimated at the end day of storage period. At 12th day, it was observed that the fruit decay loss percentage varied remarkably for T_0 (control) and other packaging materials. The data showed the highest decay loss percentage with T_0 (83.66), T_4 (67.19) and very closely followed by T_2 (67.1), T_1 (67.07), T_3 (50.47), T_5 (67.07), T_6 (17.05). And the lowest decay loss percentage was observed with T_7 (16.84).

Evaporative coolers reduce the temperature inside the storage area, slowing the rate of fruit ripening and ethylene production. These directly affect the fruit's shelf life extension. The deterioration of banana fruit was observed primarily after harvesting, followed by marketing, transportation, and storing, and in certain cases throughout the entire channel. This is because fresh produce, after harvesting, continues the process of respiration and transpiration until its food and water are reserved (Belay, 2022) [4].

Table 1: Effect of different packaging materials on banana (cv. Cavendish) on physiological weight loss and decay percentage during storage at ambient temperature

Treatments	Storage Days					
	Physiological Weight Loss (%)					Decay Percentage (%)
	Day 1	Day 3	Day 6	Day 9	Day 12	Day 12
T_0	2.85^{ab}	6.04^{a}	10.31^{a}	15.37^{a}	19.98^{a}	83.66^{a}
T_1	2.6^{abc}	4.74^{c}	8.38^{c}	13.18^{c}	17.65^{bc}	67.07^{b}
T_2	2.84^{ab}	5.21^{bc}	9.09^{b}	13.77^{b}	17.14^{c}	67.1^{b}
T_3	2.35^{bcd}	4.92^{bc}	9.25^{b}	12.23^{d}	16.04^{d}	50.47^{c}
T_4	3.11^{a}	5.53^{ab}	9.64^{ab}	13.76^{b}	17.68^{bc}	67.19^{b}
T_5	2.06^{cd}	4.77^{c}	9.49^{b}	12.53^{d}	18.26^{b}	67.07^{b}
T_6	2.01^{cd}	3.39^{d}	5.41^{d}	8.36^{e}	10.67^{e}	17.05^{e}
T_7	1.68^{d}	3.26^{d}	5.33^{d}	7.6^{f}	9.41^{f}	16.84^{e}
C.D. ($p \leq 0.05$)	0.68	0.68	0.70	0.42	0.69	0.738
SE (m)	0.23	0.23	0.23	0.14	0.23	0.244

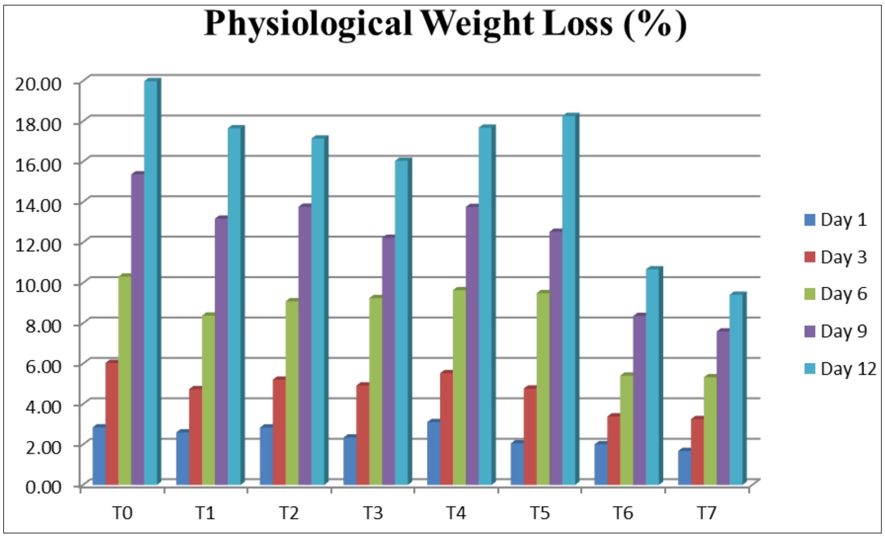

Fig 1: Effect of different packaging materials on banana (cv. Cavendish) on physiological weight loss during storage at ambient temperature

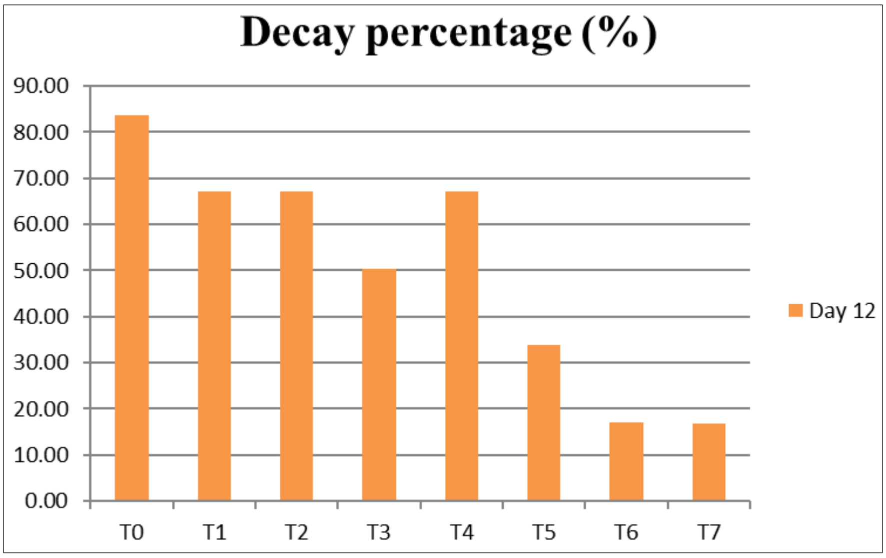

Fig 2: Effect of different packaging materials on banana (cv. Cavendish) on decay percentage of fruits during storage at ambient temperature

Total soluble solids (TSS) (ºBrix)

The effect of treatments and the day of storage on total soluble solids (TSS) of banana under ambient condition are represented in Table 2 as well as Fig. 2. As the storage period keeps increasing, the total soluble solids of banana fruits also increased. At 1st day, there was no significant but slight difference among the treatments. The highest TSS was recorded with T_3 (16.64) and the lowest TSS on 1st day was observed with T_0 (14.29). On 3rd day, the maximum TSS was observed with T_3 (17.08) while the minimum TSS was recorded with T_0 (14.73). At 6th day, the highest TSS was recorded with T_7 (23.19) and the lowest TSS was recorded with T_0 (20.51). At 9th day, the maximum TSS (26.76) was observed with T_7 again and similarly the minimum TSS was observed with T_0 (23.68). At 12th day, once again the minimum TSS (25.83) was recorded under T_0 while the maximum TSS was recorded with T_7 (28.72).

The increase in total soluble solids was observed in the current experiment agrees with the report made by (Youryon *et al*., 2017) [29] which affirms that total soluble solids of fruits increase along the storage duration. The increased total soluble solids value might be because of the physiological characteristics of bananas, suppressed respiration as well as metabolic process, which included increasing of total soluble solids at various magnitudes (Abiso *et al*., 2018) [1].

Vitamin-C (mg)

The effects of different packaging materials and storage days on vitamin C content of banana under ambient condition are presented in Table 2 and Fig. 4. The value of vitamin C was significantly affected by the treatments and the days of storage. The highest vitamin C content (4.3) was recorded under T_7 followed by T_6, T_5, T_3, T_4, T_2 and T_1 while the lowest vitamin C (1.48) was recorded under T_0. On day 3, the maximum vitamin C was recorded under T_7 (5.12) and the minimum was recorded under T_0 (2.25). On day 6, the maximum vitamin C was recorded under T_7 (5.58) followed by T_6, T_4, T_1, T_5, T_2 and T_3) and the minimum vitamin C was recorded under T_0 (3.43). On day 9 and 12, the highest vitamin C was recorded under T_7 (7.28 and 7.58) respectively and T_0 has found to have the least vitamin C content with values (4.44 and 5.69) respectively. During the storage period of banana fruits at ambient condition, the vitamin C content in fruits were subjected to different packaging treatments showed an increasing pattern. The fruits packaged in high density polyethylene had recorded to have highest vitamin C which is followed by low density polyethylene bag and the lowest vitamin C content was recorded under unpackaged control banana fruits. There observed significant variations amongst the different packaging materials over the storage period of 12 days. The present investigation was in line with the report of (Kader, 2002) [10] that, the role of packaging materials was decrease the respiration rate of fruit as well as vegetables by retarding the metabolic activities.

Table 2: Effect of different packaging materials on banana (cv. Cavendish) on total soluble solids and vitamin C during storage at ambient temperature

Treatments	Storage Days									
	Total Soluble Solids (%)					Vitamin C (mg)				
	Day 1	Day 3	Day 6	Day 9	Day 12	Day 1	Day 3	Day 6	Day 9	Day 12
T_0	14.29^{c}	14.73^{c}	20.51^{d}	23.68^{d}	25.83^{d}	1.48^{e}	2.25^{d}	3.43^{b}	4.44^{d}	5.69^{d}
T_1	14.91^{c}	15.34^{c}	21.12^{cd}	23.99^{cd}	26.58^{c}	1.68^{de}	2.78^{c}	3.75^{b}	5.07^{c}	6.44^{c}
T_2	16.01^{ab}	16.44^{ab}	21.33^{c}	24.09^{cd}	26.38^{cd}	2.01^{cd}	2.79^{c}	3.67^{b}	5.14^{c}	6.55^{c}
T_3	16.64^{a}	17.08^{a}	21.36^{c}	24.07^{cd}	26.9^{c}	2.14^{c}	2.68^{cd}	3.64^{b}	5.02^{c}	6.68^{c}
T_4	16.37^{ab}	16.81^{ab}	21.35^{c}	24.17^{c}	26.57^{c}	2.12^{c}	2.84^{c}	3.93^{b}	5.19^{c}	6.77^{bc}
T_5	15.67^{b}	16.11^{b}	21.35^{c}	24.21^{c}	26.38^{cd}	2.3^{c}	3.11^{c}	3.75^{b}	5.23^{c}	6.69^{c}
T_6	14.92^{c}	15.36^{c}	22.22^{b}	25.74^{b}	27.79^{b}	3.27^{b}	4.02^{b}	5.09^{a}	6.55^{b}	7.18^{ab}
T_7	16.11^{ab}	16.54^{ab}	23.19^{a}	26.76^{a}	28.72^{a}	4.3^{a}	5.12^{a}	5.58^{a}	7.28^{a}	7.58^{a}
C.D. ($p \leq 0.05$)	0.69	0.70	0.58	0.42	0.61	0.36	0.45	0.56	0.39	0.43
SE (m)	0.23	0.23	0.19	0.14	0.20	0.12	0.15	0.18	0.13	0.14

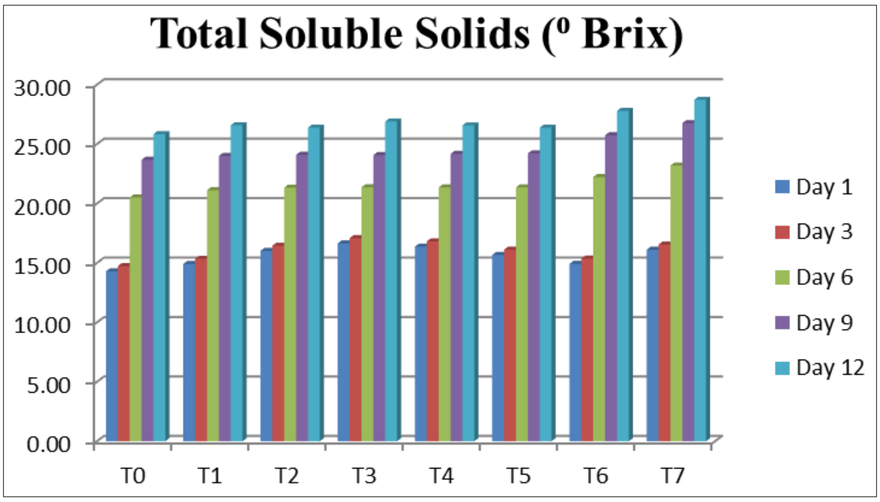

Fig 3: Effect of different packaging materials on banana (cv. Cavendish) on total soluble solids during storage at ambient temperature

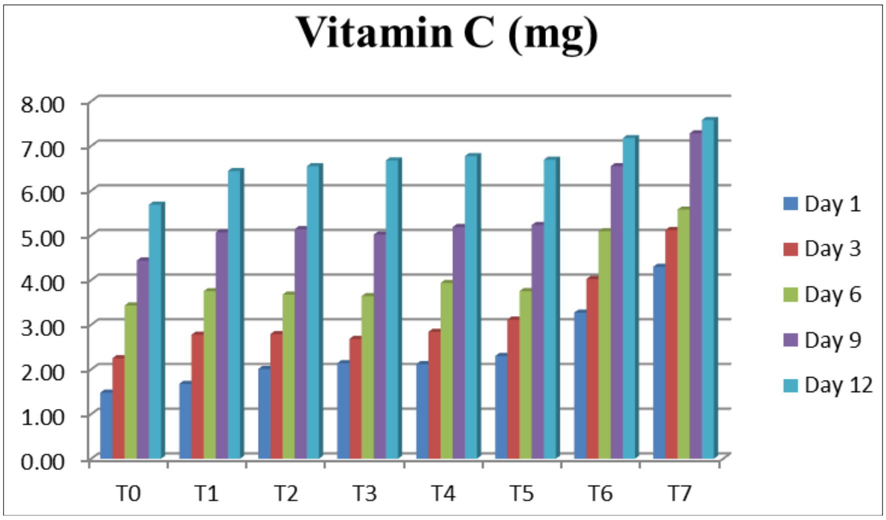

Fig 4: Effect of different packaging materials on banana (cv. Cavendish) on Vitamin C during storage at ambient temperature

Total Phenol Content (TPC) (mg/GAE/100g): The data Table 3 and Fig. 5 below indicates the values of total phenol content of banana and storage days under ambient condition. As the storage days increase, the values of total phenol content significantly increased. The minimum total phenol content was observed under T_0 (34.48) and highest total phenol content was observed under T_7 (39) on day 1. On day 3, the maximum total phenol content was observed under T_7 (39.5) followed by T_6, T_5, T_4, T_1, T_2 and T_3 and the minimum total phenol content was recorded under T_0 (34.91). Again on day 6, the maximum total phenol content (41.91) was recorded under T_7 which is followed by T_6, T_5,

T_2, T_1 and T_4 while the minimum total phenol content was recorded under T_0 (38.41). On day 9 and 12, the maximum total phenol content was recorded under T_7 (42.95 and 44.97) respectively while the minimum was recorded under T_0 (40.14 and 41.98)

Phenolic compounds are significant fruit ingredients because they have antioxidant properties, such as inactivating lipid free radicals or preventing hydroperoxides from decomposing into free radicals. The current investigation methanol was utilized, that resulted in higher extraction yields of phenolic compounds because of its higher polarity (Maisuthisakul *et al*., 2007) [14].

Total Flavonoids Content (TFC) (mg Catechin/100g)

The data in Table 3 and Fig. 6 below indicates the values of total flavonoids content of banana and storage days under ambient condition. As the storage days increase, the values of total flavonoids content significantly increased. On day 1, the highest total flavonoids content was observed under T_7 (42.15) followed by T_6, T_4, T_5, T_3, T_2 and T_1 while the lowest total flavonoids content was observed under T_0 (39.09). On day 3, the maximum total flavonoids content was observed under T_7 (43.61) and the minimum total flavonoids content was observed under T_0 (40.18). On day 6, 9 and 12, the maximum total flavonoids content was recorded under T_7 (44.14, 45 and 46.22) respectively while the minimum total flavonoids content was recorded under T_0 (41.15, 42, 32 and 43.22) respectively.

The increased in total flavonoids content might be due to flavonoids' stability is strongly temperature-dependent, resulting in slower oxidation reactions at lower temperatures. The products packed in polyethylene bags retained maximum total flavonoids content which may be because of improved pouch conditions, reduced moisture and oxygen transport, minimizing flavonoids oxidation compared to other packaging materials. The present investigation was in line with the report of (Sonawane and Arya, 2015) [25] that is the effect of packaging materials on phenols, flavonoids and antioxidant characteristics of mechanical dried wild pomegranate.

Table 3: Effect of different packaging materials on banana (cv. Cavendish) on total phenol content and total flavonoids content during storage at ambient temperature

Treatments	Storage Days									
	Total Phenol Content (mg/GAE/100g)					Total Flavonoids Content (mg Catechin/100g)				
	Day 1	Day 3	Day 6	Day 9	Day 12	Day 1	Day 3	Day 6	Day 9	Day 12
T_0	34.48^{d}	34.91^{d}	38.41^{d}	40.14^{c}	41.98^{c}	39.09^{e}	40.18^{d}	41.15^{d}	42.32^{d}	43.22^{d}
T_1	36.65^{c}	37.09^{c}	40.13^{c}	41.46^{b}	43.48^{b}	39.84^{de}	41.82^{c}	42.65^{c}	43.45^{c}	44.58^{bc}
T_2	36.11^{c}	36.56^{c}	40.41^{bc}	42.26^{ab}	43.88^{ab}	39.88^{de}	41.72^{c}	42.83^{bc}	43.62^{bc}	44.59^{bc}
T_3	35.84^{c}	36.29^{c}	40.01^{c}	41.7^{b}	43.08^{bc}	40.39^{cd}	41.53^{c}	42.63^{c}	43.39^{cd}	44.59^{bc}
T_4	36.34^{c}	36.77^{c}	39.94^{c}	42.29^{ab}	43.5^{b}	41.23^{bc}	42.16^{bc}	43.03^{bc}	43.22^{cd}	44.15^{cd}
T_5	36.81^{c}	37.26^{c}	40.37^{bc}	42.17^{ab}	43.54^{b}	40.97^{bc}	41.81^{c}	42.43^{c}	43.06^{cd}	43.84^{cd}
T_6	37.92^{b}	38.4^{b}	41.45^{ab}	42.97^{a}	44.76^{a}	41.66^{ab}	42.78^{ab}	43.7^{ab}	44.59^{ab}	45.64^{ab}
T_7	39^{a}	39.5^{a}	41.91^{a}	42.95^{a}	44.97^{a}	42.15^{a}	43.61^{a}	44.14^{a}	45^{a}	46.22^{a}
C.D. ($p \leq 0.05$)	0.91	0.91	1.21	0.92	1.14	0.85	0.86	0.89	0.98	1.11
SE (m)	0.30	0.30	0.40	0.30	0.38	0.28	0.28	0.29	0.32	0.37

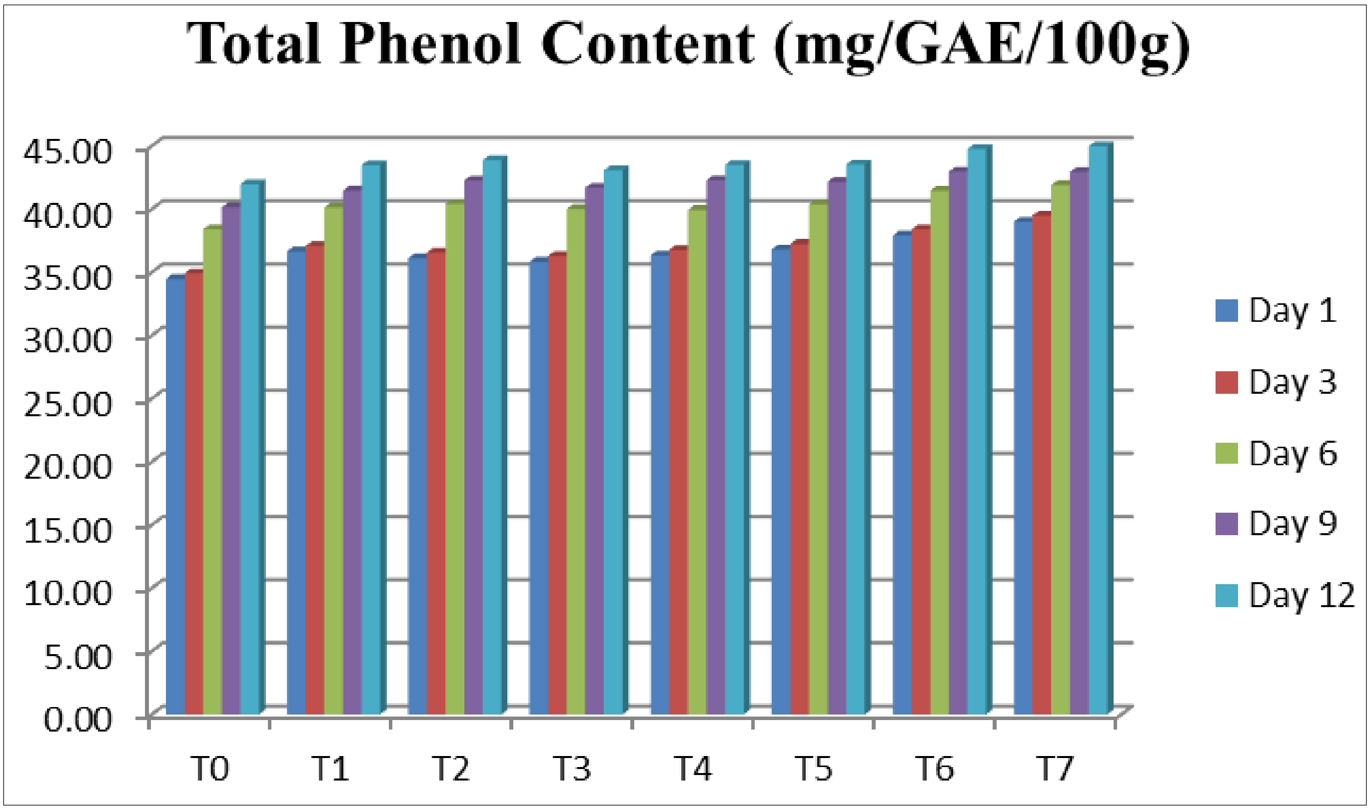

Fig 5: Effect of different packaging materials on banana (cv. Cavendish) on total phenol content during storage at ambient temperature

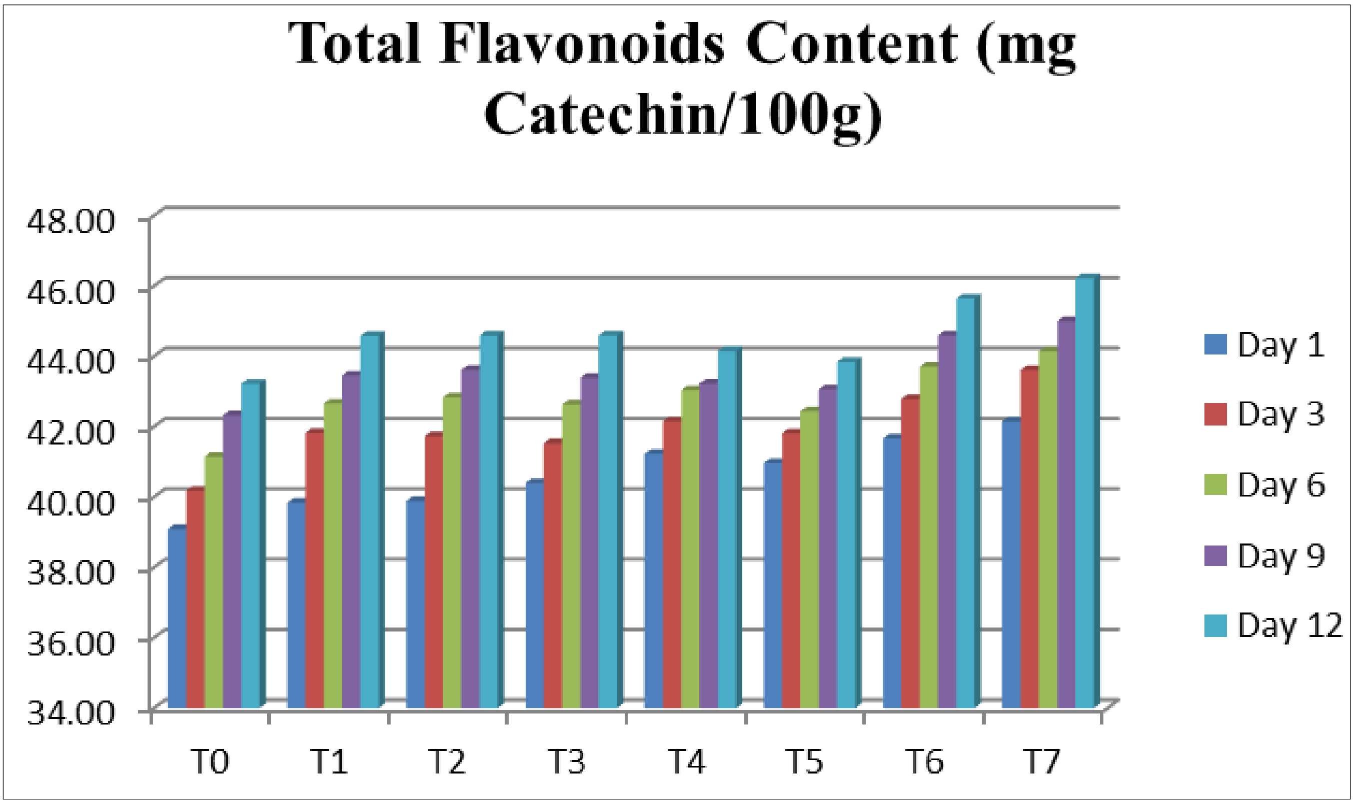

Fig 6: Effect of different packaging materials on banana (cv. Cavendish) on total flavonoids content during storage at ambient temperature

Conclusion

Based on the findings from the experiment, it can be acknowledged that the combined application of different packaging materials proved to be the best post- harvest treatments in terms of shelf life, physiological weight loss and decay percentage. Unpacked fruits did not show any variation in chemical parameters like total soluble solid, vitamin C, total phenol content, total flavonoids content. As per the results from the recent study, banana (cv. Cavendish) treated with different packaging materials such as Plastic container with cover, Brown Paper Bag, CFB (Newspaper), CFB (Straw), Wooden crates, Low Density Polyethylene Bag (LDPE), High Density Polyethylene Bag (HDPE) significantly slowed down changes in case of decay (%) and increases in total soluble solid, vitamin C, total phenol content, total flavonoids content as compared to control (unpacked) banana fruits. From this experiment, it can be understood that the banana fruits packed in high density polyethylene had maximum levels of chemical as well as physical parameters. Overall, all of the packaging materials increased the shelf life of banana (cv. Cavendish).

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