EFFECT OF PACKAGING MATERIALS AND POSTHARVEST TREATMENTS ON POSTHARVEST QUALITY AND SHELF LIFE OF BANANA FRUITS (*Musa Spp*)

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Abstract
Banana is considered as a short life fruit. Extending shelf life and maintaining postharvest quality of the fruit can be accomplished when ripening is not induced by a large ethylene exposure, stored at appropriate temperature and relative humidity. Afar region of Ethiopia, very hot temperature and very low relative humidity makes the shelf life of banana fruits less than two days. This study initiated to extend the shelf life and maintain postharvest quality of banana fruits by applying different postharvest treatments and packaging materials locally available. Three packaging materials (carton, jute sack and newspaper) and three post-harvest treatments (ginger, clove, hot water treatment with 55^0*c for 40 seconds and ambient (control)) had been used. This two factor experiment was arranged with Completely Randomized Design each replicated three times. Chemical and physical attributes including total soluble solids, pH value, moisture content, physiological weight loss, peel to pulp ratio, decay percentage, color and shelf life were assessed every four days as response parameters and data were analyzed using SAS version 9.2 statistical software. Result of the study showed that retaining of postharvest shelf life was better using combinations of postharvest treatments and packaging. Best result was showed for fruits packed with carton and treated by ginger (8 days) followed by fruits packed with carton and treated with clove. Fruits stored at ambient were immediately unmarketable after 2-day storage. Generally, moisture content, physiological weight loss, and peel to pulp ratio, decay percentage and color were much better for fruits treated and packed in different packaging materials as compared to the control. All the chemical attributes also performed better relative to the ambient. So generally it can be concluded that all the three postharvest treatments and packaging can prolong shelf life and other quality parameters of banana fruit.*

Keywords: banana, packaging material, postharvest treatment, temperature, relative humidity, shelf life, postharvest quality, physical attributes, chemical attributes

Received: 02.01.2018 Received in revised form: 19.05.2018 Accepted: 22..05.2018

1. INTRODUCTION

Banana (*musa spp*) is a member of Musacea family and native to south east Africa. It is the most popular fresh fruit all over the world and its name comes from the Arabic word 'banan', which means finger. Banana is a large perennial herb with leaf sheaths that form the trunk like pseudostem. They vary in height from 1.5-8 m and generally divide in to starchy type called plantation and the desert type known as banana (Hailu *et al*, 2014).

Banana is a very popular fruit due to its low price and high nutritive value. It is consumed both in fresh and cooked form both as ripe and raw fruit. Banana is a rich source of carbohydrate and is rich in vitamins particularly vitamin B. It is also a good source of potassium, phosphorus, calcium and magnesium. The fruit is easy to digest, free from fat and cholesterol. It helps in reducing the risk of heart diseases when used regularly and is recommended for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders. Processed products, such as chips, banana puree, jam, jelly, juice, wine and halwa can be made from the fruit. Banana can be utilized for the production of edible vaccine against Hepatitis- B virus (HBV). The plant based vaccine for HBV from edible banana seems to be an economical alternative for human healthcare by many scholars.

The total area under banana in the world is 11.13 million ha, producing 97.38 million tons of banana and plantains. India is the largest producer of banana in the world, contributing 24 % to the global production with a total area of 0.565 million ha and production 19.19 million tons reported for the year 2011 (FAO, 2011).

Ethiopia lies in the tropics where vast areas are suitable for banana growing. Banana production in Ethiopia ranges from homestead to large commercial plantations. At present, bananas are the leading fruit crops produced in the country both in terms of area coverage (28,695 ha) and production (1,245,615.60 q year−1) (Central Statistics Authority, 2004).

In Ethiopia there is no proper means of postharvest handling of fruits and vegetables at the retail and wholesale levels, which results in poor quality of banana at the consumer level. Although the country is experiencing huge postharvest losses of banana very little or no emphasis is given to postharvest handling of the fruit (Workneh *et al*, 2011).

In Afar region where temperature is high (some times as high as 45^0C) and very low relative humidity, the shelf of the fruits lasts less than two days. Most of the fruit retailers bring the banana fruit from the nearby towns like Kombolcha and Dessie which drives more than 200 km. So availability of the fruit all the week on market is the main challenge consumers are facing as the market day is only on Thursday and Sundays.

The spoilage of banana is mainly due to harvesting at improper stage of maturity. Physical damage during transport, consequent fungal infections, and fungal breakdown primarily leads the fruit to senescence. Packaging of the fruit protects from physical damages and contaminations at retail level. As extract of different spices and herbs have an antifungal characteristic they suppress development of fungus on the surface of the fruits. Hot water dip also suppresses growth of some fungi and inactivates enzymatic activities which fasten ripening of the fruit.

2. MATERIALS AND METHODS

2.1. Experimental Materials

Banana fruit harvested at commercial maturity with uniform size, shape, and color were brought from kombolcha. The fruits transported to the experimental site one day after harvest. Different locally available packaging materials (Jute sack, Carton, News Paper) and Postharvest treatments (Ginger, clove and hot water) were used. Ginger and clove (both 1kg) was brought from Logia market, crushed and immersed in 5 liters of water and stayed overnight before decant and use as treatment. Hot water at 55^0C was used for the treatment and the fruit finger was blanched for 40 seconds. Fifteen banana fruits were used for this experiment both for qualitative and quantitative data.

2.2. Experimental Design

The experiment was a 4*3 factorial design arranged in complete randomized design (CRD). The experiment is a two factor experiment. Factor one is different postharvest treatments (hot water, ginger, and clove) and factor two is different packaging materials (jute sack, newspaper, and carton) where each treatment replicated three times.

2.3. Data Collected

Different qualitative and quantitative data were collected for the following parameters. Observation and recording of the data were done on the 4^{th} and 8^{th} day during the storage period. On the first storage day data for initial weight was recorded

Storage Environment

Data were collected for the temperature and relative humidity during the storage period for 10 days. The following table shows the average data of temperature take three time: morning, afternoon and night time.

Physiological Weight Loss

Weight loss was determined by using Portable Electronic Scale balance. The weight loss of banana fruit sample was calculated as the percentage of the initial fruit weight. The following formula used to compute physiological weight loss (Monerzumma *et al.,* 2009).

$$\mathbf{PWL\ (\%)} = \frac{\mathbf{Initialweight - Finalweigh}}{\mathbf{Initialweight}} \mathbf{x100}$$

Moisture Content Determination

The moisture content of the fruit was determined by using Moisture Analyzer MB 25.

Peel to Pulp Ratio

Banana fruits from each treatment were peeled off and the pulp and peel portion of each finger were weighted separately by electronic sensitive balance. The following formula was used to determine the percentage of peel to pulp.

$$\text{Peel to pulp (\%)} = \frac{\text{Peel weight}}{\text{Pulp weight}} \times 100$$

Fruit Color Determination

Fruit color analysis was assessed visually by matching the color with standardized color charts that describe the given ripening at eight stages and color score was assigned accordingly: 1=green, 2=green with trace yellow 3=most green, 4=green and yellow, 5=most yellow,6=almost yellow,7 =yellow, 8= yellow with brown flex and 9 =black. Banana fruit was considering unripe at stages of 1-4, and ripe at stages of 5-8.

Decay Percentage

Decay or rotting was determined by visual observation. Development of spots on the fruit and softening and rotting of the fruits was recorded (Monerzumma *et al.,* 2009).

Shelf life

Shelf life of banana fruits as influenced by different postharvest treatment and packaging material was calculated by counting the days required to ripe fully as to retaining optimum marketing and eating qualities. The shelf life of the fruit was determined by the long lasting of the fruit.

Determination of pH

The pH value of the banana fruit was determined by using digital pH meter (Bellingham + Stanley 45-2, UK).

Total soluble solid (TSS)

Total soluble solids (TSS) content of banana fruit pulp was recorded using refractometer (Bellingham + Stanley 45-2, UK). A drop of banana juice was squeezed from the fruit pulp on the prism of the refractometer and percent of total soluble solids (TSS) content was recorded as ^{0}Brix from direct reading of the instrument.

2.4 Statistical Analysis

The collected data were subjected to Analysis of Variance (ANOVA) by using SAS version9.2 computer software (SAS Institute Inc. 2008). Fisher's Least Significance Difference (LSD) was used to establish the multiple comparisons of mean values. Mean values were considered at 5% significance level ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1 Physiological Weight Loss and Moisture Content

Weight loss of fresh fruits is primarily due to transpiration and respiration ((Tadesse, 1991). On current study weight loss of banana fruit was significant within the storage period. Table 1 showed that there was a significant variation in physiological weight loss between the different treatments on the 4th and the 8th days of storage period. The highest physiological weight loss was recorded on the HC treated fruits (32.41%) followed by CN (27.61%) and the lowest physiological weight loss was observed in banana fruits treated by CO (20.29%) at the 4th days of storage period. Whereas, on the 8th days of storage the highest physiological weight loss was recorded. Treatment HC had the highest physiological weight loss (38.98%) followed by CO (36.93%) and the lowest physiological weight loss was observed in banana fruits which were treated by HJ (19.96%). The highest physiological weight loss was observed with fruits treated by HC. This might be due to the packaging material (carton) increases the transpiration and respiration rate as compared to the room temperature storage.

Loss of weight progressively increased with storage time. Weight loss of fresh banana is primarily due to transpiration and respiration.

Table 1: Physiological Weight Loss and Moisture Content of bananas stored at different packaging materials and postharvest treatments for 8 days (%)

Treatment combinations	Physiological Weight loss (%)		Moisture content (%)	
	Day 4	Day 8	Day 4	Day 8
GC	23.87[cd]	35.48[bcd]	67.13[d]	74.83[e]
GJ	21.44[de]	25.19[e]	91.19[a]	96.86[a]
GN	27.32[b]	33.31d[c]	90.71[ab]	91.57[bc]
CC	25.74[bc]	33.94b[cd]	71.35[d]	82.78[d]
CJ	21.90[de]	24.92[e]	84.31[bc]	89.63[c]
CN	27.61[b]	32.91[cd]	87.45[abc]	93.68[abc]
HC	32.41[a]	38.98[a]	89.42[abc]	95.41[ab]
HJ	13.54[f]	19.96[f]	82.83[c]	94.94[ab]
HN	20.96[de]	35.2[bcd]	88.06[abc]	94.52[ab]
CO	20.29[e]	36.93[ab]	90.28[ab]	94.80[ab]
LSD (5%)	**3.07**	**3.30**	**6.85**	**4.41**
CV (%)	**7.76**	**6.06**	**4.74**	**2.84**

Means with same letter within a column are not significantly different

*Where: **GC**, Ginger with carton; **GJ**, Ginger with jut sack; **GN**, Ginger with newspaper ;**CC**, Clove with carton; **CJ**, Clove with jut sack ;**CN**, Clove with newspaper; **HC**, Hot water with carton; **HJ**, Hot water with jut sack ;**HN**, Hot water with newspaper and **CO**, is Control.*

Table 2: Peel to pulp ratio for bananas stored at different packaging materials and postharvest treatments for 8 days (%)

Treatment combinations	**Pulp to peel ratio (%)**	
	Day 4	**Day 8**
GC	62.14[aa]	28.00[cb]
GJ	59.64b[ac]	35.86[aa]
GN	55.71bd[ec]	26.53[cd]
CC	55.02[cd]	26.62[cd]
CJ	56.31[bdec]	25.71[cde]
CN	53.84[de]	23.13[ee]
HC	51.68[ee]	35.95[aa]
HJ	52.96[ee]	30.06[bb]
HN	58.21[bdac]	24.41[de]
CO	60.45[ab]	24.56[de]
LSD (5%)	**5.25**	**3.26**
CV (%)	**5.41**	**7.01**

Means with same letter within a column are not significantly different

Transpiration is a mechanism in which water is lost due to differences in vapor pressure of water in the atmosphere and the transpiring surface (Tasdelen and Bayindirli, 1998). Respiration causes a weight reduction because a carbon atom is lost from the fruit, each time a carbon-dioxide molecule is produced from an absorbed oxygen molecule and evolved into atmosphere (Bhowmik and Pan, 1992). Higher respiration rate also resulted in higher transpiration of water from the fruit surface which led to increase in percentage of weight loss (Sabir *et al.*, 2004).

Table 1 showed there was a significant variation in moisture content observed between the different treatments combination. The highest moisture content was observed in bananas which were treated by GJ(91.19) and the lowest moisture content was recorded in bananas which were treated by GC (67.13) after 4 days of storage. Whereas at the 8th days of storage the highest moisture content was recorded in banana fruits treated by GJ (96.86) and the lowest moisture content were observed in banana fruits which were treated by GC (74.83).

Water comprises about 60 to 86 % of the fresh weight of the banana fruit with the size of the fruit influenced by availability of water to the plant (Babitha and Kiranmayi, 2010). Ripening in fruits is proceeded by softening, with the resultant effect of increased moisture content of the fruit.

The moisture content of banana fruit was observed increasing until the 8thdays of storage. Pulp moisture content was continued to increasing until last days of storage. This reveals fruit moisture has been migrated from peel to pulp. However, the acceleration in pulp moisture content was increased from fourth to eighth days of storage. Mohapatra and Sabayasachi (2010) reported that the increased in moisture content of pulp was occurred due to increase in sugar content in the pulp as a result of starch hydrolysis to sugar.

3.2 Peel to pulp ratio (%)

There was a significant variation in peel to pulp ratio between the different treatment combinations both after 4 and 8 days of storage. The highest peel to pulp ratio was observed in bananas which were treated by GC (62.14%) and the lowest peel to pulp ratio were found in bananas which were treated by HC (51.68%) after 4 days of storage. On the other hand, in the 8th day of storage the highest peel to pulp ratio was recorded in bananas which were treated by HC (35.95%) and the lowest peel to pulp ratio were observed in bananas which were treated by CN (23.13%). The difference among the treatments could be due to the effect of different loss of water from the peel to the atmosphere and to the pulp because of different storage conditions.

3.3 pH and Total Soluble Solid Content (^{0}Brix)

Changes in pH and TSS of the fruits treated at different packaging material, postharvest treatment and at room temperature are shown in Tables 3.

In general, pH of the banana fruit increased with the advancement of fruit ripening. Since acidity of the fruits is due to various organic acids that are consumed during respiration (Albertini *et al.*, 2006). the acidity thus decreased with advancing maturity or increasing storage duration with a corresponding increase in fruit pH (Moneruzzaman *et al.*, 2009).

Highest pH value was recorded for bananas treated by GN, HN and CO (5.37) and least value was recorded treated by CN (3.70) after 4 days of storage.

Table 3: pH and total soluble solid content of banana stored under different packaging material and postharvest treatments for 8 days

Treatment combinations	pH			Total Soluble Solids (^{0}Brix)		
	Day 0	Day 4	Day 8	Day 0	Day 4	Day 8
GC	4.58^{aa}	4.89^{aa}	4.79^{aa}	23.01^{aa}	23.20^{bb}	24.40^{dd}
GJ	4.85^{aa}	4.98^{aa}	4.55b^{ac}	22.89^{aa}	23.93^{ab}	27.67^{aa}
GN	4.93^{aa}	5.37^{aa}	4.66b^{ac}	22.98^{aa}	25.33^{aa}	28.00^{aa}
CC	4.58^{aa}	5.16^{aa}	4.64b^{ac}	22.76^{aa}	23.53^{ab}	25.73^{bdc}
CJ	4.89^{aa}	5.3^{aa}	4.34^{cc}	22.01^{aa}	24.13^{ab}	25.33^{dc}
CN	4.88^{aa}	3.70^{bb}	4.48b^{ac}	23.00^{aa}	24.00^{ab}	27.33^{ab}
HC	4.92^{aa}	4.95^{aa}	4.41^{bc}	23.21^{aa}	22.83^{bb}	26.67^{bac}
HJ	4.78^{aa}	5.08^{aa}	4.62b^{ac}	22.86^{aa}	23.93^{ab}	25.67^{bdc}
HN	5.02^{aa}	5.37^{aa}	4.71^{ba}	22.96^{aa}	24.27^{ab}	25.67^{bdc}
CO	4.69	5.37^{aa}	4.67b^{ac}	23.0^{aa}	24.57^{ab}	24.57^{aa}
LSD (5%)	**0.63**	**0.58**	**0.37**	**0.94**	**0.94**	**0.95**
CV (%)	**3.56**	**6.72**	**4.72**	**3.36**	**4.62**	**4.22**

Means with same letter within a column are not significantly different

Table 4: Decay percentage of banana stored under different packaging material and postharvest treatments for 8 days

Treatment combinations	Decay percentage (%)	
	Day 4	Day 8
GC	**70.00**(0.0078)[b]	**100**(0.0157)[a]
GJ	**70.00**(0.0078)[b]	**100**(0.0157)[a]
GN	**13.33**(0.0013)[de]	**33.33**(0.0033)[cd]
CC	**36.66**(0.0037)[c]	**70.00**(0.0078)[a]
CJ	**13.33**(0.00130[de]	**15.00**(0.0015)[de]
CN	**10.00**(0.0010)[de]	**40.00**(0.0041)[c]
HC	**13.33**(0.00130[de]	**23.33**(0.0023)[cde]
HJ	**26.66**(0.0026)[cd]	**40.00**(0.0041)[c]
HN	**13.33**(0.00130[de]	**15.00**(0.0015)[de]
CO	**100**(0.0157)[a]	**100**(0.0157)[a]
LSD (5%)	**0.0015**	**0.0018**
CV (%)	**9.58**	**8.86**

Means with same letter within a column are not significantly different*: Data in brackets are transformed using Arcsine transformation*

On the other hand, in the 8th day of storage the highest pH was recorded in bananas which were treated by GC (4.79) and the lowest pH were observed in bananas which were treated by CJ (4.34).
The pH of fruits decreased with the storage period. Amino acid has also been showed to be the main acid in banana juice, with pH of fruit normally between 4.6 and 5.2 (Babitha and Kiranmayi, 2010).
Different treatment combinations used in the investigation showed statistically significant variations in relation to TSS at the 4th and 8th storage days. Maximum value of TSS was recorded on treatments treated by ginger packed by newspaper (GN) (25.33 ^{0}Brix) on the the 4th day of storage and on GN (28 ^{0}Brix) after 8 days of storage. The minimum value of TSS was recorded in HC (22.83 ^{0}Brix) and GC (24.40 ^{0}Brix) at the 4th and 8th days of storage respectively. Increase of TSS content was observed in the present investigation agrees with the report by Abdullah *et al.* (1985) and Sarker *et al,* (1995) which confirms TSS of fruits increase along the storage time. The increased TSS value for different treatment combinations might be due to the physiological aspects of banana fruits, suppressed respiration and metabolic processes, which involve in increasing TSS at different magnitudes (Awoke, et al., 2012).

3.4 Decay percentage

In present study it is clearly identified that decay percentage increased with the storage time for fruits stored inside different packaging materials and treated with different postharvest treatments. However, the decay was early and was very massive for control (without any treatment and packaging materials) comparing to those fruits treated and stored inside different packaging materials. The main cause for fruit deterioration is fruit ripening and ethylene production. High temperature fastens the rate of fruit ripening, thus fastens the rate of fruit deterioration. The evaporative coolers reduce the inside storage temperature which slows the rate of fruit ripening and ethylene production. These have a direct effect on shelf life extension of the fruit (Esa et al., 2015).
The deterioration of banana fruit was recorded mostly during harvesting followed by marketing, transporting, storage, and in some causes through the entire channel. This is because fresh produce after harvest continues the process of respiration and transpiration until its reserved food and water are reserved (Sirivatanapa, 2006). This physiological

process is influenced by temperature, composition of surrounding air, and humidity of the environment. Table 4 showed that there was a significant variation in decay percentage among the treatments. The highest decay % was found in bananas stored at ambient on the 4th storage day (100%) and the lowest decay % was observed in bananas which were treated by CN (10%). On the 8th days of storage on most storages the fruit was 100% deteriorated but storages like CJ and CN still performs to the best (only15% deterioration). Generally, combination of the packaging and postharvest treatment together perform better than the ambient storage condition.

3.5 Shelf life

Shelf life is the period from harvesting up to the last edible stage (Sewed et al., 2006). The shelf life of a product depends on initial quality of the food products, amount of quality change that can be allowed, prevailing environmental condition, and brakes properties of the packaging materials, and compatibility between food product and packaging (Esa et al., 2015). Significant variation was obtained among the treatment combination in relation to shelf life extension of bananas. The banana fruit treated by clove with cartoon (CC) and ginger by cartoon (GC) showed the longest shelf life (8 days) followed by HC and CN (6 days). The lowest shelf life had been recorded on HJ and CO (4 days). Similar results were also obtained by the effects of different postharvest treatments used in the investigation were significant in respect of prolonging the shelf life of banana. Control banana fruits showed the lowest shelf life as compared to those treated.

4. CONCLUSIONS

The postharvest treatments and packaging material has a significant effect on quality and shelf life of banana fruit stored for 8 days. Post-harvest treatment was used to remove adhering microorganisms that cause disease spoilage and decay of the fruit. As the extracts of both ginger and clove have characteristics of inhibiting microorganisms it contributes to increase the shelf life and maintain quality of the fruit.

Treatment with hot water also makes some enzymes inactive so that it delays the fruit ripening. Each treatment combination had its own effect on quality parameters and shelf life of banana. Treatment combinations were significantly different ($P \leq 0.05$) for most quality parameters after 8 days of storage. Fruits treated by GC (Ginger with carton) were found to be the best in terms of most of the chemical and physical quality parameters followed by CC (Clove with carton).

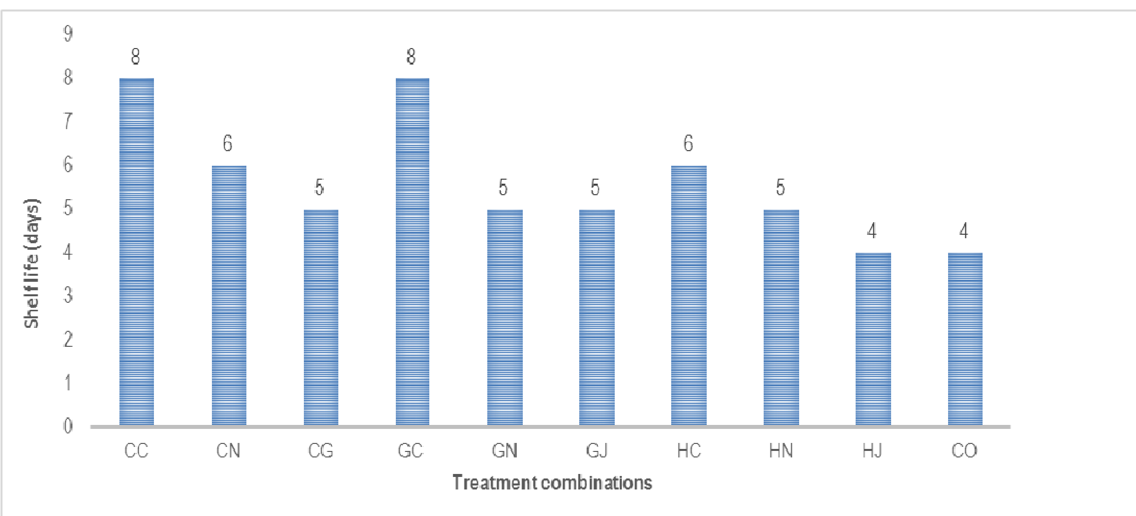

Figure 1. Shelf life of bananas stored under different packaging materials and postharvest treatments

The use of ginger with carton was found to be best in extending the shelf life and maintaining the physiochemical quality attributes of banana fruits throughout the storage period followed by clove with carton (CC). Banana stored without any postharvest treatment and packing shows a least performance in all quality parameters and their shelf life. So from this experiment it could be concluded that postharvest treatments and different packaging materials can extend the shelf life of banana fruits and maintain the postharvest quality of the fruit.

Accordingly, banana wholesalers, retailers and consumers are recommended to use these postharvest technologies to maintain quality and extend shelf life of their banana fruit. However, as the costs of the spices/herbs is increasing from time to time it is recommended using of this plants up on their availability as almost all the treatments showed a better result comparing to the ambient. However, all the above conclusions and recommendation were derived from results of studies conducted within one time. So, further studies in other months and locations should be conducted in order to give confirmative results.

5. ACKNOWLEDGEMENTS

Authors are highly thankful to the Department of Horticulture, Samara University for providing the financial assistance to carry out this research.

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