EFFECT OF CURING ON THE SHELF LIFE OF AMBERSWEET ORANGES (*CITRUS SINENSIS* OSBECK) STORED AT AMBIENT TROPICAL CONDITION

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ABSTRACT

Curing is a pre-storage treatment that can be carried out on certain products by using natural environmentally-friendly conditions. Sweet orange fruits from 2007 and 2008 harvests were subjected to curing treatment by exposing them in the sun at 35^0-39^0C or cool air at room temperature. The fruits were allowed to dry to 1, 3, 5, 7, and 9% weight loss before storage in normal atmosphere at 28^0C and 85% relative humidity. The incidence of infection was higher in sun-cured fruits. The causal organisms were *Penicillium digitatum*, *Phytophthora* sp. and *Alternaria citri*. Incidence was lowest in fruits cured in the shade to 7% weight loss. Juice content was higher in shade-cured fruits but was unaffected by the level of drying. Juice content also decreased significantly with storage. Weight loss was higher in sun-cured fruits, was dependent on level of treatment and increased with storage in both sun and shade methods. Colour change to yellow was faster with sun curing and fruits initially cured to 7% weight loss in shade retained the attractive greenish-yellow colour for 9 weeks. Titratable acidity (TA) was higher in shade-cured fruits and it decreased with storage while total soluble solid (TSS) content ranged from 10.20 to 12.90^0Brix. Sun-cured fruits had higher TSS and it increased slightly with level of curing in both methods. More ascorbic acid was retained by shade curing to higher levels. Fruit firmness and stoniness were significantly affected by curing method. Sun-cured fruits had harder, leathery rinds giving the effect of moderate stoniness. Curing in the shade to an initial 7% weight loss resulted into fruits that were the most stable for storage. Despite the reduction in weight, juice content and ascorbic acid concentration of cured fruits, natural pre-storage curing is convenient and has potential advantage in extending the storage life of orange fruits.

Keywords: Fruit, Sun-cured, Shade-cured, Weight Loss, Storage,

INTRODUCTION

Curing is holding fruits at temperatures and humidities that are conducive to wound healing and detrimental to pathogen development. The treatment is given after harvest and in addition, it encourages water loss from the outermost parts, toughens the outer layers and gives a total effect of prolonged shelf life. The agent used is warm or hot air. The level of curing depends on peel thickness and the length of time the fruit is to be stored (Zhang and Swingle, 2005; Perez *et al.* 2005).

Orange fruits have a shelf life of about 14 days at ambient tropical conditions. The fruits are difficult to harvest without some minor damage, and most postharvest fungi are wound pathogens taking advantage of harvest injuries. Curing is presently used for oranges in some places. Lanza *et al* (2000) noted that 'Tarocco' oranges cured at temperatures >30^0C had limited fungal attack. Nunes *et al* (2007) reported excellent control of both *Penicillium digitatum* and *Penicillium italicum* on 'Valencia late' oranges cured at 40^0C for 18 h. Kinay *et al* (2005) also reported low incidence of green and blue mould among fruits thermally cured at 30^0C and 90 - 95% relative humidity for 72 h. After curing, fruits are stored at temperatures 20^0C (Nunes *et al.*, 2007) but storage at 28^0C within the tropical ambient temperature range is uncommon.

This study therefore seeks to investigate the effect of curing naturally in the sun and shade conditions on the shelf life of orange fruits subsequently stored at $28^0 \pm 2^0$C.

MATERIALS AND METHODS

Preparation

The experiments were carried out independently on fruits harvested in December 2007 and December 2008. Fruits were harvested at maturity based on total soluble solids/titratable acidity contents when they were still green, or green with only traces of yellow = 5%. Harvesting was done early in the morning between 6.00 and 8.00am. Fruits were picked individually from only one tree for genetic homogeneity taking care to avoid injury. They were washed in 0.385% $^m/_v$ sodium hypochlorite solution and allowed to drain and air-dry. The fruits were individually labelled and weighed.

Curing Treatment and Storage

Fruits were separated into two lots and kept in rhombus container with wooden base and frame surrounded by plastic mosquito gauze netting. The container allowed free air flow. One of the holding containers was left outside from 11.00am till 3.30pm at 35^0-39^0C while the sun was up. The other container was left in the laboratory at 24^0-26^0C under good ventilation. Fruits were individually weighed periodically and were culled when 1, 3, 5, 7 and 9% weight loss had been attained. The specified weight losses were attained in the sun in averages of 17, 36, 66, 81 and 104 hours; while they were attained in 23, 48, 90, 138 and 160 hours respectively in the shade of the laboratory. After curing, they were stored in closed metal cabinets sterilized by swabbing thoroughly with 70% ethanol and formaldehyde and kept at $28^0 \pm 2^0$C with controlled ventilation. The ventilation was controlled from the vents at the top of the cabinet. Disease incidence was determined at weekly intervals and decaying fruits were removed from storage.

Determination of Quality Parameters

Percentage weight loss during storage was determined on individual fruits and the results were pooled to obtain the average for the week. Colour change was rated visually from 1 to 5; where 1 = completely green; 2=green with traces of yellow up to 10%; 3=green and yellow up to 40%; 4= yellow with traces of green; 5= complete yellow. Juice content from each fruit sample was measured using a measuring cylinder after filtering off solids through muslin cloth. Fruit texture was determined in the fourth week of storage by measuring firmness using a cone penetrometer (ELE Model no ELE 240540; capacity 0 400x0.1mm). Each fruit was punctured randomly at three points to obtain the depth of penetration which was then converted to Newtons. The total soluble solids (TSS) was measured with a hand refractometer and expressed in ^{0}Brix. Titratable acidity (TA) was dertermined as citric acid in g/100ml juice and ascorbic acid (AA) content expressed in mg/100ml juice.

Statistical Analysis

All data were subjected to Analysis of Variance (ANOVA) and where significant, the means were compared using New Duncan's Multiple Range Test ($p=0.05$).

RESULTS

In the first year's harvest, percentage decay was highest among fruits cured to 9% weight loss in the sun and lowest among those cured to 7% weight loss in shade. The same trend was observed in the second year. Highest decay of 42.5% occurred in 7 and 9% sun- cured while the least of 2.5% occurred in 7% shade- cured fruits by the 8^{th}week (Table 1) . This low incidence of decay lasted even beyond the 8^{th} week of storage. There were no rotten fruits among 5, 7, and 9% shade-cured up to the 3^{rd}, 7^{th} and 4th weeks of storage respectively. All sun-cured fruits had about the same level of decay. By the 8^{th} week, no treatment had lost up to 50% of its number (Table 1). Green, brown and black moulds caused by *Penicillium digitatum*, *Phytophthora* sp. and *Alternaria citri* were the types of decay observed.

Curing in the sun significantly ($p<0.05$) affected weight change. Highest weight loss of 25.01% was observed in 5% sun-cured (Fig. 1). Fruits cured in the shade to 1% weight loss showed the lowest amount of weight loss (Fig 2) when those sun-cured to 7% weight loss showed the highest weight loss in storage. The weight changes in both at the 8^{th} week of storage were 15.36 and 20.90% respectively. Those cured in the shade to 7% weight loss, lost 17.49% by the same period and 31.31% by the 12^{th} week. Weight loss increased with storage after both methods of curing (Figs. 1 & 2).

Treatment (% Wt. loss)	Period of Storage (Weeks)/ Incidence of Decay (%) 1	2	3	4	5	6	7	8
Sun – 1	0	5.0	12.5	20.0	30.0	35.0	37.5	40.0
3	0	10.0	15.0	22.5	30.0	35.0	37.5	40
5	0	15.0	20.0	22.5	27.5	30	35.0	40
7	0	10.0	17.5	20.0	30.0	37.5	40.0	42.5
9	0	15.0	22.5	27.5	32.5	35	37.5	42.5
Shade								
1	0	0	5.0	10.0	15.0	25.0	30.0	32.5
3	0	0	5.0	10.0	17.5	20.0	27.5	30.0
5	0	0	0	5.0	12.5	17.5	25.0	30.0
7	0	0	0	0	0	0	0	2.5
9	0	0	0	0	5.0	10.0	15.0	22.5

Table 1: Percentage Incidence of Decay in Ambersweet Orange (*Citrus sinensis*) Fruits During Storage at 28^{0}C after Curing Treatment.

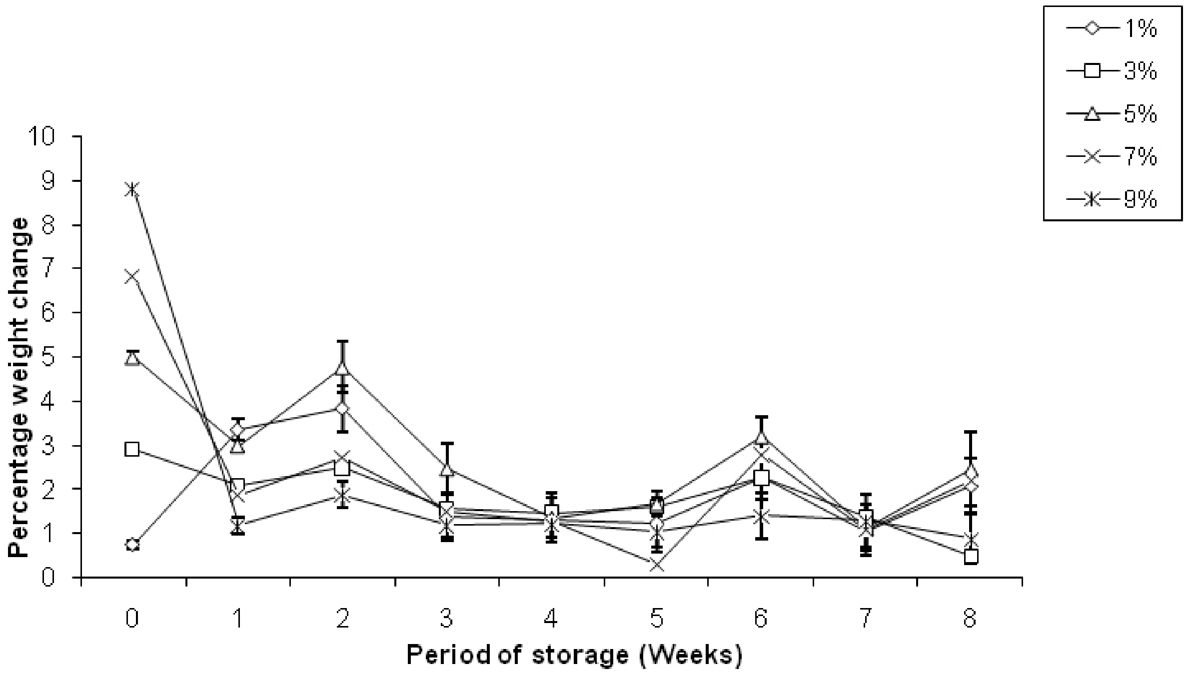

Fig. 1: Weekly Weight Changes in Orange Fruits Stored at 28^{0}C after Curing Treatment in the Sun.

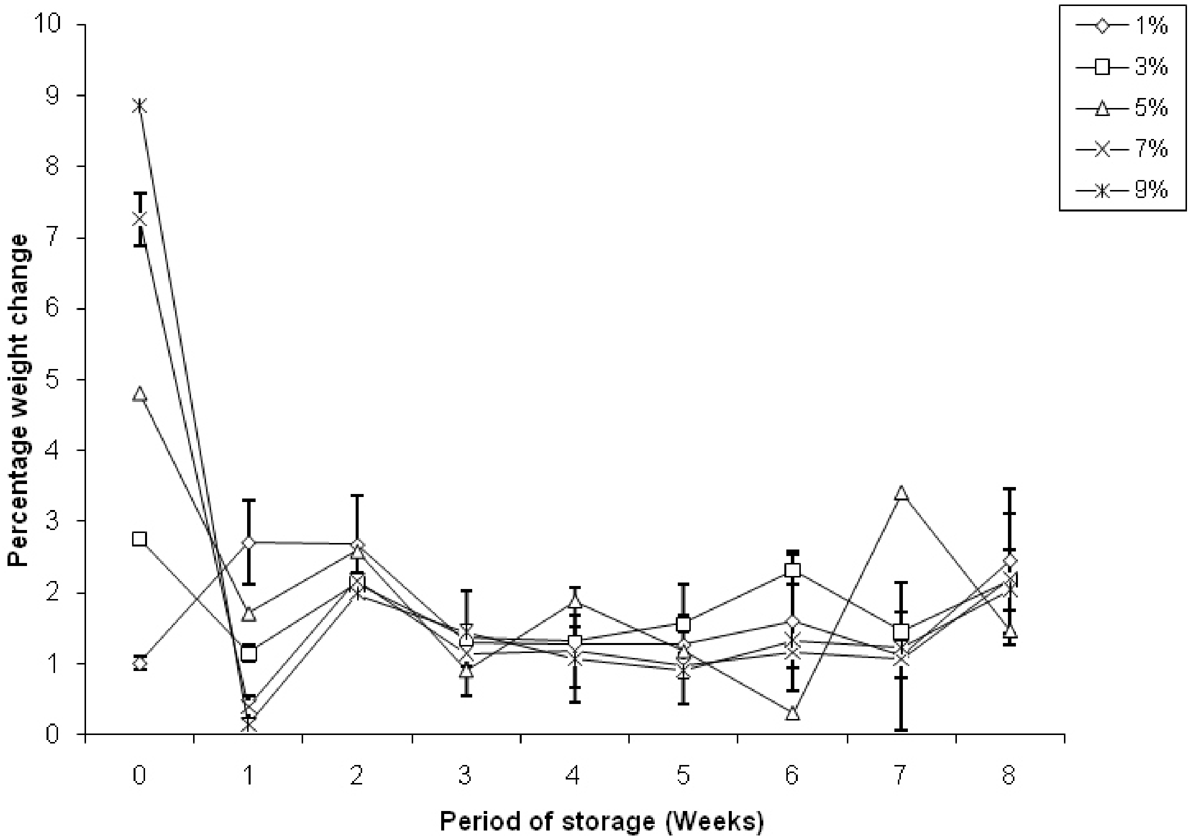

Fig. 2: Weekly Weight Changes in Orange Fruits Stored at 28^0C after Curing Treatment in the Shade.

Juice content was also significantly affected by curing treatment in the sun. It generally decreased with increased level of curing and the lowest was obtained in 7% sun-cured fruits (Fig.3). It was however not affected by the level of curing in the shade (Fig. 4).

Colour development to yellow was more rapid and intense in sun-cured fruits but was not significantly ($p>0.05$) affected by the level of curing (Fig. 5). From the 5^{th} and 6^{th} weeks of storage, there was significant difference between fruits shade-cured to 7% weight loss and all other treatments in the shade. These fruits maintained the lowest level of colour development throughout storage, getting only to 4.0 by the 8^{th} week (Fig. 6). These fruits retained the greenish-yellow colour longer than all other treatments.

Fruit firmness was not affected by level of curing but was significantly affected by curing method (Fig. 7). Sun-cured fruits had harder rinds and were stony. Only decayed fruits from both methods softened. The fruits that remained healthy in storage had slight to moderate stoniness. The total soluble solid content was not significantly ($p>0.05$) affected by either curing method or level but it increased with storage for most treatments (Fig. 8). The titratable acidity was affected only by method and not by level of curing but it also decreased with storage (Table 2).

Ascorbic acid content generally decreased with storage up to the 8^{th} week. Shade-cured fruits retained more ascorbic acid than sun-cured fruits. Sun cured fruits retained about 50% of the initial content. Fruits that were shade-cured to 7% weight loss had a reduction from 212.40 mg/100ml at the start to 204.0mg/100ml representing about 96% retention by the 7^{th} week of storage. The content was also significantly ($p<0.05$) affected by method but not by level of curing (Fig. 9).

DISCUSSION

This study has shown that the incidence of decay can reduce with curing treatment of oranges in the sun or shade but more significantly by shade curing. The incidence of decay which occurred within two weeks of storage among sun-cured fruits while shade-cured had none is probably a direct result of the differences in curing temperature. The higher sun temperature probably caused an increase in the physiological processes in both the fruits and decay pathogens alike such that the pathogens thrived more on the more physiologically-injured host which had their own metabolic processes speeded up resulting into their quick establishment on the host fruits. The organisms presently associated with decay have already been reported on citruses (Ismail and Zhang, 2004; Palou *et al.*, 2001).

Weight loss with storage has been reported for oranges in all postharvest treatments (Alemzade

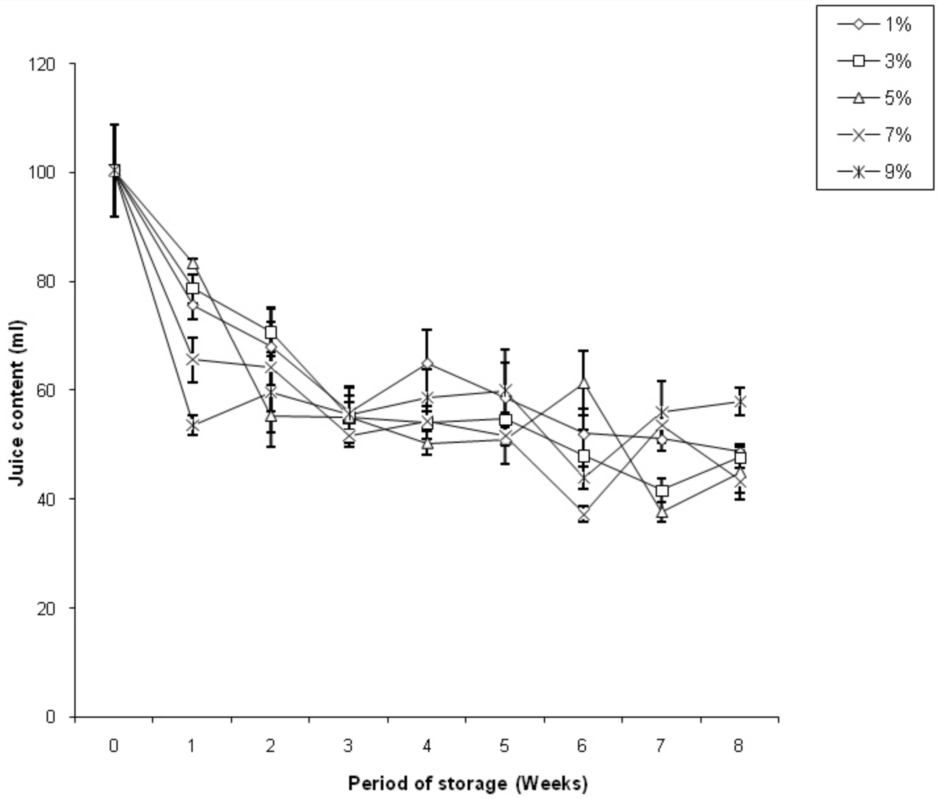

Fig. 3: Juice Content of Orange Fruits Stored for 8 Weeks at 28⁰C after Curing in the Sun.

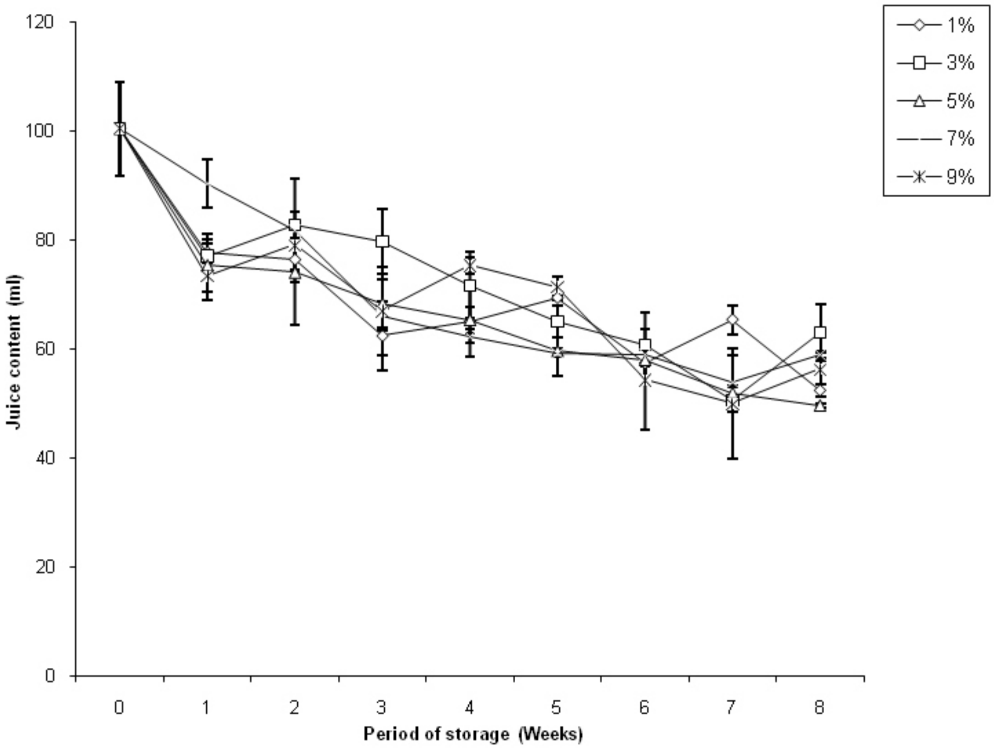

Fig. 4: Juice Content of Orange Fruits Stored for 8 Weeks at 28⁰C after Curing Treatment in the Shade

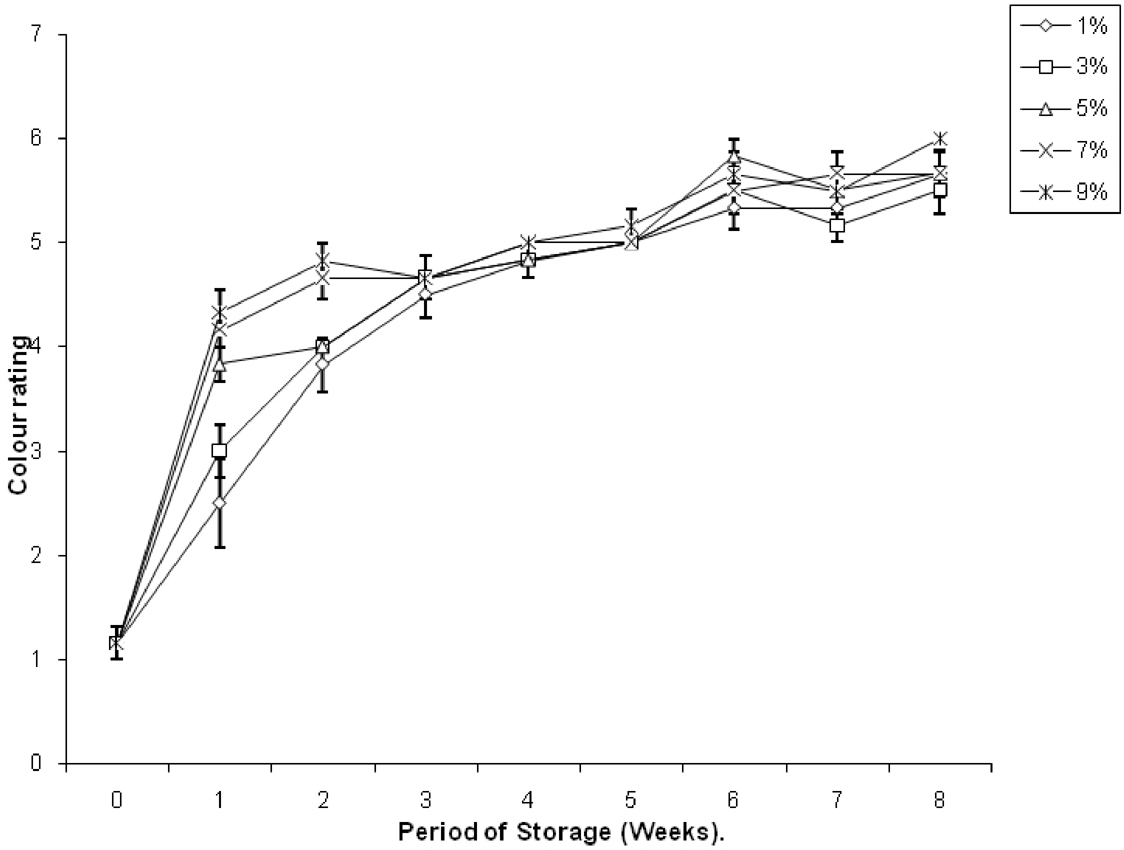

Fig. 5: Colour Development in Orange Fruits Stored for 8 Weeks at 28⁰C after Curing Treatment in the Sun.

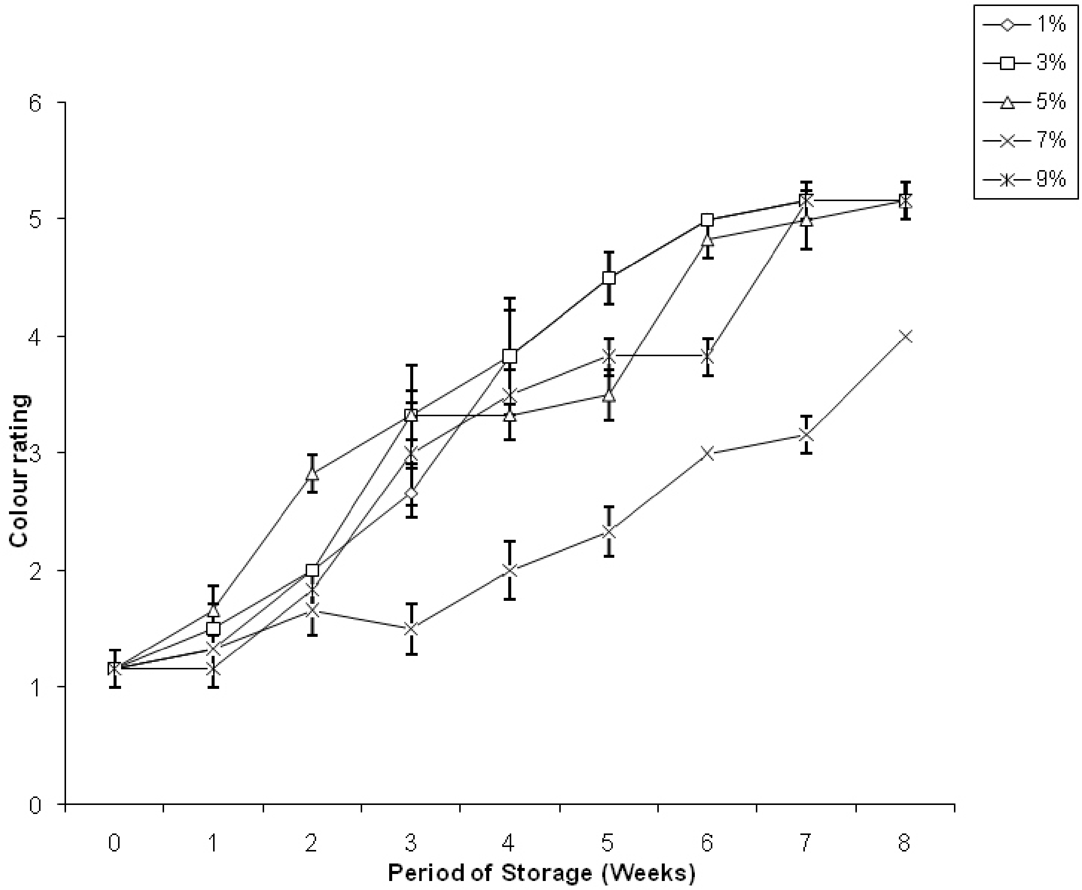

Fig. 6: Colour Development in Orange Fruits Stored for 8 Weeks at 28⁰C after Curing Treatment in the Shade.

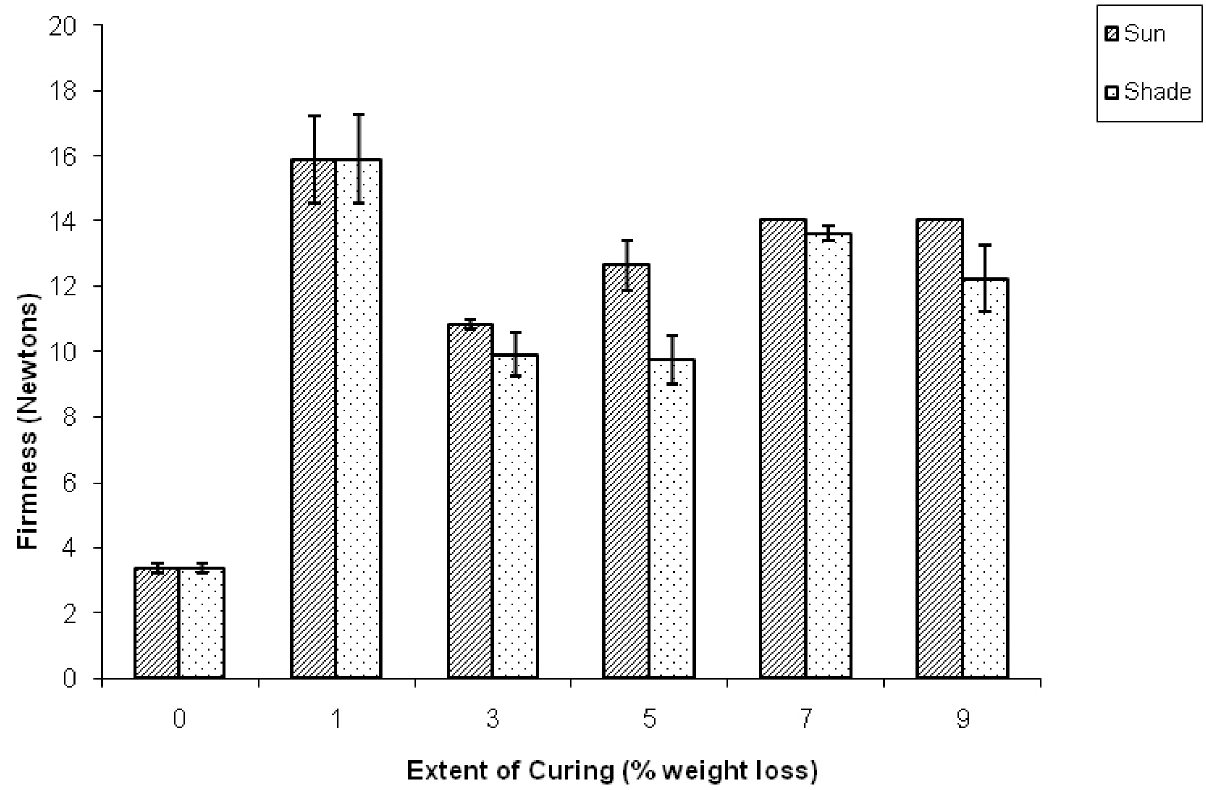

Fig. 7: Firmness of Orange Fruits Stored for 4 Weeks at 28⁰C after Curing Treatment.

Columns of the same pattern followed by different letters are significantly different ($p<0.05$) by New Duncan's Multiple Range Test.

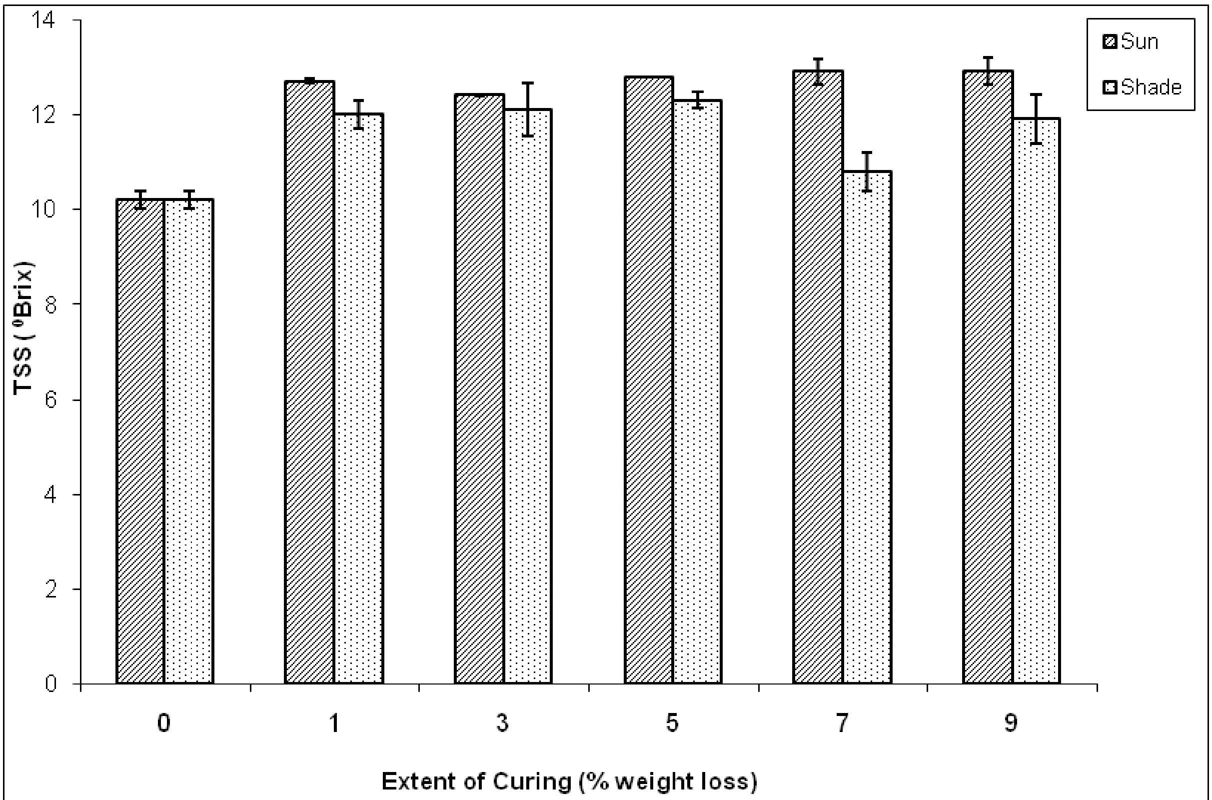

Fig. 8: Total Soluble Solid Content of Orange Fruits Stored for 8 Weeks at 28⁰C after Curing Treatment.

Columns of the same pattern followed by different letters are significantly different ($p<0.05$) by New Duncan's Multiple Range Test.

Table 2: Titratable Acidity in Ambersweet Orange (*Citrus Sinensis*) During Storage at 28^{0}C after Curing Treatment

Treatment	Period of Storage (Weeks)/ Acidity (g/100ml)							
(%Wt. Loss)	1	2	3	4	5	6	7	8
Sun – 1	1.56±0.34^{c}	1.48±0.03^{b}	1.39±0.04^{a}	1.00±0.04^{a}	1.14±0.02^{b}	1.09±0.03^{c}	1.01±0.01^{bc}	0.98±0.04^{c}
3	1.46±0.34^{ab}	1.40±0.01^{a}	1.34±0.02^{a}	1.30±0.02^{c}	1.28±0.03^{c}	1.22±0.01^{d}	1.09±0.05^{c}	0.76±0.03^{a}
5	1.44±0.02^{ab}	1.36±0.03^{a}	1.32±0.02^{a}	1.26±0.03^{bc}	1.10±0.05^{b}	1.07±0.04^{c}	0.99±0.05^{bc}	0.94±0.02^{c}
7	1.54±0.02^{bc}	1.37±0.02^{a}	1.30±0.01^{a}	1.22±0.02^{bc}	1.06±0.03^{b}	0.96±0.03^{b}	0.91±0.04^{b}	0.84±0.02^{b}
9	1.40±0.02^{a}	1.32±0.01a	1.28±0.04^{a}	1.19±0.01^{b}	0.94±0.03^{a}	0.86±0.03^{a}	0.73±0.03^{a}	0.70±0.01^{a}
Shade								
1	1.69±0.05^{d}	1.61±0.01^{c}	1.56±0.03^{b}	1.49±0.04^{d}	1.30±0.02^{c}	1.24±0.01^{d}	1.24±0.02^{d}	1.20±0.01^{d}
3	1.68±0.04^{d}	1.63±0.01^{c}	1.51±0.01^{b}	1.56±0.03^{d}	1.44±0.04^{d}	1.37±0.02^{e}	1.34±0.02^{de}	1.27±0.03^{de}
5	1.67±0.03^{d}	1.63±0.01^{c}	1.56±0.03^{b}	1.48±0.04^{d}	1.40±0.02^{d}	1.36±0.03^{e}	1.50±0.02^{f}	1.30±0.02^{e}
7	1.70±0.01^{d}	1.68±0.04^{c}	1.59±0.05^{b}	1.54±0.02^{d}	1.48±0.03^{d}	1.44±0.02^{e}	1.49±0.04^{f}	1.41±0.01^{f}
9	1.67±0.02^{d}	1.67±0.01^{c}	1.56±0.03^{b}	1.49±0.02^{d}	1.43±0.01^{d}	1.40±0.02^{e}	1.36±0.03^{e}	1.30±0.02^{e}

Values are means of three replicates ± standard error of the mean. Figures followed by the same letter in a column are not significantly different by New Duncan's Multiple Range Test at p=0.05.

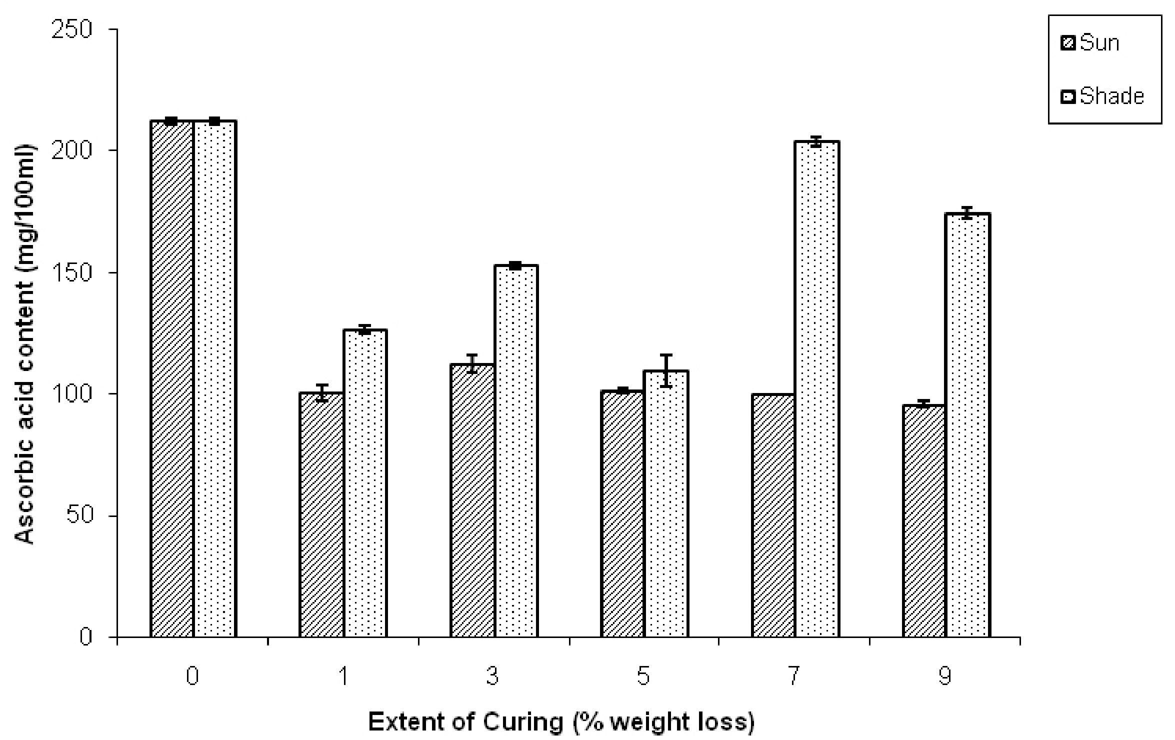

Fig. 9: Ascorbic Acid Content of Orange Fruits Stored for 7 Weeks at 28^0C after Curing Treatment.

Columns of the same pattern followed by different letters are significantly different ($p<0.05$) by New Duncan's Multiple Range Test.

and Feridoon, 2007). The higher weight loss observed during storage of sun-cured fruits is also probably due to the higher temperature of curing. The sun-cured fruits continued to lose moisture more readily possibly because of increased respiration which was accompanied by loss of moisture and dry matter. The rate of weight loss was consistently higher in sun-cured fruits after treatment. By the eighth week however, none of the treated fruits had lost more than 25% of their saleable weight. This is significant as it shows that at shelf conditions of storage, it is possible to maintain fruits in good state at 28^0C after curing. Those cured to higher levels of 5, 7 and 9% lost more weight in storage. Plaza *et al* (2003) also reported increased weight loss when fruits were cured at 33^0C for 65 h and stored at 20^0C for 7 days. Singh and Sreenivasula (2006) reported 19.4% weight loss in oranges stored at ambient temperature for 17 days. None of the treatments presently reported lost that much weight at the 3^{rd} week of storage.

The observed decrease in juice content with storage is indicative of its contribution to weight loss. Its independence on the level of curing is probably due to its location in juice vesicles deep within the segments of the fruits. The treatment where highest weight was lost was also a treatment that had about the lowest juice content. This is evidence that weight loss probably included some juice loss. Although the cause of increase or decrease in fruit water loss following heat treatment remains to be elucidated (Schirra *et al.*, 1997), all weight loss was therefore probably only as a result of evapo-transpiration from the peel, initially the flavedo, and later in storage from the albedo and then juice vesicles within the segments. Although the juice content decreased with storage, 43-63% of the initial quantity was retained; the highest being from shade-cured fruits. This has potential economic advantage when approximately 50% of the nutritionally-useful part of the fruit can still be recovered at low cost even when storage is at tropical ambient conditions.

The slower degreening with shade-curing makes the method more attractive in order to preserve the attractive yellowish green colour for longer period for better market appeal. Shade-curing to 7% is the most beneficial treatment in this regard as it preserved fruits in this colour up to eight weeks. Shade curing to 5 and 9% also preserved fruits at this stage of degreening for 5 and 6 weeks respectively. Shade curing to higher levels is therefore useful for colour preservation. Contrary to the observations of Singh and Sreenivasula (2006) that bioyield point, firmness, puncture force and cutting energy, all of which are indices of fruit hardness decreased, increase in fruit hardness was observed in this study.

The increase in TSS with storage is also probably due to concentration of the juice after moisture loss from the outer parts. Greater retention of moisture in shade-cured fruits had a dilution effect which resulted into slightly lower TSS but the level of treatment was insignificant in sugar content. Perez *et al* (2005) reported that quality parameters such as sugars and organic acids contents of mandarins Clemenules fruits (*Citrus reticulata*) were not affected by curing. The limited effects of the level of curing on pH suggests that the acidity of fruit is not subject to change as a result of level of treatment but on method as shade-cured fruits were more acidic. This is evidenced by the higher titratable acidity measured in shade-cured fruits and their lower level of degreening.

Colour change is evidence of ripening and it is associated with a number of biochemical changes including reduction in content of organic acids. The shade-cured fruits which retained their yellowish green colour longest also had the highest concentration of titratable acidity. The observed decrease with storage is also probably as a result of degreening process whereby more of the organic acids in the fruits were used up in respiration. The greater hardness (stoniness) in sun-cured fruits is possibly a result of greater loss of moisture from the peel which resulted into its hardening and made it more difficult to penetrate. This is contrary to reports by Plaza *et al* (2003) that curing at 33^{0}C increased firmness loss.

Results show that ascorbic acid was retained more in shade-cured fruits and decreased with storage after both methods of curing. The retention of 204.0mg/100ml of ascorbic acid by the 7^{th} week of storage in fruits shade-cured to 7% weight loss show that sufficient quantities of the nutrient was still retained. The Recommended Nutrient Intake (RNI) of the nutrient is 45 mg day^{-1} for adults (Anonymous, 2004). None of the treatments here reduced the nutrient to this level. However, in spite of the potentials including the ease of curing operation, the economic advantage of this method still has to be investigated.

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