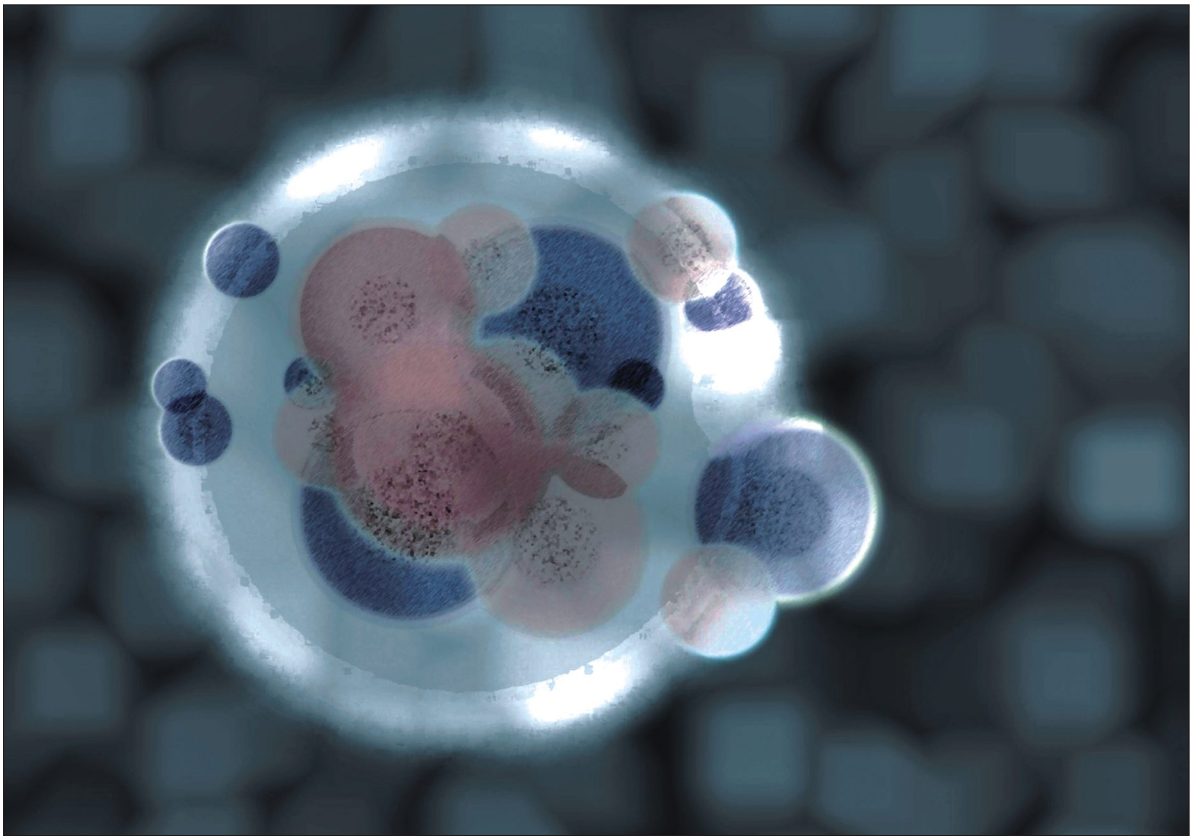

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Effect of Curing and Packaging on Damaged Citrus Fruit Quality

[1]Muhammad Akram Tariq, [2]Faqir Muhammad Tahir, [1]Ali Asghar Asi and [2]M. Aslam Pervez
[1]Horticulture Section, Ayub Agricultural Research Institute, Faisalabad
[2]Department of Horticulture, University of Agriculture, Faisalabad, Pakistan

Abstract: Sealing and curing was found favourable to maintain the fruit quality and to extend its shelf life upto 6-7 weeks. The treatments also helped in healing and inhibited softening. Higher O_2 and lower CO_2 contents were found in sealed-cured fruit bags. The combined treatment (sealing + curing + washing) was found more effective than individual treatments.

Key words: Citrus fruit, damage, curing, packing, shelf life, quality, gases, deformation and firmness

Introduction

In the past, much emphasis has been put on growing more fruit, while the postharvest aspect has been generally ignored. Postharvest losses of citrus fruits affect both the nutritional values and quality of the citrus fruits which is badly affecting the economy of the country.

Bancroft *et al*. (1984) reported that the total decay loss of lemons and sweet oranges during storage and marketing averaged around 8 percent in three central California packing houses. Citrus fruits stored for several months or shipped long distances often show losses ranging from 9 to 25% (Pienaar, 1969). Kitagawa and Kawada (1984) estimated the decay loss in all citrus fruits imported into Japan in 1983 at $5 to $10 million (US). Waks *et al*. (1988) observed that the prestorage curing of citrus fruits sealed in plastic film has been reported to reduce decay. The Pakistan National Commission on agriculture estimated that defects and inadequate facilities in postharvest handling, transport, storage and marketing may cause up to 20-40 percent losses of fruits and vegetables (Farooqi, 1994). Losses during handling and marketing of tropical produce are often high, particularly for imported goods, with postharvest losses sometimes exceeding 50% (Campbell, 1994).

Much of this posthatvest loss is due to mechanical damage inflicted during harvesting and handling (Thompson, 1996). There have been many studies on how to reduce mechanical damage to crops but this project helped to estimate the possibility of negating the effects of the damage.

Materials and Methods

The studies being reported in this write-up were conducted on three cultivars of citrus i.e. Sweet orange, Satsuma mandarins and lemons in Silsoe College Silsoe Cranfield University Bedford Mk45 4DT U.K. during 1998-99. The fruits were produced in Spain and obtained from a U.K. commercial source. There were three different experiments as mentioned below.

Experiment 1: The fruits of Sweet oranges, mandarin and lemons were damaged with a pendulum or Sweet oranges by dropping from 2.4 m height on compacted soil to inflict damage. Then the fruits were sealed in polyethylene film bags and cured at 35°C with 95% RH for 48 hours then stored at 5°C with 90% RH. Pendulum damaged fruits were analysed after 30, 31, 32 days, respectively and the fruits damaged by dropping were analysed after 28 days of storage. The experiment was a completely randomized factorial design (2 damage levels x 2-polyethylene film levels), replicated thrice.

Experiment 2: In this experiment Sweet oranges and Satsuma mandarins were damaged by scuffing and compression methods. The fruits were seal-packed, cured at 35°C with 95% RH for 48 hours then stored at 5°C with 90% RH. and analyzed after 34 and 32 days of storage respectively. The experiment was a completely randomized factorial design (3 damage levels x 2 Polyethylene film levels), replicated thrice. Following observation were recorded (Fig. 1).

Weight loss percentage, fruit firmness, TSS, acidity, TSS/acid ratio and pH.

Experiment 3: First and second experiment exhibited significant difference between sealed and nonsealed cured fruits. Hence, this experiment was conducted to ascertain whether the significant differences are due to polyethylene film or curing. Further combinations (nonsealed-cured, nonsealed-noncured, sealed-noncured and sealed and cured) were made to study the effects of curing on oranges and Clementine mandarins. Freshly harvested fruit without any postharvest treatment were used after washing with distilled water. The fruits were damaged, sealed-packed, cured, stored with the same methods as in the last experiments except that some were not cured and stored directly at 5°C with 90% RH. The fruits were analysed after 46 or 48 days of storage (Fig. 2). The experiment was a completely randomized factorial design (4 damage x 2 polyethylene x 2 curing), replicated four times. Juice percentage and deformation of the fruit at various levels was measured. The O_2 and CO_2 content of the sealed polyethylene bags were also measured using gas chromatography in addition to the characters observed in experiment 1 and 2.

Results and Discussion

The results (Table 1-4) show that the weight loss of fruits was higher in nonsealed-cured damaged and undamaged fruit than in sealed-cured damaged and undamaged fruits. The lowest firmness was recorded in damaged fruit cured without polyethylene film and the highest firmness values were noted in undamaged and damaged fruit cured with polyethylene film. Damaged fruits were the softest due to moisture loss while sealed fruit produced the best firmness. TSS were not affected by treatments while acidity of the fruits exhibited significant difference. The damaged fruits cured without polyethylene film produced less acidity and the TSS/acid ratio and pH increased with a reduction in acidity.

The results (Table 5-6) of experiment 2 show that the higher weight loss figures were recorded in damaged and undamaged fruit cured without polyethylene film than damaged and undamaged fruit cured within polyethylene film. The weight loss results were similar in cured damaged and undamaged sealed fruit but the weight loss values were significant between damaged and undamaged cured and unwrapped fruit.

Table 1: The effect of damage (caused by a pendulum) and sealed packaging in 120 gauge polyethylene film bags on the quality of sweet oranges after curing at 35°C with 95% RH for 48 hours and subsequent storage at 5°C with 90% RH for 30 days

Characters	Undamaged	Damaged	Undamaged sealed in P. Film	Damaged Sealed in P. Film	LSD (p=0.05)
Weight loss (%)	3.15	4.41	0.65	0.79	0.21
Firmness (N mm^{-1})	4.40	3.63	5.03	4.93	0.37
TSS (%)	12.40	12.10	12.80	12.63	N.S
Acidity (%)	0.66	0.62	0.69	0.68	0.03
TSS/acid ratio	18.79	19.52	18.55	18.57	0.44
pH	3.64	3.68	3.44	3.52	N.S

N.S = non significantly different (p=0.05)

Table 2: The effect of damage (caused by dropping) and sealed packaging in 120 gauge polyethylene film bags on the quality of sweet oranges after curing at 35°C with 95% RH for 48 hours and subsequent storage at 5°C with 90% RH for 28 days

Characters	Undamaged	Damaged	Undamaged Sealed in P. Film	Damaged Sealed in P. Film	LSD (p=0.05)
Weight loss (%)	2.95	5.50	0.78	0.95	0.44
Firmness (Nmm^{-1})	4.27	3.67	4.93	4.70	0.24
TSS (%)	12.27	11.97	12.60	12.43	N.S
Acidity (%)	0.61	0.58	0.63	0.62	0.02
TSS/acid ratio	20.10	20.63	20.03	20.07	0.31
pH	3.99	4.06	3.74	3.86	N.S

N.S = non significantly different (p=0.05)

Table 3: The effect of damage (caused by pendulum) and sealed packaging in 120 gauge polyethylene film bags and curing on the quality of Satsuma mandarins after curing at 35°C with 95% RH for 48 hours and subsequent storage at 5°C with 90% RH for 32 days

Characters	Undamaged	Damaged	Undamaged Sealed in P. Film	Damaged Sealed in P. Film	LSD (p=0.05)
Weight loss (%)	3.79	5.39	0.89	1.22	0.49
Firmness (Nmm^{-1})	1.90	1.63	2.23	2.10	0.16
TSS (%)	11.67	11.37	11.93	11.80	N.S
Acidity (%)	0.74	0.70	0.76	0.75	0.03
TSS/acid ratio	15.77	16.23	15.70	15.73	0.27
pH	4.17	4.24	3.90	3.90	N.S

N.S = non significantly different (p=0.05)

Table 4: The effect of damage (caused by dropping) and sealed packaging in 120 gauge polyethylene film bags on the quality of lemon after curing at 35°C with 95% RH for 48 hours and subsequent storage at 5°C with 90% RH for 31 days

Characters	Undamaged	Damaged	Undamaged Sealed in P. Film	Damaged Sealed in P. Film	LSD (p=0.05)
Weight loss (%)	4.10	5.47	0.94	1.27	0.65
Firmness (Nmm^{-1})	5.80	5.50	5.67	6.37	0.16
TSS (%)	10.03	9.83	10.26	10.10	N.S
Acidity (%)	2.08	2.01	2.15	2.11	0.03
TSS/acid ratio	4.82	4.89	4.75	4.79	0.27
pH	3.30	3.34	3.24	3.27	N.S

N.S = non significantly different (p=0.05)

Table 5: The effect of damage caused by compression and scuffing methods and sealed packaging in 120 gauge polyethylene film bags on the quality of sweet oranges after curing for 48 hours at 35°C with 95% RH and subsequent storage for 34 days at 5°C with 90% RH

Treatments	Sealed in Polyethylene Film			Without Polyethylene Film			LSD (p=0.05)
	Undamaged	Compression damage	Scuffing damage	Undamaged	Compression damage	Scuffing damage	
Weight loss (%)	0.75	0.92	1.05	3.28	5.60	6.10	0.52
Firmness (Nmm^{-1})	4.43	4.36	4.27	3.79	3.67	3.55	0.18
TSS (%)	12.95	12.84	12.71	12.26	12.14	11.98	N.S
Acidity (%)	0.74	0.72	0.70	0.64	0.62	0.60	0.05
TSS/acid ratio	17.50	17.38	18.15	19.16	19.58	19.96	0.94
pH	3.58	3.68	3.77	4.08	4.17	4.29	0.23

N.S = non significantly different (p=0.05)

The highest firmness was recorded in damaged and undamaged fruit cured with polyethylene film and the lowest firmness was found in damaged and undamaged fruit cured without polyethylene film. Sealed fruit maintained the initial firmness due to less moisture loss while damaged and undamaged unwrapped fruit became softer. TSS were not affected by all treatments but the acidity of damaged and undamaged unwrapped fruit decreased and TSS/acid ratio and pH increased. The TSS/acid ratio and pH increased with a reduction in acidity.

The results (Table 7-8) indicate that the main effect of curing and the interactions between curing and sealed packaging and curing and damage on weight loss and juice percentage were not significant (p=0.05). The main effect of damage on weight loss and juice percentage was that all the damaged fruit lost more weight and had lower juice percentage values

Table 6: The effects of damage caused by compression and scuffing methods and sealed packaging in 120 gauge polyethylene film bags on the quality of Satsuma mandarins after curing for 48 hours at 35°C with 95% RH and subsequent storage for 32 days at 5°C with 90% RH

Treatments	Sealed in Polyethylene Film			Without Polyethylene Film			LSD (p=0.05)
	Undamaged	Compression damage	Scuffing damage	Undamaged	Compression damage	Scuffing damage	
Weight loss (%)	0.97	1.17	1.40	3.84	5.74	6.15	0.49
Firmness (Nmm^{-1})	4.57	4.33	4.20	3.60	3.33	2.90	0.39
TSS (%)	13.58	13.74	13.61	13.21	13.09	12.94	N.S
Acidity (%)	0.58	0.57	0.56	0.51	0.50	0.49	0.04
TSS/acid ratio	23.88	24.11	24.30	25.90	26.18	26.41	0.53
pH	4.37	4.40	4.46	4.62	4.66	4.73	0.13

N.S = non significantly different (p=0.05)

Table 7: Effect of damage (caused by pendulum, compression and scuffing methods) and sealed packaging of sweet oranges in 120 gauge polyethylene film bags on their fruit quality after curing for 48 hours at 35°C with 95% RH and subsequent storage at 5°C with 90% RH for 46 days or storage for 48 days at 5°C with 90% RH. Figures are the mean of two curing and non-curing treatments since the main effect of curing was not significant (p=0.05)

Treatments	Sealed in Polyethylene Film				Without Polyethylene Film				LSD (p=0.05)
	Undamaged	Pendulum damage	Compression damage	Scuffing damage	Undamaged	Pendulum damage	Compression damage	Scuffing damage	
Weight loss % (g)	0.93	1.09	1.16	1.25	4.57	5.92	6.06	6.25	0.36
Juice (%)	41.77	41.64	41.59	41.49	39.96	39.21	39.12	38.98	0.38
Deformation (mm) at 5 N.	0.91	1.01	1.09	1.17	1.71	2.13	2.19	2.35	0.28
Deformation (mm) at skin failure	4.00	4.11	4.20	4.25	5.48	5.98	6.11	6.20	0.31
Firmness (Nmm^{-1})	7.00	6.97	6.93	6.87	6.42	6.12	6.10	6.05	0.18
TSS (%)	11.82	11.74	11.63	11.51	11.07	10.98	10.86	10.76	0.40
Acidity (%)	0.69	0.68	0.67	0.66	0.59	0.58	0.57	0.56	0.04
TSS/acid ratio	17.25	17.38	17.48	17.56	18.91	19.09	19.09	19.32	0.59
pH	3.69	3.72	3.75	3.79	4.13	4.17	4.17	4.27	0.19

Table 8: Effect of damage (caused by pendulum, compression and scuffing methods) and sealed packaging of Clementine mandarins in 120 gauge polyethylene film bags on their fruit quality after curing for 48 hours at 35°C with 95% RH and subsequent storage at 5°C with 90% RH for 46 days or storage for 48 days at 5°C with 90% RH. Figures are the mean of two curing non-curing treatments since the main effect of curing was not significant (p=0.05)

Treatments	Sealed in Polyethylene Film				Without Polyethylene Film				LSD (p=0.05)
	Undamaged	Pendulum damage	Compression damage	Scuffing damage	Undamaged	Pendulum damage	Compression damage	Scuffing damage	
Weight loss % (g)	1.17	1.35	1.39	1.52	5.57	6.90	7.07	7.24	0.37
Juice (%)	51.40	51.22	51.20	51.13	49.01	48.28	48.14	47.93	0.39
Deformation (mm) at 5 N.	0.96	1.10	1.16	1.22	1.65	2.13	2.21	2.42	0.31
Deformation (mm) at skin failure	3.86	3.96	4.10	4.14	5.66	6.18	6.25	6.40	0.30
Firmness (Nmm^{-1})	5.20	5.16	5.12	5.06	4.61	4.31	4.29	4.24	0.17
TSS (%)	12.32	12.23	12.11	11.98	11.51	11.41	11.28	11.24	0.35
Acidity (%)	0.86	0.85	0.84	0.83	0.72	0.70	0.68	0.66	0.08
TSS/acid ratio	14.40	14.46	14.49	14.51	16.09	16.42	16.71	16.99	0.93
pH	3.44	3.48	3.52	3.57	3.94	3.99	4.05	4.12	0.24

than control but there were no significant differences between different methods of damaging fruits at the (p=0.05).

The significant interaction between damage and sealed packaging was that for sealed fruit there were no significant differences between damage levels but for fruits which were not wrapped those which had been damaged had higher weight and juice percentage losses than those which had not been damaged.

The effect of curing all the three species of citrus fruit in polyethylene film bags was to reduce the effect of damage on the fruit. Scuffing generally had the most extreme effect on the fruit which can be seen from the weight loss data (Table 7-8).

Transpiration is the major process leading to weight loss and this was due to moisture loss, which correlated with weight loss and damage of the fruit. In unwrapped damaged and undamaged fruit weight loss was higher and juice percentage was lower than in sealed undamaged and damaged fruit. This happened because the unwrapped damaged and undamaged fruit exhibited a higher rate of transpiration and evaporation which resulted in decreased weight and juice percentage due to loss of moisture. Weight loss was also observed in sealed undamaged and damaged fruit but this was not too high due to sealed packaging, which reduced the loss of moisture from fruit surface and produced the water-saturated atmospheres and reduced respiration rate. It is possible that the major requirement for extending the postharvest life of citrus fruit is to slow down transpiration (Ben-Yehoshua, 1985). Weight loss after 15 days storage at 20°C with 70% (RH) was lower in seal packaging than those stored unwrapped (Martinez-Javega *et al*., 1991). Curing of non-sealed fruits was less effective than curing sealed fruit and caused prohibitive weight loss (Ben-Yehoshua *et al*., 1987).

The sealed cured fruit maintained the initial deformation and firmness while unwrapped damaged and undamaged cured and non-cured fruits became softer. In seal packaging the evaporation/transpiration decreased and the moisture of the fruit was preserved which is a prerequisite for fruit firmness. On the other hand the respiration and moisture loss of non-sealed fruits increased and fruits became softer and firmness

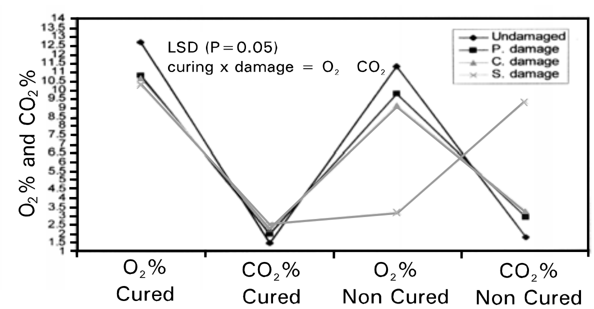

Fig. 1: Effect of curing and sealed packaging of Sweet oranges in 120 gauge polyethylene film bags on their O_2 and CO_2 after curing for 48 hours at 35°C with 90% RH and subsequent storage at 5°C with 90% RH for 42 days or storage for 44 days at 5°C with 90% RH

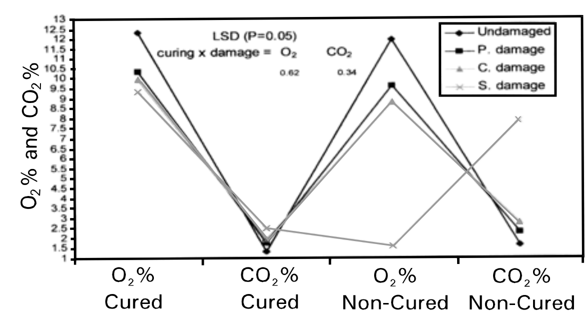

Fig. 2: Effect of curing and sealed packaging of Clementine mandarins in 120 gauge polyethylene film bags on their O_2 and CO_2 after curing for 48 hours at 35°C with 90% RH and subsequent storage at 5°C with 90% RH for 42 days or storage for 44 days at 5°C with 90% RH

reduced. Softening and subsequent deformation of the fruit may increase due to increase in soluble pectins and pectinates. Carefully handled grapefruit during storage were more resistant to deformation than roughly handled fruit (Rivero *et al*., 1979). The control fruits (oranges) were the softest, while seal packaged fruit exhibited the best firmness (Martinez-Javega *et al*., 1991).

Sealed and non-sealed fruits showed significant results for TSS, acidity, TSS/acid ratio and pH. Sealed fruits had higher TSS and acidity. The TSS and acidity of unwrapped fruit may be reduced due to the higher respiration rate where organic acids may be utilized as respiratory substrates/ for energy production. The reduction in acidity was mainly due to a decrease in citric acid content (Kawada and Kitagawa, 1986). Seal packaging had no effect on TSS/acid ratio (Martinez-Javega *et al*., 1991). Acidity and ascorbic acid content of sweet oranges was shown to decrease during storage (Chattopadhyay *et al*., 1992).

The different effects which seal packaging and curing had on gas exchange were that the curing of sealed damaged and undamaged fruit bags had higher O_2 and lower CO_2 than non-cured sealed damaged and undamaged fruit bags. Higher O_2 and the lower CO_2 concentrations were found in undamaged, cured and non-cured fruit bags than in damaged, cured and non-cured fruit bags where the O_2 levels were lower and CO_2 levels were higher than those in undamaged fruit bags. Where the fruits were damaged with pendulum and compression method, the O_2 levels were higher and CO_2 levels were lower in sealed non-cured and cured fruit bags than in fruit damaged by scuffing.

The tissues of the non-cured fruits remained softer and took more O_2 and evolved more CO_2 than cured fruits where the tissues of the fruits remained firmer and reduced respiration. In scuffing damage the CO_2 concentrations of non-cured fruit bags rose and that of O_2 declined compared to cured fruits. The CO_2 reached around 10% and O_2 declined by around 2%. This atmosphere may be toxic to citrus fruits. The CO_2 production by scuffing damaged fruit clearly increased as increased symptoms of the disorder occurred on the fruit peel of non-cured fruit. The CA conditions for maintaining quality in citrus fruits appear to be about 0 to 1 percent CO_2 and 10-15% percent O_2 (Oogaki and Manago, 1977). Respiration of oranges was reported to be a function of O_2 tension in the range of 0-8% O_2 with anaerobic reactions occurring below 2.5% O_2 (Biale, 1961).

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