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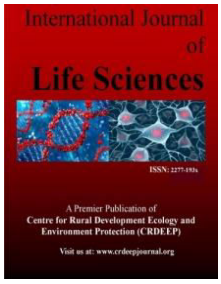

Full Length Research Paper

Effect of Different Packaging Materials on Shelf Life and Post-Harvest Quality of Mango (*Mangifera indica* (L.)) at Wolaita Sodo, Southern Ethiopia

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ABSTRACT

Mango (Mangifera indica (L.)) is a tropical evergreen fruit tree commercially grown in many countries .The fruit is highest postharvest losses due to the most perishable and climacteric fruit that requires specialized postharvest handling to extend its storage life. The study was undertaken at Wolaita Sodo University laboratory in 2018 academic year at laboratory to test the effect of different packaging material on shelf life and quality of mango fruit of locally available variety. The treatments were established in four different packaging material which are locally available materials i.e., (T1=Mango fruit covered with plastic sheet, T2= Mango fruit covered with carton (CFB), T3=Mango fruit covered with banana leaves and T4= Mango fruit stored on open or necked ground). The experiment was laid out in Completely Randomized Design (CRD) with three replications. Mature green Mango fruits were selected and stored by covering with above facilities, then allowed to good shelf life in the ambient condition of the study area. The result has shown all the packaging material with differences on color, aroma, flavor, firmness and overall acceptance on the responses of the respondents and pulp/peel ratio, PWL, decay percentage, marketability percentage and shelf life results. The fruits packed or covered by plastic sheet as packaging material have observed to provide all respondents preferred excellent to marketable skin color, aroma, flavor, firmness and provide a significant result of physiological weight loss decay percentage marketability percentage pulp ratio and shelf life. Next to plastic sheet banana leave packaging material showed highest number of the respondent preferred fair and good result.

Introduction

Mango (*Mangifera indica* L.) is a tropical evergreen fruit tree commercially grown in many countries and popular both in the fresh and the processed forms (Mukherjee, 1997, Mitra and Bildwin, 1997). It is one of the most popular fruits of the world, because of its attractive color, delicious taste and excellent nutritional properties (Rice *et al.*, 1990). Among fruits cultivated in different Regional States of Ethiopia, mango is preceded only by banana; and the first in Gambela and Southern Ethiopia Regions (Edossa *et al.,* 2006) which is one of the most versatile and widely grown fruit crops of tropical and subtropical regions (Vasugi *et al.,* 2012).It is believed to have originated from South East Asia and more than 1000 varieties have been identified all over the world (Rymbai *et al.,* 2014). Mango is cultivated approximately on 3.7 million hectares worldwide, occupied the 2nd position among the tropical fruit crops (Jahurul *et al.,* 2015) and 5th from fruit crops of the world after citrus, banana, grape, and apple (Shi *et al.,* 2015). Asian countries share the largest (77%) of global production, followed by Americans (13%) and African countries (10%) (Rekha Priyadharshini, 2015). Mango is known as the king of the fruits due to its excellent flavor, delicious taste and high nutritive values (Ullah *et al.,* 2010) that makes the crop valued for both food and nutritional security especially for developing countries like Ethiopia where the realization of food and nutritional security is still a challenge.

Ethiopia has great potential and encouraging policy to expand fruit production for fresh market and processing both for domestic and export markets. Besides, fruit crops are friendly to nature, sustain the environment, provide shade, and can easily be incorporated in any agro-forestry Programs (MoARD, 2009). A total of 69,743.39 tons of mango is produced from 12,799 ha of land (CSA, 2015). Moreover, within the past 10 years (2003 to 2013), both area coverage and production of mango increased by 208.4 and 247%, respectively (Dessalegn *et al.,* 2014). It is grown in several parts of the country where the western and eastern Ethiopia are among the major producing belt that accounts >50% of the total mango production in Ethiopia (CSA, 2015). Growing and marketing of fresh produce in Ethiopia are complicated by post-harvest losses in quantity and quality

between harvest and consumption. In Ethiopia, postharvest losses of same horticultural commodities in state farm and peasant sectors are estimated to be 25-35% caused by a combination of several factors (Fekadu, 1991). This high loss was attributed party to lack of packaging, storage facilities, poor means of transportation and handing. Several mango postharvest techniques have been developed for controlling disease and insets and for protection against injury during packaging and storage (pinto *et al.,* 2004). Many physical and chemical treatments have been used for control of postharvest losses in mango (Johnson *et al.,* 1997).

Currently, the local mango industry is constrained with two important postharvest challenges. Firstly, most of our mangoes are packed in wooden crates; which apart from causing physical injuries and bruises to fruit during transit (Anwar *et al.,* 2006), are being restricted in international markets on account of quarantine concerns and special disinfestations treatments necessary for international trade(FAO, 2002).

Secondly, calcium carbide (CaC2) is the commonly used chemical for ripening of mango fruit, due to its low price and availability in local market, however, use of this chemical in fruit industry is being discouraged worldwide due to dangers of explosion and carryover of toxic materials like arsenic and phosphorus to consumers, thus making the healthy fruit poisonous (Maria pan, 2004).Since no technical knowledge is considered necessary for it anomalous use (Subramanian, 2004), higher quantity of calcium carbide needed to ripen immature fruit, makes them tasteless (Medlicott, 1986; Padmini & Prabha, 1997).

In view of the above two problems, studies for an alternate packaging and ripening agent for mango fruit was imperative. While, the corrugated cardboard packaging(CBP) is commercially used for fruits and vegetables in international markets, its use in domestic mango industry is ANWAR *et al.* / Int. J. Agri. Biol., Vol. 10, No. 1, 2008not common, which necessitates studies on its effects on mango fruit shelf life and quality. Further, the local industry is also looking to replace calcium carbide with any suitable alternate. Calcium carbide absorbs moisture and produces acetylene, which is a weak analogue of ethylene, responsible for triggering ripening process (Cua & Lizada, 1990; Singh &Jane's, 2001). Research literature indicates that ethrel/ethephon (2-chloroethylphosphonic acid) and ethanol are the two potential chemicals which can be used to ripen mango fruit (Cua & Lizada, 1990; Medlicott *et al.,* 1990; Padmini & Prabha, 1997; Singh &Janes, 2001). On application, these chemicals penetrate into the fruit and decompose into ethylene.

While, there are only few reports about the effectiveness of ethephon as a ripening agent (Nair& Singh, 2003), ethanol with trade name of Ripened-I (70% ethanol) is being used for ripening mango fruit. In spite of the importance of mango in diet and economy subsistent farmers and country level less attention has been given to the management of its postharvest losses in Ethiopia. There is a need to develop affordable postharvest treatments. Therefore evaluating the effect of different packaging materials on shelf life and post-harvest quality of mango was the objective of this paper.

Materials and methods

Description of the Experimental site

Laboratory experiments were conducted at wolaita zone, southern Ethiopia. It is located at southern part of Ethiopia. It, is 390 km far from Addis Ababa and geographically 6049'N and 37045' E and lies on an altitude of 1483 meters above sea level. The annual average temperature of the zone is 20^{o}c and the mean annual rainfall ranges from 1200 to 1300mm. the rainfall has a bi-modal distribution pattern with small rains from March to May and long and heavy rains from June to September. The zone covers an area of 44,721km2 and found in the altitude range of 1500-2100 masl. (Hailu *et al.,* 2011).

Sampling Techniques and Sampling Size

Locally available cultivar of mango fruit was collected from wolaita area or zone. Based on visual maturity determination, mature grin with similar sized mango were collected. The mango fruit used for the experiment were collected by considering uniformity with regard to color, shape and size and freeform defects.

Experimental Procedures

On the way to break the green color of Kent mango fruits were obtained from Sodo Zuria woreda of southern region. Maturity of fruits were determined with the aid of uniform unblemished fruits having similar size and color are then selected and by using glove and hand washed with tap water to remove field heat, soil particles, and to reduce microbial populations on the surfaces. After washing, the fruits were subdivided in to 3groups for dipping treatments. Plastic containers were washed and rinsed with distilled water prior to use for the dipping treatments. After surface drying of the washed fruits, prepackaging disinfecting treatments were performed on the same day. All treatments were carried out in Horticulture laboratory.

Treatments and Experimental Design

The experiment were contains four different packaging materials which are locally available at community level, open Ground (control),pack with corrugated fiber board carton (CFBC),banana leaves, plastic sheet. The experiment had a total of 12 number of observation. The design of experiment was complete random design (CRD with three replication in each treatment there were half (0.5) kg per experiment, in accordance with specification of design, each treatment was assigned randomly to the experimental unit within a replication.

Data Collected

Color Change

Days required to reach different stages of color during storage and ripening were determined objectively using numerical rating scale of 1-3 where 1= represents on the way to break green color, 2=50% yellow and 50% on the way to break green color, and 3=100% yellow (Miller and McDonald, 1991).

Shelf Life (day)

Shelf life is one of the important quality parameters of mango. Shelf life of mango fruit was a period of time which started from harvesting and extends up to the start of rotting of fruits (Bevery, R. B. *et al*., 1992). Shelf life of mango fruits were calculated by counting optimum marketing and eating qualities.

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).The percentage weight loss was calculated for each sampling interval using the formula given bellow and the cumulative WL is expressed as percentage for the respective treatments.

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

Firmness

Firmness of mango was determined by hand feeling using numerical rate scale.

Decay percentage (DP)

Any day during the storage time were assessed and it was identified by;-

DP=ND/TS *100

where;-DP=decay percentage

-ND=number of decay

-TS=total sample

Pulp to peel ratio

Pulp and peel was separated when mango reach color stage .peel and pulp be weighing individual and it was expressed as;-

Pulp to peel ratio=pulp weight/peel weight

Data analysis

The collected data from the study for all parameters were analyzed by analysis of variance (ANOVA) techniques based on completely randomized design (CRD)and the significance difference between means was separated by using LSD at p=0.05probability level.

Results and discussion

Effect of packaging material on shelf life and postharvest quality of mango

The effect of different packaging material on shelf life and quality of mango fruits was determined in terms of physiological weight loss, pulp to peel ratio, decay percentage, marketability shelf life and quality parameters such as skin color, aroma, flavor, firmness and over all acceptance was discussed separately in the following section for packaging period after harvest according to statically result and respondent response.

Table1: Effect of different packaging materials on weight loss of mango

Treatments	**Physiological Weight Loss**			
	4day	8day	12day	15day
Plastic sheet	1.0^{d}	1.3^{d}	1.7^{d}	2.2^{c}
Carton(CFB)	9.4^{b}	16.1^{b}	26.9^{b}	31.5^{a}
Banana leaves	1.6^{c}	6.1^{c}	11.9^{c}	11.9^{b}
Open ground	12.6^{a}	19.3^{a}	34.7^{a}	34.7^{a}
Mean	6.15	10.7	18.8	20.1
LSD at 5%	0.57	0.69	0.3	1.02
CV	4.97	5.4	4.69	9.7

Mean with the same letter in the same column are not significant different, CV=coefficient of variation, Lsd= least significant difference among treatments

Effect of different packaging material on mango fruit physiological weight loss after 4days, 8days, 12days, and 15days, packed

Physiological weight loss (PWL) of 4 days

The result showed there was a significant difference on PWL after 4days (Appendix1).The highest percentage of weight loss (12.6) was obtained in open ground due to it was not resistance to environmental factors, pests and metabolism action. The lesser PWL (1.0) was obtained from the treatments plastic sheet, this could be due to the fact that the resistance ability of the packaging materials to different environmental factors, pests and low metabolism activity than the other treatments. According to Gonzalez *et al.* reported that plastic covering plays an important role in preventing dehydration by creating a saturated micro-atmosphere around the fruit.

Physiological weight loss (PWL) of 8days

The result showed there was a significant difference on PWL after 8days (appendix2).The highest percentage of weight loss (19.3) was obtained in open ground due to it was not resistance to environmental factors, pests and metabolism action. The lesser PWL (1.3) was obtained from the treatments plastic sheet, this could be due to the fact that the resistance ability of the packaging materials to different environmental factors, pests and low metabolism activity than the other treatments. This finding strongly agrees with Farooqi *et al.* who reported that polyethylene and polyethylene green are impermeable to water; unpacking in such materials raises the humidity around the commodity and decrease moisture loss and results in decrease in weight loss.

Physiological weight loss (PWL) of 12 days

The result showed there was a significant difference on PWL after 12days (appendix3).The highest percentage of weight loss (34.7) was obtained in open ground due to it was not resistance to environmental factors, pests and metabolism action. The lesser PWL (1.7) was obtained from the treatments plastic sheet, this could be due to the fact that the resistance ability of the packaging materials to different environmental factors, pests and low metabolism activity than the other treatments. According to Ashenafi *et.al*(2014)was observed that day 12, nearly all mango fruits were unmarketable while those groups treated act 520c for 10 minutes were left. As, previously reported by Singh *et al.*

(2003) that fruit packaging not only reduces water loss but also delays ripening in mango fruit.

Physiological weight loss (PWL) of 15 days

The result showed there was a significant difference on PWL after 15days (appendix4).The highest percentage of weight loss (34.7) was obtained in open ground due to it was not resistance to environmental factors, pests and physiological activity. The lesser PWL (2.2) was obtained from the treatments plastic sheet, this could be due to the fact that the resistance ability of the packaging materials to different environmental factors, pests and low physiological activity than the other treatments. These results are in agreement with those of Carrillo *et al.*(2000) who observed that coated or uncoated Haden mango in Mexico had an increasing trend of weight loss with the passage of storage time. However, weight loss was lower in coated fruits as compared to control having higher percent weight loss.

Effect of different packaging material on mango fruits shelf life, decay percentage, pulp/peel ratio and marketability percentage after 15days.

Table2. Effect of packaging materials Pulp/peel ratio, Decay percentage and shelf life of mango

Treatments	Pulp/peel ratio	Decay %	Marketability%	Shelf life
Plastic sheet	8^{a}	13.3^{d}	86^{a}	14.33^{a}
Carton(CFB)	4.6^{c}	73.3^{b}	26^{c}	8^{c}
Banana leaves	6.3^{b}	20.6^{c}	53^{b}	11^{b}
Open ground	4.3^{c}	100^{a}	-	6.3^{d}
Mean	5.8	51.8	41.25	9.91
LSD at 5%	0.34	5.06	1.27	1.43
CV	6.8	4.48	3.98	7.76
Significant level	**	**	**	**

Mean with the same letter in the same column are not significant different, CV=coefficient of variation, Lsd= least significant difference among treatments

Peel ratio after 15days

Peel ratio after 15days was significantly (P< 0.05) affected by treatments (appendix5). The highest pulp/peel ratio obtained in plastic sheet due to the fact the resistance ability of packaging materials to different environmental factors, pests and metabolism process than other treatments. The lesser pulp/peel ratio was obtained from the treatment open ground due to it was not resistance to environmental factors, pests and metabolism action.

Decay percentage after 15days

Analysis of variance showed that there was a significant difference among treatment (appendix6). The mean of decay percentage at different treatment were obtained each replication that receives the decay percentage of plastic (13.3), carton(73.3), banana leaves(20.6), open ground(100), from this the highest decay percentage was observed in open ground, whereas the lesser decay percentage was observed in plastic sheet material(13.3) table2. The pathological disorder increased linearly with the increase in days of storage. BhattaRai BP and Shah R (2017)

Marketability percentage after 15days

Analysis of variance showed that there was a significant difference among treatment (Table 2, Appendix7). The mean of marketability percentage at different treatment were obtained each replication that receives the marketability percentage of plastic (86%), carton(26%), banana leaves(53%), but marketable fruit wasn't observed in open ground, from this the highest marketable percentage was observed in plastic sheet, whereas the lesser marketable percentage was observed in carton material(13.3) table2.These results are in agreement with those of Chavez S (2007) the disease development proceeds due to advancement in autocatalytic changes as the storage period are increased, which in turn decreases the market and consumer acceptability of fruit.

Shelf life

Analysis of variance showed that there was a significant difference among treatment (Table2, Appendix7). The mean of marketability percentage at different treatment were obtained each replication that receives the shelf life of plastic (14.33), carton(8), banana leaves(11), open ground(6.3), from this the highest shelf life was observed in plastic sheet, whereas the shortest shelf life was observed in open ground treatments (13.3) .According to Kader and Arpaia, the most important factors affecting postharvest shelf life and quality include rootstock, cultivar, cultural practices, harvest conditions, and maturity stage, while the postharvest factors involve the operational efficiency, pre-cooling, various fruit treatments (fungicide, waxes etc.) and storage conditions

Effect of packaging material on sensory evaluation of mango fruit aroma after 15days packed.

Table3: Number of respondents for aroma, where 1 is for very bad,2 is for poor, 3 is for fair, 4 is for good,5 is for very good**.**

Treatment	Number of respondents that said				
	1	**2**	**3**	**4**	**5**
Plastic sheet			1	3	**5**
Carton(CFB)	5	3	1		
Banana leaves	2	4	3		
Open ground	9				

The result showed that most of the respondent (44.4% of them) preferred excellent, 33.3% of the respondent said good aroma that packed in plastic sheet.5 of the respondent (55.5% of them) said very bad, 33.3% of the respondent said poor, the mango fruit that packed in carton. Most of the respondent (44.4%of them) said poor, 33.3% of the respondent said the aroma of mango fruits was fair that packed in banana leaves. The entire respondent (100%) said the aroma of mango fruits was very bad that packed in open ground.

Effect of packaging material on sensory evaluation of mango fruit flavor after 15days packed.

Table4: Number of respondents for flavor, where 1 is for very bad,2 is for poor, 3 is for fair, 4 is for good,5 is for very good.

Treatment	Number of respondents that said				
	1	2	3	4	**5**
Plastic sheet			1	2	**6**
Carton(CFB)	6	2	1		
Banana leaves	1	4	3	1	
Open ground	9				

The result showed that most of the respondent (66.6% of them) said the plastic sheet had excellent flavor, 22.2% of the respondent said good flavor that packed in plastic sheet. 6 of the respondent (66.6% of them) said very bad, 22.2% of the respondent said poor flavor, the mango fruit that packed in carton.

Most of the respondent (44.4%of them) said poor, 33.3% of the respondent said the flavor of mango fruits was fair that packed in banana leaves. The entire respondent (100%) said the mango fruit had very bad flavor that stored on opened. Ground. Flavor (Test and aroma) is an important quality trait that determine to a great extent consumer acceptance of the .According to (Baldwin, 2010). In the present study the acceptance flavor of Mango fruits was achieved after 15day that stored in plastic sheet.

Effect of packaging material on sensory evaluation of mango fruit firmness after 15days packed.

Table5: Firmness of mango was determined by hand feeling using a numerical rating scale of 1-5,where 1=mature hard,2=sprung,3=between sprung and eating ripe,4=eating ripe and 5=over ripe.

Treatment	Number of respondents that said				
	1	**2**	**3**	**4**	5
Plastic sheet			2	4	3
Carton(CFB)	3	4	2		
Banana leaves		2	5	2	
Open ground		9			

The result showed that most of the respondent (44.4% of them) said the plastic sheet had eating ripe, 33.3% of the respondent said over ripe that packed in plastic sheet. Most of the respondent (44.4% of them) said sprung, 33.3% of the respondent said mature hard, the mango fruit that packed in carton (CFB).

Most of the respondent (55.5%of them) said between sprung and eating ripe, 22.2% of the respondent said the firmness of mango fruits was sprung that packed in banana leaves. The entire respondent (100%) said the mango fruit had sprung firmness that stored on open ground. Firmness is important criteria of fruits quality. The firmness of mango pulp from hard to eating ripe are obvious changed which occur during storage. During firmness change the pulp become softer and sweeter as the ratio of the sugar to starch increases and characteristic aroma is produced. The firmness of mango changes due to conversion of starch into sugars. The results of the experiment are supported by the findings of Pesis *et al* (2005).In this experiment the acceptable firmness was achieved or determined after 15day of packed in plastic sheets.

Effect of packaging material on sensory evaluation of mango fruits color after 4days, 8days, 12days, and 15days packed.

Table-6: Color was measured by comparing with color chart .The color chart consisted of the seven stage of mango fruit color where 1 is dark green, 2 is light green, 3 is more green than yellow, 4 is more yellow than green, 5 is yellow with green tips, 6 is full yellow and 7 is flecking(spot).

	Color skin on 4days intervals				
Treatment	Initially	4^{th}days	8^{th}days	12^{th}days	**15^{th}days**
Plastic sheet	1	2	3	5	**6**
Carton(CFB)	1	2	4	4	**4**
Banana leaves	1	2	3	5	**5**
Open ground	1	3	4	4	**4**

The result showed that mango fruit with plastic sheet treatments color change was highly significant at the 15day(6.00) and at 12day was scores(5.00) similar with banana leave treatment. While the lowest score (4.00) was found in the Mango fruit with open ground treatment. But in 4days and 8days data records

showed that faster change of color scores at 4day (3.00)and at 8day(5.oo) Table(6).

The peel color scores increased as the duration of storage progressed at ambient temperature. The increase in color score during storage might be due to series of physico-chemical changes like the breakdown of chlorophyll and increase in carotenoid pigments of the pulp caused by enzymatic oxidation and photo degradation.

The faster rate of color change of mango under control treatment may be due to the rapid activity of some enzymes that are responsible for the color changes of mango. The delay in ripening and senescence of mango fruits in the low temperature treatment may be attributed to the inhibition of different chemical changes like chlorophyll breakdown. The result of the present study is also supported by the findings of Robinson (1996). He stated that during color changes, the pulp of the fruit became softer and sweeter as the ratio of sugars to starch increased and the characteristics aroma was produced. These findings where at par with Doreyappa-Gowda and Huddar (2001) who reported that the green peel color of mature Alphanso and other varieties of mango turned from light green or green or dark green to light yellow or yellow or orange yellow due to the breakdown of chlorophyll due to a series of physico-chemical changes during ripening, leading to disappearance of green color.

In this experiment the acceptable color was achieved or determined after 15day of packed in plastic sheets. This finding strongly agrees with Baldwin et al., Buttery *et al.,* and *Butter yet al.,* who reported that Ethylene and CO2Production influences the qualitative nature of color, flavor volatiles, sugars, and organic acids in tomato, which determines whole concept of fruit quality. In the process of fruit ripening to decay changes occur in the pattern of climacteric ethylene production. Eugenol decreases during ripening increased in concentration, peaking in the turning, pink, or red stage of maturity, and all flavor components except ethanol and hexanol in the red stage.

Conclusion and Recommendation

The study was conducted determine or identify the effect of different packaging material on shelf life and postharvest quality of mango (*Mangifera indicia* L.). Mango fruits were packed in different packaging material i.e. plastic sheet, carton(CFB), banana leaves and open ground, which are locally available community level and showed significant difference of physiological weight loss and sensory evaluation(general appearance). In general as it was described in result and discussion portion of this experiment above, the plastic sheet packaging material was observed to provide highest number of respondent with excellent aroma, flavor, firmness and a significant result of marketability percentage, shelf life, pulp/peel ratio, with lesser decay percentage and physiological weight loss than the other treatments. Next to plastic sheet the respondent preferred and the result showed that banana leave packaging material that had fair flavor, aroma, and firmness and also showed a good result of shelf life, marketability, pulp/peel ratio and lesser decay percentage and PWL next to plastic sheet than other treatments.

In this experiment out of four treatments the plastic sheet packaging material has observed to provide highest number respondent preferred excellent aroma, firmness, flavor and skin colors and good shelf life, marketability, pulp/peel ratio and lesser decay percentage and PWL in each day, therefore, plastic sheet which are very available at the community level were recommended as appropriate packaging material on shelf life and quality of mango fruit. On the other hand open ground is not recommended as storage material due to absence of ability to resist unfavorable environment, pests and physiological activity of mango fruits. The major weakness in existing post-harvest handling is the integration of all operations into the marketing system. The focus is on packing line and transport operations with little attention paid to wholesale and retail handling. Future research and development is needed into extending marketable life, sapburn, disease control, packing line automation, cooling, controlled atmosphere transport, ripening, disinfestations, and quality assurance.

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Appendices

Appendix 1: Mean square of ANOVA of Peel Ratio at 15thday

Source of variation	DF	Sum of squares	Mean of squares	F value
				F cal
Treatment	3	25.1	8.3**	41.5
Error	8	1.6	0.2	
Total	11	26.7		

Appendix 2: Mean square of ANOVA of 4thday PWL

Source of variation	DF	Sum of squares	Mean of squares	F value
Treatment	3	298.1	99.4**	F cal
Error	8	0.74	0.09	1065
Total	11	299.5		

Appendix 3: ANOVA of 8thday PWL

Source of Variation	DF	Sum of Squares	Mean of Squares	F value	
				F cal	5%
Treatment	3	638	212.7	64.5	
Error	8	26.3	3.3		
Total	11	664.3			

Appendix 4: ANOVA of 12thday PWL

Source of variation	DF	Sum of squares	Mean of squares	F value	
				F cal	5%
Treatment	3	1975.8	658.6	146.4	
Error	8	35.8	4.5		
Total	11	2011.6			

Appendix 5: ANOVA of 15thday PWL

Source of variation	DF	Sum of squares	Mean of squares	F value	
Treatment	3	2187.7	729.2	F cal	5%
Error	8	110.3	13.8	52.8	
Total	11	2298.03			

Appendix 6: ANOVA of Shelf Life

Source of Variation	DF	Sum of Squares	Mean of Squares	F value	
				F cal	5%
Treatment	3	12000	4000	842.11	
Error	8	38	4.75		
Total	11	12038			

Appendix 7: ANOVA of Decay Percentage

Source of Variation	DF	Sum of Squares	Mean of Squares	F value	
				F cal	5%
Treatment	3	1200	4000	551.72	
Error	8	58	7.25		
Total	11	12058			

Appendix 8: ANOVA of marketability Percentage

Source of Variation	DF	Sum of Squares	Mean of Squares	F value	
				F cal	5%
Treatment	3	12366.67	4122.2	1498	
Error	8	22	2.75		
	11	12402			