Effect of Storage Conditions on Fruit Quality and Durability of Sweet Orange Variety "Sisila"

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Abstract
Current experiment was done at horticultural laboratory at Regional Agricultural Research and Development Center, Bandarawela to evaluate fruit quality and durability of sweet orange. Fruits at 50% maturity stage were selected and six different treatments were applied to find the best storage conditions. Treatments were ambient temperature packed in transparent polythene (T1), stored in ambient temperature packed in black polythene (T2), stored in ambient temperature without packing (T3), stored in refrigerator packed in transparent polythene (T4), stored in refrigerator packed in black polythene (T5) and stored in refrigerator without packing (T6). Physiological characters (weight, firmness, juice content and rotten %) and biochemical characters (TSS, pH and Acidity) of the initial and stored fruits were examined weekly for a period of 35 days. Sensory evaluation was conducted using 10 panelists to find out consumer preferences. According to the results, black polythene covered samples stored in refrigerator condition (T5) showed highest shelf life. During storage period, minimum weight losses (from 85.1g to 73.1g), highest TSS (11.2), gradually decreasing of firmness, increase of pH (from 2.6 ± 0.1) and reduction of pH (from 1.6 ± 0.1 to 1.2 ± 0.06) and 0% of rotten fruits were observed for fruits stored in refrigerator, packed in black polythene. Specially, glossy appearance and yellow colour similar to naturally ripen fruits was successfully developed in fruits of above treatment. Sensory evaluation also proved the higher quality of black colour polythene covered fruit stored in refrigerator, by giving significantly higher peel colour appearance (98%), taste (88%) and juice content (88%). Therefore, refrigeration of sweet orange packed in black polythene was the best storage condition.

Keywords: Orange, Packing materials, Storage, Fruit, Quality
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Introduction

Sweet orange (*Citrus cinensis* L.) is, a highly valued fruit crop in Sri Lanka. At present sweet orange production mainly distributed in dry and intermediate zone in Sri Lanka. The sweet orange fruits primarily provide vitamin C and rich in other nutrients such as calcium, potassium, thiamin, niacin, folacin and magnesium. Sweet orange fruits were taken as a fruit and for medicinal purpose. Therefore, it is becoming an increasingly popular among people. Sweet orange variety Sisila was most recently DOA released variety, which was recommended to the wet and intermediate zones of Sri Lanka. This variety has big demand with good flavor, juice content and, especially due to attractive yellowish orange colour at fully maturity stage.

The peel colour and flavor of sweet orange fruits highly varied with the varietal characters as well as climatic conditions in cultivated area. In citrus fruit, generally entire maturity is stopped after harvesting. The fruits normally harvest at 50% maturity stage for selling. In Sri Lankan condition, almost sweet orange fruits store in ambient temperature without packing and kept as bulk in boxes. Therefore, the study on quality performances and consumer preference with different storage conditions are important to increase the shelf life of sweet orange. Keeping quality is also important to catch the consumer market as well as to create reasonable price limits. The measurements of peel colour development, TSS, pH, acidity, rotten percentage and firmness are important to detect fruit quality in different storage conditions and durability. According to Sakhale and Kapse (2012), sweet orange fruits have 5 – 7 days shelf life in ambient temperature. It is necessary to improve storage conditions to keep sufficient shelf life to utilize the entire production in local as well as in export market. Improper storage results in rapid loss of sugars, ascorbic acids and enhances weight loss (Malcki and Sarkissian, 1967). Therefore, evaluation of packing materials and storage conditions are important to improve fruit quality, shelf life and reduction of postharvest losses of sweet orange.

Materials and methods

The experiment conducted in year 2013, Horticulture laboratory at RARDC Bandaraewla. Sweet orange fruits in green mature stage (50% mature), without any pest and diseases were harvested from an orchard in Badulla districts for the experiment. Fruits selected were of similar size, light green peel colour, and weight

with good appearance for minimum defects. As packaging materials transparent polythene and black polythene with the same gage of 200 were used. Each fruit was weighed beginning of the experiment. Thirty transparent polythene bags and Thirty black polythene bags were used for the experiment separately. Similar number and similar sizes of punches were made on each of them. Total 360 fruits were used for the experiment. Fruits were arranged in to the following order. Fruits stored in ambient temperature packed in transparent polythene bags (T1), stored in ambient temperature packed in black polythene bags (T2), stored in ambient temperature without packing (T3), stored in refrigerator packed in transparent polythene bags (T4), stored in refrigerator packed in black polythene bags (T5) and stored in refrigerator without packing (T6). Four fruits per each polythene bag were packed and therefore 60 fruits per each treatment were used. All bags were sealed and kept in relevant storage conditions according to the treatments. Each treatment was replicated three times. The 4 fruits were analyzed / treatment / replicate by weekly intervals for 35 days. An ambient temperature was 24±1ºC and refrigerator temperature was 8ºC throughout the experiment. Parameters such as weight (electrical balance), juice content, pH (pH meter), TSS (Brix) (hand held refractometer), firmness (penetrometer), acidity, rotten (%), colour development and consumer preference were examined from each treatment.

Experiment was arranged according to two factor factorial Completely Randomized Design with four replicates. Data were subjected to ANOVA procedure to obtain treatment means using SAS 9.1.3 statistical software for Windows. The statistical differences among treatment means were tested by Duncan multiple range (P=0.05) test. Sensory evaluation was conducted with 10 panelists team and taste, colour and juiciness parameters were also measured. Sensory data were analyzed using SPSS statistical software.

Results and discussion

According to the Table 1, during the storage period, highest weight loss was recorded due to heavier transpiration; in fruits which were stored in ambient temperature without packing (T3). On the other hand, fruits stored under refrigerator condition packed with black polythene (T5) showed the lowest weight loss.

Weight loss of citrus fruits was significantly increased with storage period. The main causes for weight loss were respiration and transpiration at higher temperature level at ambient temperature. Therefore, the fruits in ambient temperature without packing material progressively lost weight within short storage period.

The difference in water vapor transmission rate in packing materials affected to change time to reach heavy weight losses. Furthermore, Gonzalez *et al.* (1990) mentioned, lower rate of weight loss of fruits in the package could be due to slow rate of ripening and prevention of excessive moisture loss.

The treatments had significant effect on firmness. All fruits were stored under different treatments had gradual increment in fruit firmness after 21 days storage. The firmness of T4 declined from 1st day of storage up to 7th day, and it started again to increase. According to the Faasema *et al.*, (2011), reason to decrease of fruit firmness could be due to the degradation of protopectin by pectinatase. The firmness of treatments began to increase after 21st day of storage, except control treatment in ambient temperature. The firmness increase could be due to the hardening of the skin as a result of high water loss and the development of shriveling.

Juice content gradually decreased. Sweet orange fruits stored in refrigerator and packed using black polythene showed a low reduction pattern of juice content. Transpiration of water could be a main reason for the reduction of juice content.

From the beginning of storage of every treatment up to 28th day did not show significant rotten percentage of fruits. At the 35th day non packed fruits in ambient temperature condition showed significantly higher rotten percentage (50 %). Shelf life of fruits was end after 28th day and not suitable for human consumption.

Table 2 shows the TSS, pH and acidity content of sweet orange fruits with all treatments. Significantly higher TSS value was recorded in fruits stored under refrigerator condition packed with black polythene. In that treatment, TSS value was 11.2 on 35th day. During the storage period every treatment in refrigerator condition showed gradually increasing TSS value. Moreover, transparent and black polythene covered fruits stored under ambient temperature condition recorded gradually increasing TSS value up to 35th day. TSS value declined fruits which stored in ambient temperature without packing was started after 14th day. This indicates that fruits kept in normal environmental condition without packing attained a maximum TSS of 10.1. The decrease in TSS is due to exhaustions of acids and the conversion of sugars in to other organic products as substrate for respiration (Faasma *et*

Table 1: Changes in fruit physiological characters of sweet orange variety "Sisila" with different storage conditions and packing materials during storage period

Store conditions	*Packing materials*	*Parameters*	*Storage periods (Days)*					
			Initial values	*7*	*14*	*21*	*28*	*35*
Ambient temperature (24ºC)	Transparent Polythene (T1)	Weight (g)	87.1 ± 0.3	85.6 ± 0.4	81.7 ± 1.6	78.5 ± 0.3	75.6 ± 0.3	72.1 ± 1.7
		Firmness (lb)	15.7 ± 0.5	14.9 ± 1.6	11.1 ± 1.6	8.9 ± 6.1	9.6 ± 1.4	15 ± 16.7
		Juice content (ml)	36.2 ± 7.3	34.8 ± 9.3	30.2 ± 5.5	29 ± 19.5	24 ± 10.8	23.8 ± 8.1
		Rotten (%)	0	0	0	0	0	0
	Black polythene (T2)	Weight (g)	85.6 ± 1.6	83.6 ± 0.3	82.7 ± 1.3	77 ± 0.1	72.5 ± 0.7	69.7 ± 0.03
		Firmness (lb)	18.1 ± 0.9	16.4 ± 4.1	15.1 ± 6	12.8 ± 2.2	14.4 ± 3	14.5 ± 0.7
		Juice content (ml)	32.4 ± 1.9	31 ± 2.8	28.2 ± 4.4	27 ± 4	25.2 ± 5	25 ± 18.8
		Rotten (%)	0	0	0	0	0	0
	Control (T3)	Weight (g)	86.7 ± 1.9	78.2 ± 2.3	69 ± 2.7	65.4 ± 3.1	62.8 ± 0.8	57.6 ± 1.9
		Firmness (lb)	11.5 ± 1.7	9.7 ± 1.4	16.5 ± 2.3	22.4 ± 2.6	24 ± 7.4	0
		Juice content (ml)	37.5 ± 5.4	36.2 ± 9.6	29.5 ± 4.1	28.4 ± 9	27.4 ± 5.8	0
		Rotten (%)	0	0	0	0	0	50
Refrigerator (8ºC)	Transparent Polythene (T4)	Weight (g)	85.2 ± 0.5	83.4 ± 2.3	81.5 ± 1.7	78.9 ± 1.3	77.6 ± 0.9	74.5 ± 0.6
		Firmness (lb)	18.3 ± 2.6	14.8 ± 4.4	12 ± 3	8.4 ± 5.7	10.4 ± 1.5	10.2 ± 1.2
		Juice content (ml)	35.2 ± 4.1	29.6 ± 4.9	28.3 ± 2.8	26.6 ± 18.8	25.2 ± 5.1	22.5 ± 6
		Rotten (%)	0	0	0	0	0	0
	Black polythene (T5)	Weight (g)	85.1 ± 2.6	84.7 ± 0.5	82 ± 1.1	80.4 ± 0.7	77.8 ± 0.4	73.1 ± 1.2
		Firmness (lb)	19.1 ± 3.2	18 ± 7.6	14.6 ± 1	12.4 ± 0.9	11 ± 3.6	10.1 ± 3
		Juice content (ml)	31.5 ± 1.9	28.8 ± 5.6	27.8 ± 6.8	27.3 ± 11.2	26.2 ± 4.6	25 ± 6.9
		Rotten (%)	0	0	0	0	0	0
	Control (T6)	Weight (g)	86.3 ± 1.7	83.1 ± 0.6	80.1 ± 1.3	77.5 ± 2.1	72.7 ± 2.3	69.4 ± 0.9
		Firmness (lb)	16.4 ± 3.1	15.1 ± 1.7	13.8 ± 1.7	13.1 ± 1.6	14.6 ± 2.5	16.8 ± 3.4
		Juice content (ml)	32 ± 4.2	27.7 ± 7.9	27.7 ± 3.2	23.5 ± 5	24.1 ± 5.2	22.4 ± 7
		Rotten (%)	0	0	0	0	0	0

Table 2: Changes in fruit biochemical characters of sweet orange variety "Sisila" with different storage conditions and packing materials during storage period

Store conditions	*Packing materials*	*Parameters*	*Storage periods(Days)*					
			Initial values	*7*	*14*	*21*	*28*	*35*
Ambient temperature (24ºC)	Transparent Polythene (T1)	TSS	9.4 ± 0.3	9.7 ± 0.8	9.7 ± 0.5	9.8 ± 4.6	10.2 ± 0.6	10.4 ± 0.7
		pH	2.7 ± 0.2	2.9 ± 0.1	2.9 ± 0.2	3.1 ± 1.4	3.2 ± 0.1	3 ± 0.1
		Acidity	1.5 ± 0.5	1.5 ± 0.3	1.5 ± 0.7	1.5 ± 0.6	1.4 ± 0.4	1.4 ± 04
	Black polythene (T2)	TSS	9.7 ± 0.7	10 ± 1	10.1 ± 0.8	10.4 ± 1.4	10.2 ± 0.8	10.2 ± 0.5
		pH	2.9 ± 0.7	2.9 ± 0.1	3.1 ± 0.4	3.2 ± 0.1	3.2 ± 0.1	3.3 ± 0.1
		Acidity	1.6 ± 0.7	1.5 ± 0.4	1.4 ± 0.2	1.4 ± 0.6	1.3 ± 0.4	1.3 ± 0.1
	Control (T3)	TSS	9.9 ± 1.2	9.9 ± 0.6	10.1 ± 1.2	9.7 ± 0.5	9.2 ± 0.2	0
		pH	2.7 ± 0.3	2.8 ± 0.1	3 ± 0.1	3.2 ± 0.1	2.9 ± 0.2	0
		Acidity	1.5 ± 0.4	1.4 ± 0.1	1.2 ± 0.1	1.2 ± 0.05	1.5 ± 0.3	0
Refrigerator (8ºC)	Transparent Polythene (T4)	TSS	9.7 ± 0.5	9.8 ± 0.6	9.9 ± 0.8	10.4 ± 5.2	10.6 ± 0.9	10.8 ± 0.6
		pH	2.7 ± 0.02	2.9 ± 0.1	3 ± 0.1	3.1 ± 1.4	3.3 ± 0.1	3.4 ± 0.1
		Acidity	1.6 ± 0.1	1.5 ± 0.3	1.5 ± 0.2	1.4 ± 0.1	1.4 ± 0.3	1.3 ± 0.1
	Black polythene (T5)	TSS	9.8 ± 0.6	9.9 ± 1.1	10.2 ± 0.9	10.8 ± 1.1	10.9 ± 0.9	11.2 ± 0.7
		pH	2.6 ± 0.1	2.9 ± 0.2	3 ± 0.03	3 ± 0.04	3.2 ± 0.1	3.6 ± 0.08
		Acidity	1.6 ± 0.1	1.5 ± 0.1	1.5 ± 0.5	1.4 ± 0.5	1.3 ± 0.1	1.2 ± 0.06
	Control (T6)	TSS	9.7 ± 0.2	8.9 ± 0.7	9.6 ± 0.7	9.6 ± 0.5	9.7 ± 1.4	10.8 ± 0.6
		pH	2.8 ± 0.4	2.9 ± 0.08	3.1 ± 0.1	3.1 ± 0.2	3.2 ± 0.2	3.3 ± 0.04
		Acidity	1.6 ± 0.2	1.6 ± 0.4	1.5 ± 0.2	1.5 ± 0.6	1.5 ± 0.1	1.5 ± 0.3

al. 2011). Rohani *et al.* (1997) mentioned that the increase in TSS is related to ripening of fresh commodities while slower rate of respiration may reduce metabolic activities and thus result in to lower TSS values.

Normally, pH value increases with fruit maturity. Black polythene packed fruits in refrigerator condition showed significantly increasing pattern of pH. As well as fruits stored in refrigerator condition with packed of transparent polythene bags showed gradually increasing pH values. Fruits stored in transparent polythene and without covered at ambient temperature condition recorded decline pH values on day 28.

Acidity value in refrigerator condition packed with black polythene was lower than other storage conditions. All treatments showed gradually decreasing acidity values except fruits stored in ambient temperature without packing. There was no significant difference in acidity value of transparent polythene packed fruits in

refrigerator condition and black polythene packed samples in same storage conditions. Faasema *et al* (2011) mentioned, organic acids decline during ripening of fruits since they are used as substrates for respiration or converted in to sugars.

Peel colour development gradually increased in all treatments stored in refrigerator condition. The colour development showed significantly highest percentage in T5. At the same time T3 was turned in to brown during storage period.

According to the sensory evaluation, black polythene packed fruits in refrigerator gave significantly highest (Pr> F 0.05) peel colour (98%), taste (88) and juice content (88).

Conclusion

Sweet orange variety "Sisila" fruits shelf life could be extended in refrigerator condition with black polythene packing material. Fruit physical characteristics, biochemical properties and consumer preferences increased when fruit were in black polythene bags and stored under refrigerator condition. The fruit durability was higher (>35 days) in refrigerator without packing. But there colour development was very slow due to the low ripening. On the other hand, fruits stored in ambient temperature without packing had very low shelf life. Therefore, loss of glossy appearance, shriveling, symptoms of water loss and, dryness of peel directly reduce marketability.

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