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CHARACTERIZATION OF CHILLING INJURY IN SELECTED FRUITS

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Three separate experiments were conducted on citrus, banana and mango to characterize the physiological responses of these fruits to chilling temperatures and to correlate these changes with subjective evaluations of chilling injury. Subjective evaluations of CI coincided with measurements of CO_2 and C_2H_4 concentrations and were too late to determine incipient incidence of CI in order to effect corrective treatment. Low bioelectrical resistance and high electrolyte leakage were more sensitive indicators of CI revealing changes in membranae permeability prior to the initiation of visible symptom expression.

INTRODUCTION

Chilling injury (CI) is the physiological damage that is induced in tissues when they are exposed to low but nonfreezing temperatures. Most fruits of tropical and subtropical origin are sensitive to chilling injury. Internal symptoms of CI such as leakage of ions across membranes, changes in membrane fluidity, cessation of cytoplasmic streaming and inhibition of electron transport (LYONS, 1973) lead to the visible CI symptoms of pitting, discolouration, off-flavour, tissue breakdown, and invasion by postharvest pathogens (SALTVEIT and MORRIS, 1990, WANG, 1982). The detecttion and description of CI symptoms in many harvested fruits indigenous to the tropics have been subjective and qualitative using a variety of criteria. Invariably, visual symptoms have been described after single storage periods at various temperatures (CHAN et. *al.* 1985) which fail to reveal the development of CI symptoms that multiple storage periods might highlight. Accordingly, the visual symptoms of CI usually are apparent only after exposure to ripening temperatures and impart little insight into the biochemical mechanisms of CI. The minimum time-temperature combination that induces CI has not been clearly identified in several tropical fruits.

The objectives of this study wers to characterize the physiological responses of grapefruit, tangerine, banana and mango to chilling temperatures, and to correlate these changes with subjective evaluations of CI in those fruits.

MATERIALS AND METHODS

The following fruits were used in this study:

- Experiment 1: Marsh grapefruit and tangerine, cv. Dancy
- Experiment 2: Lacatan and Gros Michel bananas and
- Experiment 3: Mango cultivars Julie and Sensation.

For each experiment fruits were obtained from orchards directly. Samples of fruit of uniform size and appearance, originating in one orchard were subjected to various treatments at random. All fruits, received the conventional initial treatment, consisting of a detergent wash-bath disinfection by immersion for 3 minutes in sodium hypochlorite solution (59 litres) at 30-32°C, rinsed and then air dried for 30-40 minutes with an oscillating fan.

Experiment 1 was 3 x 2 factorial design consisting of three packages - high density polyethylene (HDPE, 0.025 _ thick), low density polyethylene (LDPE O.O25 mm thick) and non-sealed control in paper bags; three temperatures 8-lO°C, 20-22°C and 30-32°C, and two cultivars of citrus. For each treatment 3 fruits were placed in a bag. The fruits placed in HDPE and LDPE bags were sealed. The experiment was a completely randomized design with three replicates. Evaluations on marketable quality, chilling injury, fresh weight losses, flavour, pH, total titratable acidity, total soluble solids, total titratable acidity ratio were taken after 10, 20, 30 and 40 days at all three storage temperatures according to the methods previously described by BEN-YEHOSHUA (1978).

In **Experiment 2**, mature-green, Lacatan and Gros Michel bananas were stored In sealed LDPE bags with or without an ethylene absorbent. The ethylene absorbent was made by using an inert carrier perlite impregnated with potassium permaganate as described by LIU (1978). Fruits were also stored in unsealed paper bags which made up the control. Treatments were held at 8-10°, 20-22° and 28-30°C respectively in separate storage rooms. Evaluations were taken at 3 day intervals up to 12 days. Parameters investigated included those mentioned for Experiment 1 in addition to inpackage CO_2 and C_2H_4 concentrations as described by XADER (1985)

Experiment 3 consisted of mature-green sensation and Julie mangoes individually wrapped in paper bags and stored at 5-7°C. Fruits were evaluated for CI electrolyte leakage and bioelectrical resistance according to methods described by MOHAMMED *et al.* (1992).

RESULTS AND DISCUSSION

Experiment 1: The significant (P<0.05) reduction in visible symptoms of CI in grapefruit and tangerine that were stored in sealed HDPE and LDPE bags compared with the control in paper bags could be attributed to the water saturated microatmosphere in the sealed enclosure around the fruit over the 40 days at 8-10°C (Table 1). These findings are in agreement with similar investigations reported by BEN-YEHOSHUA (1978). The apparent advantage of storing fruits over the longer duration in HDPE versus LDPE bags as indicated by the lower incidence of CI (Table 1) confirmed previous reports by BEN-YEHOSHUA (1978) and MOHAMMED and SEALY (1986) that HDPR probably has more suitable permeation properties than LDPE which allowed restricted but balanced metabolism of the fruits.

The significant (P<0.005) reduction in percentage fresh weight losses induced by sealing fruits in polyethylene bags as against the control accounted for superior ratings of marketable quality of sealed versus unsealed fruits which paralled the scores obtained for lower CI in Table 1. Thus CI of fruits in paper bags was characterised by the appearance of brown pits on the rind with discrete depressed areas being several mm across and sometimes surrounded by a diffuse brown halo. These findings were consistent with previous studies reported by

WRIGHT and SIMON (1973), STEWARD and GUINN (1969) ZHOLKETVITCH *et.al.* (1962) and SELLSCHOP and SALMON (1928) that water deficit is an essential prerequisite for chilling response.

Ratings obtained for flavour retention revealed that grapefruit and tangerine in sealed LDPE and HDPE bags were higher than fruits in paper bags after 40 days at 8-10°C (Table 2). The non-detection of off-flavours in sealed bags meant that low temperature modified atmosphere packaging effectively slowed down respiration without the initiation of anaerobic respiration during the 40 day period. Chemical analyses of pH, total titratable acidity, total soluble solids and TSS/TTA ratio supported the above results (Table 3).

Experiment 2 : The data shown in Figure 1 and Table 4 indicated that bananas (Lacatan and Gros Michel) stored in sealed LDPE bags with an ethylene absorbent were effective in reducing the development of CI compared to LDPE bags minus the ethylene absorbent. The above results are therefore in agreement with CHAPLIN *et. al.* (1983) on their studies on avocado which demonstrated that the accumulation of C_2H_4 conferred on additive effect in enhancing CI. CI on samples sealed in LDPR without the ethylene absorbent and more so those stored in paper bags were characterised by fruits having dark water soaked areas on the peel. Evidence of under-peel discolouration visible on streaks in a longitudinal cut or as a ring of brown dots in transverse section through a finger was dominant on the control fruits. The skin of these fruits eventually turned black with the pulp having an off-taste.

While measurements of CO_2 concentrations in sealed bags with or without an ethylene absorbent showed a progressive increase in CO_2 with time (Table 5), significant increases ($P<0.05$) in CO_2 concentration only took place after 6 days at 8-10°C. When extrapolated against the data shown in figure 1, it is seen that increases in CO_2 concentrations actually coincided with the appearance of visible CI symptoms. Further investigations were therefore warranted to obtain an objective method of determining CI before terminal symptoms were manifested.

Experiment 3 : The data in Table 6 supported MOHAMMED *et. al.* (1992) that low bioelectrical resistance and high electrolyte were suitable indices of membrane permeability and could be used to determine the onset of CI prior to the appearance of visible symptoms. It was also shown that mango cultivars vary in their sensitivity to CI with the cultivar Julie being more susceptible to CI than the cultivar Sensation. The cultivar Julie showed CI symptoms after 5 days at 5-7°C which become more evident after subsequent storage intervals. CI was characterised by the skin having brown blotches accompanied with a grayish discolouration and pitting and a marked increase in susceptibility to decay.

The data from the three experiments showed that although terminal symptoms of CI and disease incidence are easily recognisable, the incipient incidence of these disorders are often not recognisable in time to effect corrective treatment. In view of this, subjective evidence of CI is elusive and the need to correlate such data with more precise objective measurements such as bioelectrical resistance and electrolyte leakage is warranted.

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Table 1 : effect of packaging upon CI in grapefruit and tangerine

Fruit type	Days in storage at 8-10°C					
	30 Days			40 Day		
	HDPE	LDPE	CONTROL	LDPE	HDPE	CONTROL
Grapefruit	1 0a	1.2a	1.9b	1.0a	1.7b	2.8c
Tangerinee	1.Oa	1.3a	3.4c	1.2a	1.6b	4.0d

C.I = 1-4, 1 = NO C.I, 4 = SEVERE C.I

Table 2 : effect of packaging upon fresh wt. losses; marketable quality and flavour in grapefruit (a) and tangerine (b), after 40 days at 8-10°c

Parameters	After 40 days at 8-10°C					
	HDPE		LDPE		CONTROL	
	A	B	A	B	A	B
Fresh wt. losses (%)	1.6a	1.6a	1.6a	1.9a	22 1b	25.4c
Marketable quality	2.0a	2.9b	2.8b	2.7b	3.4c	4.0d
Flavour	1.0a	2.1b	1 2a	2.7c	2.2b	3.6d

Marketable quality 1-4 with 1 : excellent, 4 = poor.
Flavour 1-4 with 1 = No off-flavour, 4 = unacceptable flavour

Table 3 : effect of packaging upon pH, T.T.A, T.S.S and TTA/TSS after 40 days at 8-10°C in grapefruit and tangerine

After 40 days at 8-10° C					
Fruit type	package	pH	TTA (mg c./ 100f..wt^{-1}	TSS(%)	TTA/TTSS
Grapefruit	HDPE	3.10a	1.03b	9.78b	9.44a
	LDPE	3.35bc	1.19c	11.29c	9.49a
	CONTROL	3.38bc	1.01bc	10.64b	10.53b
Tangerine	HDPE	3.28ab	0.74b	10.00b	13.50d
	LDPE	3.36bc	0.60a	9.83a	16.38e
	CONTROL	3.40c	0.95b	10.72b	11.28c

Table 4 : effect of packaging with and without C_2H_4 absorbent (e.a) upon in-package C_2H_4 and C.I in bananas.

	Days in storage at 10°C			
	9 DAYS		12 DAYS	
Parameter	LDPE + E.A	LDPE - E.A	LDPE + E.A	LDPE - E.A
C2H4 (PPM)	0.00a	0.41b	0.10a	0.62cd
C.I	2.2a	2.8b	2.6ab	3.4c

Table 5: effect of packaging upon in-package $C0_2$ conc. in bananas after 12 days at 8-10°C

	C02 conc.(%) aat 8-10°C			
Packagee	3 days	6 days	9 days	12 days
LDPE + E.A	0.34bc	0.51cd	0.66de	0.98f
LDPE - E.A	0.32bc	0.52cd	0.80ef	1.04f
CONTROL	0.40a	0.03a	0.04a	0.04a