

RESEARCH ARTICLE

Fruit ripening and postharvest life of banana varieties at different temperatures and packaging

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ABSTRACT

Banana (*Musa accuminata* and *Musa balbisiana*) is the fifth most important crop in world export trade after coffee, cereals, sugar and cocoa. It is the first important fruit crop produced in Ethiopia. However, the ripening, quality and postharvest life of the fruit need to be improved to meet domestic and international consumer preference. An experiment was conducted with the objectives to describe the banana fruit quality of different varieties, identify optimum temperature for ripening and evaluate the efficacy of packaging material for better ripening and long postharvest life. The result of the experiment revealed the existence of highly significant variation between fruit samples of varieties harvested at different days, ripening temperatures, packaging, and their second and third order interaction for fruit length, fruit weight, fruit volume, pulp/peel ratio, pulp diameter. Improved color development was achieved for banana ripened at 15°C and 20°C. The result of the experiment depicted that better fruit quality, firmness and color development were achieved by ripening fruits with packaging than without it. Banana fruits ripened at 15°C and 20°C with perforated plastic packaging developed better ripening quality and postharvest life. Further research on postharvest technologies that can enable to improve ripening quality and postharvest life of Ethiopian banana at producer, wholesale and retail level should be conducted.

Keywords: Packaging, ripening, temperature, pulp peel ratio, postharvest life

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INTRODUCTION

Banana comprises an array of species in the genus *Musa* of the family *Musaceas* with the majority of cultivated varieties arising from the *Musa* species. Two species from *Musa* group have been traced as the source of almost the majority of known cultivars, *Musa accuminata* (A genome) and *Musa balbisiana* (B genome) (Simmonds and Shepherd, 1955). Banana is a staple food owing to its rich and easily digestible carbohydrates with a caloric value of 67 to 137/ 100 gram fruit. It is a rich source of vitamins and minerals, and make healthier and salt free diet. Apart from its high nutritional value, delightful flavor and available in all seasons of the year; a banana is a major source of macro elements, especially potassium and contain health beneficial ingredients such as resistant starch, total dietary fibers, rapidly digestible starch and slowly digestible starch. Oligosaccharides: fructo oligosaccharide and polyphenols, catechin, epicatechin, epigallocatechin and gallic acid are other ingredients present in banana that has found applicable in the prevention of colon cancer, diabetes, muscular contraction, regulation of blood pressure and cure of intestinal disorder.

Banana is the fourth most important food crop after rice, wheat and maize (INIBAP, 2000). Millions of small scale farmers in Africa, South Asia, and Latin America grow the fruit for household consumption and local markets (Edmades et al., 2006). Banana is the 5th most important crop in world export trade after coffee, cereals, sugar and cocoa. Total world

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production of banana in 2005 was over 100 million tonnes (FAO, 2007) but approximately 20 percent of this enters world trade. The two major sweet banana producing countries are India and Brazil, but by comparison, Ecuador, the fifth largest producer, exports approximately 67 percent of its production and the major importers of banana are the European community and the USA (FAO, 2007). In Ethiopia the crop has great socioeconomic significance. It is the first important fruit crop with total production of 0.3 million tons in 2013 and the important banana growing regions include southern nations and nationality people (SNNP) followed by Oromia and Amhara regional states (CSA, 2013). In Ethiopia it is cultivated in gardens, boundaries of fields and farms and since recently the cultivation of banana in orchards was started with the introduction of different high yielding varieties such as Dwarf Cavendish William I, Grand Nain, Poyu, Giant Cavendish and Butazu. However, postharvest life, ripening behavior and quality of the fruits of these banana varieties are not studied well.

Banana is ripened locally using different methods. Smoke treatment is one of the most common methods and in this method harvested banana bunches are exposed to smoke generated by burning kerosene stove in an airtight room for 24h. However, this type of smoke treatment is crude and ineffective as it leads to non uniform ripening (poor external yellow color development) and release gases like carbon monoxide and this gas is improper for human health. Moreover, the normal (ambient) temperature of the room range from 25°C-32°C and this temperature lead to a poor fruit ripening (related to degreening of the peel during ripening), shorter postharvest life and high weight loss. Therefore, this research was designed with the following objectives 1) describing the ripening behavior and postharvest life of banana varieties, 2) identifying the factor responsible for poor ripening (poor peel degreening) of fruits in certain varieties, 3) verifying the efficacy of postharvest techniques and technologies for better fruit ripening and long postharvest life.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in the plant analysis laboratory, botany department, college of science, Bahirdar University, Ethiopian from January to August 2015. The university laboratory is located at longitude of 11°37' North and 37° 27' East with an altitude of 1915 masl. The rainfall of the area is estimated about 1200-1600 millimeter per annum. Maximum temperature ranges up to 32°C and minimum temperature range up to 14°C and average temperature is 25°C.

Experimental setup and sampling

Fruit samples from seven commonly grown banana varieties (Local variety, Dwarf Cavendish, William I, Grand Nain, Poyu, Giant Cavendish and Butazu) were harvested at optimum maturity from the Weramit horticultural research station of the Ade Agricultural Research Center. From each variety, fruit bunch was transported to the plant analysis laboratory. The bunch was immediately deheaded and hands cut into fingers and washed with clean water and allowed to air dry. Banana hands present in the top and bottom of each bunch were discarded as these were not suitable for ripening studies. Fruit fingers were divided into ten groups, each group containing up to thirty fruits. From the ten groups, five groups were put inside five different perforated plastic packages and the remaining five groups kept without perforated plastic packages. Two groups of fingers (i.e. one with and one without packaging) were put separately inside one incubator. The experiment was designed to evaluate the effect of four temperatures (30°C, 25°C, 20°C, 15°C) and thus it required four incubators. The four incubators contained eight groups (two groups/ with and without packaging/ per incubator) of fruits and the relative humidity of all the incubators was set

90% during the course of ripening. The remaining two groups of fruit fingers (one with and one without perforated polyethylene packaging) were stored at normal (ambient) temperature as a control. The maximum and minimum temperature of the control treatment was 32°C and 14°C, respectively and average daily temperature was 25 °C. These ten groups of fruits fingers were followed till they reach ripening and senescence. This experimental setup was repeated seven times using harvested banana fruits samples of the seven different banana varieties.

Data collection

Objective methods. Five representative fruit fingers were taken out from each group of stored fruits and data on quantitative postharvest traits were recorded from these fruits. Fruit length was measured from the base to the tip of the fruit, fruit diameter (cm) was taken by measuring the diameter of the pulp at the center both on the short and long sides and the average of the two was calculated, banana fruit was peeled and the peel and pulp weight was measured and the pulp weight was divided by the peel weight to know pulp/peel ratio. Fruit volume was measured by water displacement method, whereas fruit weight was taken using sensitive balance. The weight of fruits was measured before and after storage. The difference between the initial and final weight was expressed as weight loss as a percent of the initial fruit weight. Postharvest life was defined as the number of days from harvest to final stage of ripening or onset of senescence.

Subjective (sensory) assessment. Subjective (sensory) postharvest quality attributes was made based on the following criteria. Color; 1-all green, 2- green with trace of yellow, 3- more green than yellow, 4-more yellow than green, 6-all yellow , 7- all yellow with brown flecks. Firmness; 1-low firmness , 2-moderate firm, 3- moderate to high firmness, 4- good firm, 5-very good firm. Ripening behavior (quality); 1-low quality, 2- moderate quality, 3 moderate to high quality, 4- good quality, 5- very good quality

Data analysis

Quantitative data were subjected to analysis of variance using the GLM procedure (SAS 8.1 Institute, Cary, N.C.) and subjective (sensory) data were summarized using descriptive analysis.

RESULTS

Combined analysis of variance

The combined analysis of variance revealed the existence of highly significant variation between fruit samples of varieties harvested and ripened at different season (time), ripening temperatures, perforated plastic packaging, and their second and third order interaction for fruit length, fruit weight, fruit volume, pulp/peel ratio, pulp diameter, however non significant difference for the second order interaction of ripening temperature and perforated plastic packaging was depicted for fruit volume and fruit length and only significant interaction for fruit weight (Table 1). The highly significant variation in the fruits of banana varieties harvested and ripened at different season (time) might be because of the genetic difference between these varieties and difference in pre-harvest management and climatic condition during fruit development and maturation. The result can indicate that development of variety along with production packages, identification of suitable climate and optimum production season (time) need to be done to improve the postharvest quality that meet domestic and international quality

standard. The significantly high main effect of packaging happened because of the autocatalytic ethylene gas produced by the cells of banana fruits and diffuse outside and the gas do not escape rather stay inside the package and trigger the fruit ripening process. The significant difference between temperatures verifies that temperature played significant role in affecting ripening behavior and postharvest quality and indicated the need to identify optimum temperature. Moreover, the significant second order interaction, i.e. fruits of banana varieties harvested and ripened at different season (time) and perforated plastic packaging; fruits of banana varieties harvested and ripened at different season (time) and ripening temperature indicated that different fruits did not require the same ripening temperature and packaging for optimum ripening and postharvest quality.

Table 1. Combined Analysis of variance (anova) for quantitative fruit ripening traits

Source	Df	Mean squares				
		FL	FW	FV	PPR	PD
Variety	8	232.41**	13739.19**	10307.69**	7.02**	1.23**
Temperature	4	17.36**	4335.48**	5543.4**	11.2**	0.07**
Rep	4	5.2**	31.49 ns	369.3**	0.08 ns	0.04**
Packaging	1	28.7**	23750.6**	27307.8**	52.9**	0.81**
Variety*Temperature	32	7.5**	452.3**	409.5**	0.68**	0.09**
Variety*Packaging	8	9.4**	1214.5**	1815.4**	1.53**	0.17**
Temperature*packaging	4	1.32 ns	280.0*	139.5 ns	0.64**	0.14**
Variety*Temperature*Packaging	32	3.0**	344.1**	414.1**	0.29**	0.08**
Mean		16.6	93.7	98.2	2.4	2.8
CV		6.3	11.2	8.8	11.8	4.2
SE		1.04	10.5	8.6	0.28	0.11

Df-degree of freedom ;FL-Fruit length; FW-Fruit weight; FV-Fruit volume; PPR-pulp peel ratio; PD-pulp diameter

Ripening Behavior and Postharvest Quality of Ethiopian Grown Banana Varieties

Ripening behavior and postharvest quality play a significant role in the commercialization of banana fruits. As it is indicated in table 2 banana varieties differ in their mean ripening quality and postharvest life. Postharvest life ranging from 11 to 28 days and the local variety took 11 days to reach the final stage of ripening whereas Dwarf Cavendish (23 days) and Grand Nain (27 days) took the longest. Weight loss during the postharvest period recorded high for Poyu and Butazu varieties, but small weight loss was measured for the local variety. The mean finger lengths of banana fruit scored high were for William-I and Dwarf Cavendish. Grand Nain, Butazu had the heaviest mean finger weight. Fruit circumferences are used mainly to determine the size and shape of packaging. The local variety showed the largest pulp diameter followed by Dwarf Cavendish. When pulp weight is compared, William-I had the highest mean pulp weight followed by Butazu but the local variety had the least. High peel weight can be considered advantageous because it offers protection against mechanical damage and peel can also be used as animal feed. However, the high peel can also be considered as a disadvantage as it results in lower edible portions. Mechanical damage is an important factor that can lead to downgrading of banana fruits. Present quality rating in the European union takes into account the percentage of peel damage due to bruising, scarring and scratching (Liado and Dominguez, 1998). The high peel weight of William I, Dwarf Cavendish and Butazu could be an advantage in offering protection against mechanical damage during transport, handling and shipping and thus fruits of these varieties can suit for international trade.

The market quality and consumer preference of banana fruits are significantly influenced by the peel color. Therefore, assessment of peel color is important in postharvest screening (Dadzie and Orchard, 1997). The peel color of all varieties was not the same but Poyu and Local variety reached final color stage (color stage 7) however, Giant Cavendish, William I and Grand Nain could not develop attractive yellow peel color. The firmness of varieties did not vary as such, but relatively Giant Cavendish possessed firm fruit. The overall quality of the fruit was better for Local variety, Giant Cavendish, Grand Nain, Butazu as compared to William I and Dwarf Cavendish.

Table 2. Mean and standard error of ripening quality attributes and postharvest life of fruit samples of banana varieties grown in Western Ethiopia

Variety	Date of harvest	PHP	WLR	FL	FW	FV	PPR	PD
		Mean	Mean	Mean	Mean	Mean	Mean	Mean
Local variety	27/2/2015	13.4±5.6	9.5±4.7	13.1±1.2	79.3±12.9	79.3±14.7	3.0±0.6	3.0±0.1
Dwarf Cavendish	17/3/2015	22.8±9.5	10.2±6.1	19.9±2.4	120.7±13.9	120.7±13.6	1.8±0.3	2.9±0.1
William I	25/4/2015	21.2±10.0	11.8±8.6	20.1±1.5	145.4±17.7	145.4±20.1	1.9±0.3	2.9±0.2
Grand Nain	23/5/2015	28.8±13.3	11.3±3.8	17.2±1.1	110.1±22.2	110.1±14.4	1.8±0.3	2.7±0.2
Poyu	1/6/2015	22.8±8.7	11.9±4.1	15.8±1.3	104.3±11.4	104.3±12.5	1.8±0.2	2.7±0.1
Giant Cavendish	22/6/2015	16.2±5.6	7.7±4.0	17.6±1.4	102.4±11.6	102.4±17.2	1.5±0.2	2.6±0.1
Butazu	5/8/2015	18.6±5.2	10.0±8.8	18.2±1.8	114.1±19.4	114.1±12.8	2.0±0.2	2.9±0.1

PHP-postharvest period; WLR-water loss; FL-Fruit length; FW-Fruit weight; FV-Fruit volume; PPR-pulp peel ratio; PD-pulp diameter

Postharvest quality at different ripening temperatures

The result of the experiment indicated that most of the weight loss occurring in the higher temperatures 30°C and 25°C (figure 1). The fruits that were kept at lower (15 °C) temperature took a significantly longer time (32 days) to ripen than the fruits at higher temperatures 30 °C (14 days) and the control (13 days). This is because climacteric fruits give off ethylene during ripening (Sacher, 1973) and the sensitivity of bananas to ethylene is very low, within the range of 0.01 -1.0 ppm (Thompson and Seymour, 1983), and increases with increasing temperatures (Liu, 1978). Banana kept at higher temperature showed shorter finger length as compared to stored at low temperature. Similar trend recorded for fruit volume, fruit weight, peel weight and pulp weight. This indicated that the role of temperature is pronounced in affecting the quality and life of climacteric tropical fruits like banana that are harvested green and eaten after ripened. Therefore, cold storages and transportation and pre-cooling infrastructures need to be setup in the market chains and these commodities need to be handled in the postharvest following their cool chain. Comparably higher pulp/peel ratio was also observed 30°C and 25°C compared to those ripened at lower temperature. Better fruit color was developed from banana fruit samples ripened at 20°C and the control, but the poor color development was observed at higher temperature (30°C). Banana fruits stored at higher temperature and the control soften fast, whereas banana stored at a lower temperature stayed firm. Interims of overall ripening quality of banana fruits

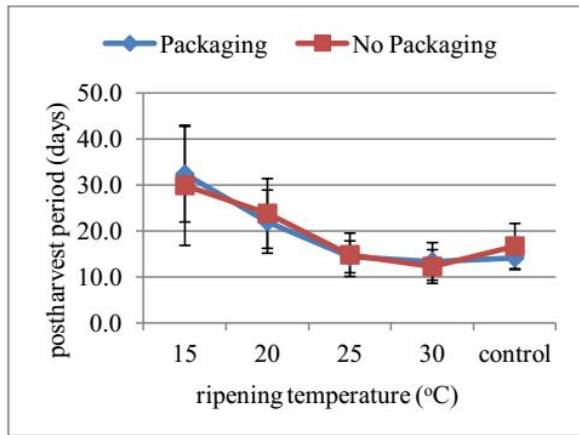
ripened at 20 °C, 25 °C and the control were preferable, however banana ripened at 30 °C and 15 °C showed poor overall quality development. The effect of temperature on fruit ripening was studied on banana fruits by Saeed et al. (2001) and similar results obtained.

Ripening Behavior and Postharvest Quality of Fruits with/without Packaging

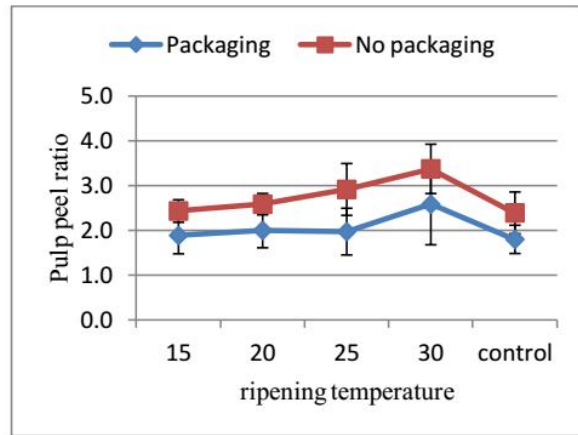
Banana fruits ripened with perforated plastic packaging showed no difference in the mean postharvest life nevertheless higher weight loss was measured for fruits ripened without perforated plastic packaging than with packaging (figure 2) and similar trend were observed for fruit weight, length, volume and pulp diameter. The pulp / peel ratio was recorder higher in fruits ripened without packaging than fruits with packaging. The overall result of the experiment indicated that better fruit quality, firmness and color development were achieved by ripening banana fruits with perforated plastic packaging than without it. In Ethiopian banana fruit market chain, fruits are handled without packaging and hence results in postharvest loss both in quality and quality/nutrition/. It is shown in the experimental result that ripening and postharvest handling of the fruit with perforated packaging worth much better than the normal practice (without packaging) as it protects the fruit against mechanical damage, postharvest pest infection, sun burning and transpiration.

Interaction of Temperature and Packaging on Ripening and Quality of Fruits

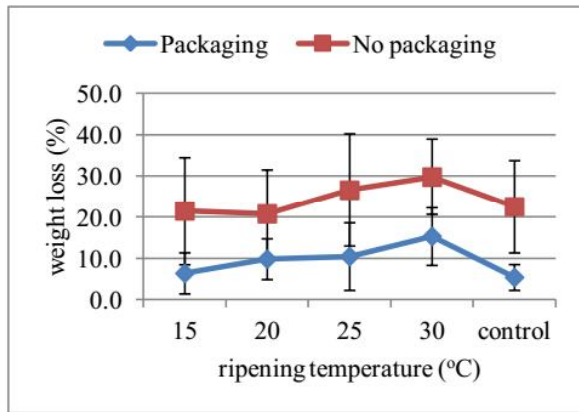
The result in figure 3 showed that banana varieties ripened at 15°C with perforated plastic packaging took the longest postharvest period (32 days) whereas the shortest were observed in fruits ripened without packaging in 30°C (12 days) and the control with packaging (13 days). It was observed that packaging of fruits at lower temperature brought longer postharvest life than without packaging. Weight loss found high in fruits stored at high temperature without packaging that fruit at higher temperatures with packaging. It is possible to generalize that ripening of the fruits of banana varieties grown in Ethiopia with perforated plastic packaging made the fruit to loss little weight than without it in the postharvest market chain. Similar results were observed for fruit length, weight and pulp diameter. When the result in relation to peel color was summarized, good peel color was developed for fruits ripened with perforated plastic packaging at 20°C, 25 °C, and the control and also best fruit ripening was achieved for banana fruits at 20 °C, 25 °C and the control with perforated plastic packaging (Figure 4). Therefore, packaging and postharvest handling of the fruit at a temperature range between 15°C to 25 °C and relative humidity (90%) is required for Ethiopian grown banana varieties for optimum ripening (bright yellow peel color development) whereas the local variety was observed developing good ripening (peel color) without these all treatments.



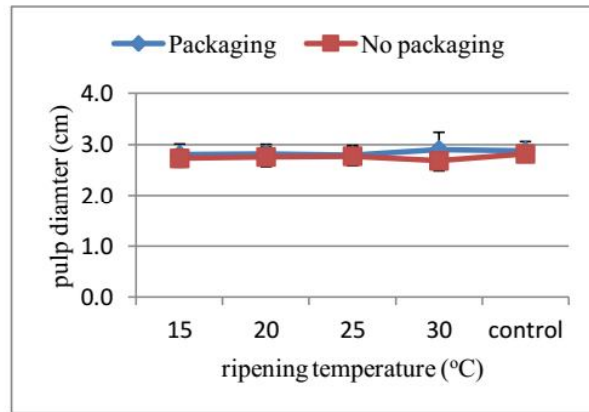
A



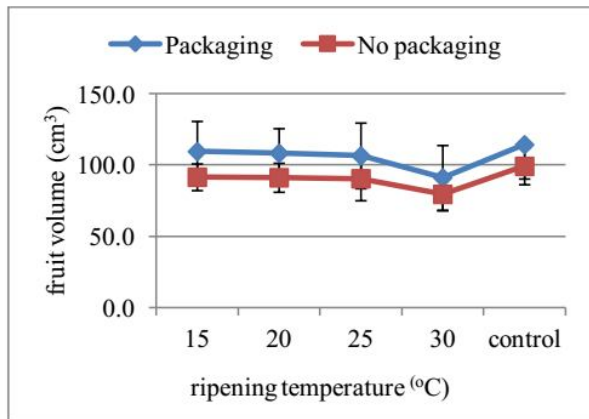
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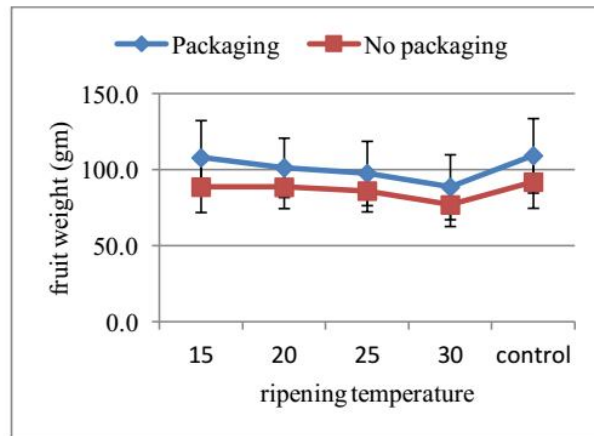
B



E



C



F

Figure 1. Trend line graphs indicating the effect of ripening temperature (15 °C, 20 °C, 25 °C, 30 °C and the control) on postharvest life (A), weight loss (B), fruit volume (C), pulp peel ratio (D), pulp diameter (E), and fruit weight (F)

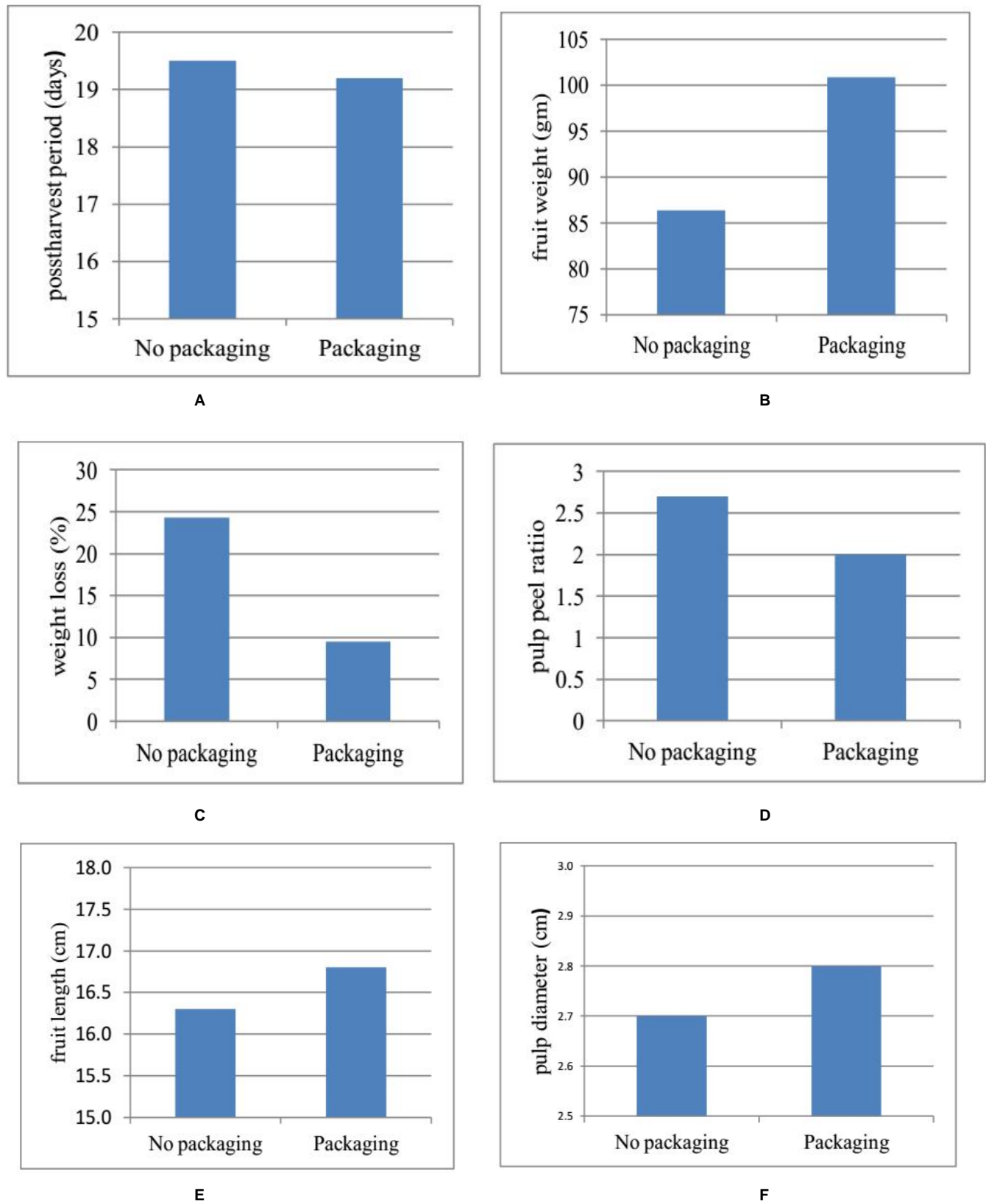


Figure 2. Trend line graph indicating of postharvest period (A), Weight loss (B), Pulp peel ratio (C), Fruit length (D), Fruit weight (E) and Pulp diameter (F) with and without proliferated plastic packaging

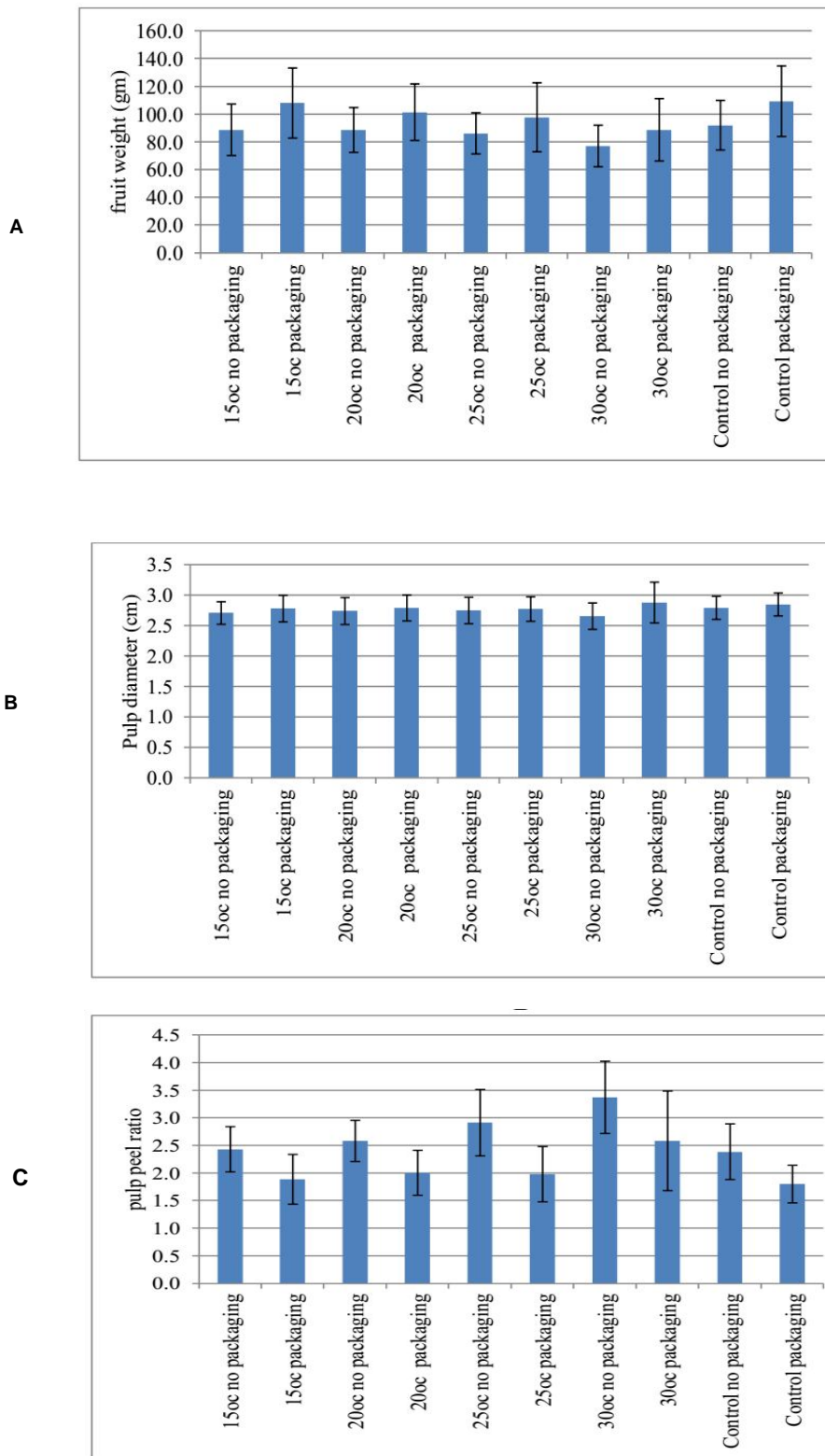


Figure 3. Interaction effect of fruit ripening temperatures and perforated plastic packaging on fruit weight (A), pulp diameter (B) and pulp peel ratio (C)

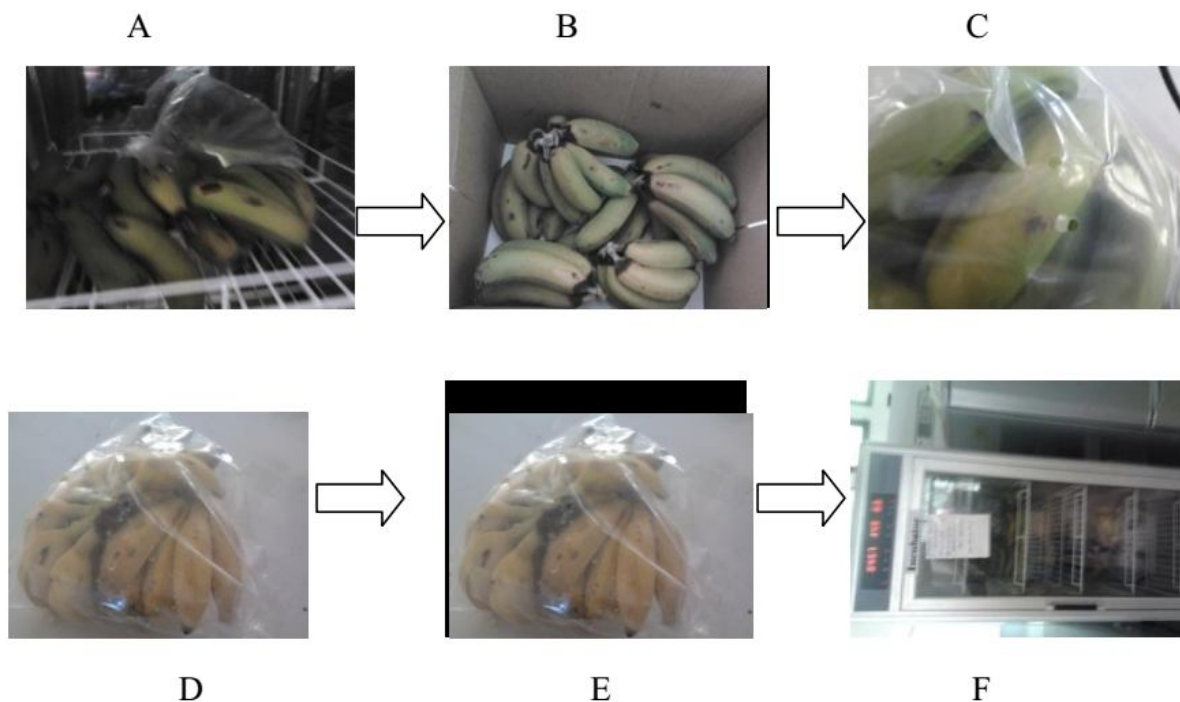


Figure 4. Effect of temperature and perforated plastic packaging on ripening behavior of banana fruits; 15°C without packaging (A), control without packaging (B), 25° with packaging (D), 20° with packaging (E) and 15°C with/without packaging (F)

DISCUSSION

All Ethiopian economy is facing trade deficient in the global markets as the country import a lot of fossil fuel, drugs and machineries but export share is comparably very low. The nutritionally balanced food intakes of the nation need also to be improved to international standard. Production of fruits like banana will have potential impact both to improve trade balance and nutritional status of the nation. However, as banana fruit perish fast, knowledge and technologies that can improve fruit postharvest quality and reduce postharvest loss are important.

Banana is ripened locally in different ways. Small scale banana producers ripen banana with covering the fruit with cereal straw and put in a relatively cool place where as smoke treatment is one of the most commonly method used by banana traders to induce ripening and in this method harvested banana bunches are exposed to smoke generated by burning kerosene stove inside the airtight room for 24h. As a result, the temperature inside the chambers also increases besides evolving ethylene gas with traces of other gases like acetylene and carbon monoxide. However, this type of smoke treatment is crude and ineffective as it lead non uniform ripening (poor external yellow color development) and carbon monoxide is improper for human health. Commercially ethylene gas is used to ripen bananas. But ethylene gas may be proving explosive when it reaches higher concentration. Commercial liquid like ethrel releases ethylene. It has been reported that exogenous application of ethylene in the form of ethrel accelerates ripening, increase color and eating quality with reduced spoilage in different varieties of Mango (Saltveit, 1999; Singh and Janes, 2001). Kulkarni (2011) studied that 500 ppm of ethrel solution was optimum for inducing uniform ripening at 20 °C in banana. In Ethiopia, producers and traders do not treat banana fruit with ethylene to commence ripening in different varieties. However, most commercial cultivars of bananas and plantains

require exposure to ethylene for 24 to 48 h at 14.4 to 18 °C (58 to 64 °F) (Thompson and Burden, 1995; Robinson, 1996). The ethylene treatment required to ripen the fruit is 10 to 50 µL/L, (Thompson and Seymour, 1982). In commercial practice the amount is larger 1000 µL/L. This is partly because many ripening rooms are not fully gas tight and the concentration may be rapidly reduced through leakage.

Temperature influences the ripening changes in bananas (Esguerra et al., 1992). An increase in temperature between 14°C and 30°C enhances the rate of ripening and the fruit softens at a faster rate (Smith, 1989). High temperature can also result in damage to ripening fruit (Smith and Thompson, 1987; Semple and Thompson, 1988). Temperature less than 14°C can cause uneven ripening due to chilling injury (Stover and Simmonds, 1987). In Ethiopia, fruit ripening and postharvest handling temperature ranges from 14°C to 32°C with the average of 25 °C. Bananas fruits fail to fully degreen when ripening at tropical temperatures, but this abnormal symptom does not occur in plantain. Thus, temperatures of up to 20 °C (68 °F) are sometimes necessary for bananas ripening (Thompson and Burden, 1995). Optimum RH levels during ripening are 90 to 95% (after coloring is underway RH should be reduced to 85% to prevent peel splitting). In addition to ethylene and temperature management, Modified Atmosphere Packaging (MAP) can extend shelf life of fresh fruits by reducing their respiration rate (Sen et al., 2012). Similarly, the result of the experiment depicted that better banana fruit quality and life, firmness and color development were achieved by ripening fruits with packaging. Banana fruits ripened well at 15°C and 20°C with perforated as compared to the control. As ripening fruit with smoke treatment and covering with straw are practiced locally and are tradition and also have health hazard; further and similar research endeavors on postharvest technologies that can improve fruit quality and shelf and green life at producer and traders level should be conducted. The fruit is being produced in varied environments and seasons in the country and the effect of environments and seasons on postharvest quality and life of the fruit need to be investigated. Moreover, pre-cooling infrastructures, cold storages, proper transportation and packaging need to be set up and followed for perishable fruits like banana in the market chains.

CONCLUSION

The result of the experiment depicted that better fruit quality, firmness and color development were achieved by ripening fruits with packaging than without it. Banana fruits ripened at 15oC and 20oC with perforated plastic packaging developed better ripening quality and postharvest life. Further research on postharvest technologies that can enable to improve ripening quality and postharvest life of Ethiopian banana at producer, wholesale and retail level should be conducted.

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