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Quality Attributes and Ripening Period of Banana (*Musa* spp.) Fruit as Affected by Plant Ethylene Sources and Packaging Materials

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ABSTRACT

This study was conducted to evaluate the effect of different plant ethylene sources and packaging materials on ripening period and quality of banana fruit. A laboratory experiment was laid at Jimma University College of Agriculture and Veterinary Medicine from January to February 2008. A two factor factorial design was employed considering ethylene source and packaging material as the two factors. Avocado, mango and tomato fruits were used in the treatment as a source of ethylene. The packaging materials were wooden box, plastic bag, polysheet and open air as a control. A randomized complete plot design was employed with three replications to arrange the experimental units in the lab. Dwarf Cavendish variety was obtained from Teppi state farm, southwest of Ethiopia to be used in the experiment. The result showed that banana fruits stored with avocado fruits exhibited the shortest ripening period without any undesirable effect on quality. On the other hand, wooden box combined with straw was the best storage material to ripen banana fruit faster. Producers, traders or consumers may use the technology in order to get quicker ripening of banana fruits.

Key words: Banana, packaging material, plant ethylene, quality, ripening period

INTRODUCTION

Banana is a member of Musaceae family and provides a dessert fruit in the world (Gowen, 1994). There are many varieties of bananas, all differing in flavour and appearance (Robinson, 1996) and are eaten when ripe (Dadzie and Archard, 1997). It is the most important fruit crop with annual (2009-2011 average) global production of about 106 million tonnes (FAO, 2014). It stood second to citrus in world fruit trade. In the commercial production, the fruit is harvested still green and transported to market where, in some countries, is ripened under controlled condition. There is usually a need to transport the fruit in green state. Therefore, harvesting time represents a compromise between leaving the fruit on the plant long enough to maximize yield but harvesting it soon enough so that sufficient green life remains to market the fruit in acceptable manner. For each week that the fruit is harvested earlier than normal, green life increases by 3-5 days but bunch weight falls by almost 10% (Mitra, 1997).

Banana is a climacteric fruit that can ripe naturally to pale yellow at ambient tropical temperature but normally, it can ripe after harvest under modified storage condition. Artificial ripening is applied to climacteric fruit by process to which the fruit maintained its maximum desired quality, texture, color, taste and desirable chemical components. Also, ripening is dramatic event in the life of fruit as it transforms a physiologically mature fruit to which the fruit maintained its maximum desired quality (Thompson and Seymour, 1982). A sharp increase in respiration is shown by increase in production of carbon dioxide or decreasing in internal oxygen concentration. The defects rate of respiration and chemical production of fruit are responsible for fruit ripening (Thompson and Seymour, 1982). Banana ripening is the process of ripening of banana fingers after harvesting. An early part of the ripening process is softening of banana that happens partly because of loss of water from the peel but primarily because of the changes in chemistry of the cell walls (Seymour *et al.*, 1993).

According to Milne (1994), estimate of post harvest loss of *Musa* crops in the traditional marketing system ranges from 20-80%. Study which was made on a link between mechanical damage, early ripening and economical loss of banana fruit, suggested that moisture loss from pre-climacteric fruit hastened maturity. An experiment in this study investigated the effect of fruit maturity and storage humidity on the ripening and climacteric response of *Musa* fruit. The treatment in the experiment stimulated the type of storage conditions expressed by fruit in the traditional, tropic marketing. The result from experiment done at Ghana confirmed that the more mature the fruit was at harvest, the more rapid was the rate of ripening (Milne, 1994).

The quality of fresh fruits and vegetables offered to consumers is constrained by the level of quality achieved at harvest and generally, cannot be improved by postharvest handling rather can be maintained. Genetic and environmental factors affect the growth, development and final quality of fresh fruits and vegetables (Shewfelt and Prussia, 1993). The quality of the fresh and processed fruit depends on the post-harvest handling during harvesting, transportation, storage and should be monitored effectively to keep the best quality of fruit at harvest. However, lack of storage facilities, limited access to transportation and risk of high losses, growers are often forced to dispose off their produce over a short period of time (Hailu *et al.*, 2013).

In Ethiopia, mostly the traditional packaging method for banana is nested packaging in which dried banana leaf and straw of teff (*Eragrostis tef*) are used but the effectiveness of these packaging materials has not been studied (Beaudry, 2000). Modified Atmospheric Packaging (MAP) has also been found to increase the shelf life of banana fruit. It is often desirable to generate an atmosphere low in O_2 and/or high in CO_2 to influence the metabolism of banana being packaged or the activity of decay causing organisms to increase storability or shelf life. In addition, MAP largely improves moisture retention and keeps the packed product from the external environment and helps to ensure quality (Beaudry, 2000). The quality of banana is reduced and considerable amount is wasted from harvesting to final consumption. This loss can be kept of minimum by improving post-harvest handling techniques through the use of packaging material or improving traditional packaging practices (Mangaraj *et al.*, 2009).

Packaging is often used to minimize weight loss and shrinkage of produce during marketing. Standardization of packaging size promote efficient handling as centre of consumption of fresh produce are usually remote from production areas (Hailu *et al.*, 2013). Careful management of distribution system will ensure that produce retains its quality and thus, economic returns are maximized. Packaging have two functions: The first is to assemble the produce in to convenient units for handling (utilization), the second is to protect the produce during distribution, storage and marketing. Now days, produce is transported and sold in wide ranges of package constructed of wood, fibre board, jute or plastics. Many packaging systems waste raw material but environmental and food safety concern have led to recycling fibre board and used many times (Wills *et al.*, 1998).

According to Stover and Simmonds (1987), destructive ripening is caused by too high or too low temperature. High temperature disorders (cooked fruit) are indicated by soft, ripe pulp with a greenish-yellow skin colour, weak neck, split peel and brown flecks on a greenish yellow peel. Uneven ripening can be caused by low temperature and insufficient ethylene. The ripening process involves the production of ethylene which in turn controls several physiological events such as loss of firmness, peel discoloration, sugar biosynthesis, etc. (Thompson and Seymour, 1982).

Climacteric and non-climacteric fruits may be further differentiated by their response to applied ethylene and their pattern of production during ripening. It has been clearly established that all fruits produce minute quantity of ethylene during development. However, coincident with ripening, climactic fruits produce much larger amounts of ethylene than non-climacteric fruits. The rise in respiration in response to ethylene may occur more than once in non climacteric fruits in contrast to the single respiration increase in climacteric fruits (Wills *et al*., 1998). All horticultural produces ethylene. Whereas, the rate of production varies from one produce to another: Banana 0.05-2.1 $\mu L\ L^{-1}$, avocado 28.9-74.21 $\mu L\ L^{-1}$, mango 0.04-3.01 $\mu L\ L^{-1}$, tomato 3.6-29.81 $\mu L\ L^{-1}$ etc. (Wills *et al*., 1998). Ethylene production of banana is lesser compared to other climacteric fruits like Avocado, tomato, mango, peach, papaya etc. Poor flavour development and uneven ripening are very common in fruit ripened by local methods like Ethiopian case which is simply done by sorting bunches in open air as whole (Stover and Simmonds, 1987).

In countries like Ethiopia where modern packaging as well as ripening facilities are almost non-existent, it is imperative to make investigation on the methods that can easily be affordable to the local banana growers. In addition, as it was pointed above, banana produces less quantity of ethylene resulting in uneven ripening that affects quality. Hence, looking at options of storing banana with other high ethylene producing fruit and vegetable crops for quicker ripening of banana might help local banana growers which are also commonly producing other fruits. Therefore, the objective of this study was to determine the effect of plant ethylene sources and packaging materials on ripening period and quality of banana fruit.

MATERIALS AND METHODS

The experimental material, banana (*Musa* spp.) variety dwarf Cavendish was brought from Teppi state farm in southwest of Ethiopia and was transported by open truck covered with banana leaf.

Experimental design and treatments: The experiment was carried out in laboratory of the department of post-harvest physiology, Jimma University College of Agriculture and Veterinary Medicine from January to February 2008. Packaging material and plant ethylene source were considered as the two factors. There were three types of packaging materials (plastic bag, poly sheet and wooden box) and open air as a control. The second factor contains three different plant ethylene sources (avocado, mango and tomato). One packaging material contains one plant ethylene source at a time where by, each packaging material gets equal weight of the three plant ethylene sources in separate. Hence, there were 12 treatments (plastic bag with avocado, polysheet with avocado, wooden box with avocado, open air with avocado, plastic bag with mango, polysheet with mango, wooden box with mango, open air with mango, plastic bag with tomato, polysheet with tomato, wooden box with tomato, open air with tomato) with three replications to give a total plot number of 36 experimental units. In total, 13 uniform bunches of banana were used for the experiment. All bunches were cut by using a knife and three hands were taken to each treatment where, one hand left for shelf life recording and the others were used for destructive sampling. Only good looking and non-injured hands were used. These hands were weighed before packing in to different materials using a sensitive balance. The polysheet were enclosed at one side and tied as other ends using string. The plastic bags were covered with their covering except for those in wooden box where they are covered with straw from all sides and that of open air left uncovered.

The dimension of the packaging material was 27×36 cm for plastic bag, 60×100 cm for polysheet, 46×50 cm for wooden box and 40×40 cm for open air. All the polysheets were white and transparent.

Data collection

Ripening period: The data on ripening period was taken in days from the day of packing to the day of ripening where more than 95% fruits ripened. Ripening period was judged on the basis of change of peel colour i.e., when it reaches stage six and seven (Stover and Simmonds, 1987) and when the Total Soluble Solid (TSS) approaches the standard value.

Weight loss: The initial weight of the hands (kg) was taken before packing. After two days, the hands were weighed before two sample fingers were excised for other destructive measurements and weight loss was obtained by subtracting the second weight measurement from the first (initial) weight measurement. Then the hands were weighed after the two sample fingers were taken for the next day weight loss determination. This was continued with two days interval until ripening achieved. Hence, the sum of the weight loss taken as the two days interval gave total weight loss which was converted to percentage weight loss using the following Eq. 1:

$$\text{Weight loss (\%)} = \frac{\text{Weight of fresh fruit (g)-Weight after interval (g)}}{\text{Weight of fresh fruit (g)}} \times 100 \quad (1)$$

Titrable acid: Sodium hydroxide solution of 0.1 N was prepared by dissolving 4 g sodium hydroxide pellet in 1 L of distilled water. Phenolphthalein solution was prepared from 1 g of the phenolphthalein powder dissolving in 100 mL of distilled water to be used as an indicator to create purple colour. To determine titrable acid, extraction of banana juice was first done and then the burette was filled with 0.1 N sodium hydroxide solutions and was adjusted to zero mark. Then, 1 mL of juice was taken using pipette and transferred to volume flask by means of pipette. The juice of conical flask was titrated with alkali solution. The alkali was added drop by drop to the conical flask with continuous shaking until purple colour is observed. Finally, the alkali consumption was recorded and the percentage acidity was determined by using the following Eq. 2:

$$\text{Acid (\%)} = \frac{\text{Titer} \times 0.0067 \text{ (malic acid factor)}}{\text{Juice(1 mL)}} \times 100 \quad (2)$$

Total Soluble Solid (TSS): Total soluble solid was measured from the already extracted juice using hand refractometer (model 45-02) and then recorded with two days interval until the ripening period was completed.

Temperature: The temperature of the packaging material and the ripening room was recorded on daily basis using hygrometer during the whole experimental period and average values were used for analysis.

Relative Humidity (RH): The relative humidity of the packaging materials and the ripening room were recorded using hygrometer at the same time with the temperature recording on daily basis until the completion of the experiment. Like temperature, the mean values were used for analysis.

Shelf life: Shelf life of the fruit was recorded in days at 30% spoilage level.

Statistical analysis: All the recorded quantitative data was subject to analysis of variance using GenStat 12th edition (VSN International, 2010).

RESULTS AND DISCUSSION

Influence of exogenous ethylene and packaging materials on ripening period: There was a highly significant difference ($p<0.01$) among different plant ethylene sources tested in the study. The banana stored with avocado ripened early (6.4 days) followed by banana stored with tomato (6.5 days). The longest ripening period (7.1 days) was recorded from the banana stored with mango (Table 1). The result obtained, here, corresponds to the ethylene releasing capacity of avocado, mango and tomato as indicated by Wills *et al.* (1998). Avocado has the highest ethylene producing capacity enabling the banana fruit within short period of time than tomato and mango which has a relatively low ethylene releasing capacity taking longer time.

There was also a highly significant difference ($p<0.01$) among the packaging materials for ripening period. The banana stored in wooden box ripened within six days. On the other hand, the banana which was placed in polysheet took seven day (Table 2). There was a high concentration of CO_2 and low concentration of O_2 in the polysheet since it was sealed from one side and tied from the other end which prevented air exchange. This phenomenon had a detrimental effect in reducing rate of respiration which, in turn, results in longer ripening period.

The combined effect of the ethylene source and packaging material also showed highly significant difference ($p<0.01$) among the treatments (Table 3). The banana stored in wooden+straw and placed with avocado ripened first. This might be due to the synergetic effect of the ethylene released from better ethylene source (avocado) and the atmospheric modification effect of the packaging material.

Influence of exogenous ethylene and packaging materials on weight loss: No significant differences were observed in weight loss among the fruits treated with different ethylene sources. This might be due to the fact that ethylene enhanced ripening without a detrimental effect on the weight loss (Mitra, 1997). However, a highly significant difference ($p<0.01$) was observed among packaging materials used. Banana fruits kept in open air showed higher percentage weight loss (Table 2). The result displayed that open air experienced the lowest (73%) relative humidity which could be the probable reason for higher weight loss. On the other hand, the lowest weight loss (4.2%) was recorded from banana stored in polysheet (Table 2). This might be due to the highest relative humidity present in the polysheet.

Table 1: Influence of plant ethylene sources on quality and ripening period of banana fruit

	Parameters						
Plant ethylene sources	TSS (°Brix)	TA (%)	WL (%)	RP (Days)	SL (Days)	T (°C)	RH (%)
Avocado	10.325	0.749	10.203	6.40	9.80	25.447	77.402
Mango	10.025	0.723	8.971	7.10	10.50	25.452	77.797
Tomato	10.800	0.769	8.589	6.50	10.50	25.452	77.083
LSD (0.05)	NS	NS	NS	0.1912**	0.2512**	NS	NS
CV (%)	15.60	14.15	19.82	3.34	2.89	0.62	1.88

TSS: Total soluble solid, TA: Titrable acid, WL: Weight loss, RP: Ripening period, SL: Shelf life, T: Temperature and RH: Relative humidity, NS: Non-significant, **Highly significant

Table 2: Influence of packaging materials on quality and ripening period of banana fruit

	Parameters						
Packaging materials	TSS (°Brix)	TA (%)	WL (%)	RP (Days)	SL (Days)	T (°C)	RH (%)
Plastic bag	9.589	0.766	11.836	6.60	10.20	25.399	74.203
Polysheet	10.783	0.746	4.206	7.30	11.40	25.654	85.611
Open air	10.050	0.717	12.053	6.70	9.80	25.376	72.883
Wooden box	11.117	0.760	8.922	6.10	9.50	25.372	77.013
LSD(0.05)	NS	NS	1.793**	0.2208**	0.2900**	0.1546**	1.423**
CV (%)	15.60	14.15	19.82	3.34	2.89	0.62	1.88

TSS: Total soluble solid, TA: Titrable acid, WL: Weight loss, RP: Ripening period, SL: Shelf life, T: Temperature, RH: Relative humidity, NS: Non-significant, **Highly significant

Table 3: Combined effect of plan ethylene sources and packaging materials on ripening period and quality of banana fruit

	Parameters						
Treatments	TSS (°Brix)	TA (%)	WL (%)	RP (Days)	SL (Days)	T (°C)	RH (%)
Plastic bag with avocado	9.500	0.737	12.363	5.60	9.30	25.393	74.47
Polysheet with avocado	10.900	0.737	6.224	7.60	11.30	25.613	86.163
Open air with avocado	9.950	0.787	12.534	6.60	9.30	25.403	72.670
Wooden box with avocado	12.950	0.737	9.693	5.60	9.30	25.377	76.310
Plastic bag with mango	9.400	0.763	12.831	7.60	11.30	25.393	73.847
Polysheet with mango	11.450	0.717	2.946	7.60	12.00	25.787	85.810
Open air with mango	9.350	0.670	11.803	6.60	9.30	25.337	73.310
Wooden box with mango	9.900	0.740	8.301	6.60	9.30	25.293	78.220
Plastic bag with tomato	11.850	0.797	10.315	6.60	10.00	25.410	74.293
Polysheet with tomato	10.00	0.783	3.444	6.60	11.00	25.563	84.860
Open air with tomato	10.850	0.693	11.823	7.00	11.00	25.387	72.670
Wooden box with tomato	10.50	0.803	8.773	6.00	10.00	25.447	76.510
LSD (0.05)	NS	NS	3.106**	0.382**	0.502**	NS	NS
CV (%)	15.60	14.15	19.82	3.38	2.89	0.62	1.88

TSS: Total soluble solid, TA: Titrable acid, WL: Weight loss, RP: Ripening period, SL: Shelf life, T: Temperature, RH: Relative humidity, NS: Non-significant, **Highly significant

The combined effect of ethylene and packaging materials also showed a highly significant difference ($p<0.01$) among treatments. Hence, the highest percentage weight loss (12.8%) was observed in plastic bag combined with mango and the lowest weight loss (2.9%) was recorded in the polysheet which is placed with mango (Table 3). The probable reason for low percentage weight loss exhibited in a combined treatment effect of polysheet and mango might be due to fact that there was relatively lower air circulation into and out of the polysheet which resulted in higher relative humidity that in turn allowed lower respiration rate. Slow respiration rate implied low energy exhaustion that keeps the weight loss to the minimum. In addition, mango has relatively lower ethylene releasing capacity which results in slow respiration rate in comparison to the other plant ethylene source used in the study (Wills *et al.*, 1998).

Influence of exogenous ethylene and packaging materials on titrable acid and total soluble solid: In this experiment, effect of plant ethylene sources, packaging materials and the combined effect resulted in non-significant difference among the treatments on titrable acid

(Table 1-3). Moreover, effect of plant ethylene sources, packaging materials and also the combined effect showed non-significant difference on total soluble solid (Table 1-3). As stated by Mitra (1997), application of ethylene was the best method to hasten ripening without loss in the fruit quality.

Influence of exogenous ethylene and packaging materials on temperature and relative humidity: Plant ethylene sources resulted in a non-significant difference for both temperature and relative humidity (Table 1). There was however, a highly significant difference ($p<0.01$) observed between packaging materials on temperature and relative humidity. The highest reading for the temperature and relative humidity were 25.7°C and 85.6% whereas, the least readings were 25.4°C and 77.0%, respectively. The highest values were scored from banana stored in polysheet and the lowest in wooden box+straw. This might be due to the fact that there was relatively lower air circulation in and out of the polysheet compared to wooden box+straw which in turn resulted in higher relative humidity and temperature in polysheet.

Influence of exogenous ethylene and packaging materials on shelf life: The ethylene sources highly significantly ($p<0.01$) affected shelf life. The banana stored with avocado completed its shelf life (30% loss) 10 days after storage time compared to that of banana fruits stored with tomato and mango which took 11 days (Table 1). This might be due to the fact that avocado has relatively higher ethylene releasing capacity compared to other plant ethylene sources used (Thompson and Seymour, 1982). The more ethylene released, the shorter the shelf life will be. Similarly, there was a highly significant difference ($p<0.001$) among the packing materials on the shelf life of banana fruits. Wooden box+straw reached senescence after 10 days from packing time while banana fruits kept in polysheet took the longest period to complete its shelf life (11 days) (Table 2). According to Hopkins (1999), simple polysheet bag is adequate to extend storage life about a week at warm ambient temperature compared to other packaging materials. The highest relative humidity exhibited in the polysheet might be responsible for the extended shelf life recorded by slowing down rate of respiration. The combined effect of plant ethylene source and packaging material also showed a highly significant difference ($p<0.001$) among the treatments (Table 3). Banana stored in wooden box together with avocado finished its storage life earlier from the others. This might be due to the synergetic effect of ethylene and packaging material used as a treatment.

CONCLUSION

From the experiment, it can be concluded that plant ethylene sources (exogenous ethylene application) enhances ripening period considerably than normal ripening period without any undesirable effect on quality of banana fruit. Among plant ethylene source used, avocado resulted in the shortest ripening period since has high ethylene releasing capacity. Wooden box with straw shortens ripening period and shelf life of banana. The longest ripening period and shelf life was exhibited in banana stored in polysheet. Packaging materials influence quality of banana fruit through its modification effect on temperature and relative humidity. Producers, traders or consumers may use exogenous plant ethylene sources (if needed) and packaging materials to shorten ripening period of banana. Based on the experiment avocado in combination with wooden box can be used to get shortest ripening period without any undesirable effect on the quality of the fruit.

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