crose was decreased. These cycles of proline and sugars in grapefruit trees subjected to cool and warm temperatures suggest that the fruit were in cold-acclimated, deacclimated, and cold-acclimated states, respectively. However, the fruit were tested for CI only at the end of the experiment.

Although this study does not prove that lipids play a role in preventing or reducing CI, various lipid changes (e.g., major differences in linoleic acid levels in phosphatidyl choline and phosphatidyl ethanolamine), with cold hardening indicate membrane lipids are involved. Thus, it is suspected that lipids play a different role in preventing CI of fruit than in protecting the whole plant from freeze damage.

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Effect of Postharvest Heat Treatment and Storage on Sugar Metabolism in Polyethylene-wrapped Muskmelon Fruit

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Additional index words. *Cucumis melo*, muskmelon, carbohydrates, sucrose-phosphate synthase, sucrose synthase, invertase

Abstract. **Postharvest sugar content and activities of four enzymes of sucrose metabolism were followed in the edible mesocarp tissue of the netted muskmelon (*Cucumis melo* L., var. *reticulatus*, cv Magnum 45). Melons harvested at full-slip were shrink film-wrapped to inhibit water loss and/or heated to 45°C for 3 hr before storage at 4°C for up to 18 days. Sucrose content of edible mesocarp remained constant between harvest and 12 days of storage. The sucrose content of nonheated fruit declined between 12 and 18 days of storage, but there was no coincident increase in glucose or fructose. There was little acid invertase activity. Neutral invertase activity did not vary significantly with storage, but was slightly higher in heated, wrapped fruit than in nonheated, wrapped fruit. Sucrose synthase activity increased with storage, and was higher in heated than nonheated fruit. There was no discernible pattern of sucrose–phosphate synthase activity. No enzyme activity was correlated with the content of any sugar.**

Sugar content is an important aspect of fruit quality in netted muskmelon. The soluble solids content (4, 12, 13) and sweetness or sugar complement (1, 2) of muskmelon fruit have been the object of several investigations. Most authors have reported decreases in sugar and/or soluble solids after harvest (3, 11, 12); others have shown that sucrose content increases or does not change after harvest (7, 10). These discrepancies may be the result of differences in cultivar, maturity at harvest, or postharvest storage conditions. Little is known about sugar metabolism during postharvest storage of the fruit.

Water loss during storage has been identified as a possible factor influencing storage life of netted muskmelon fruit (6). High temperatures during harvest also can have a detrimental effect on storage life (5), possibly mediated through water loss induced by high temperatures. To separate the effect of water loss and high temperature on sugar metabolism in muskmelon fruit, fruit of the netted muskmelon ('Magnum 45') were shrink-wrapped with 12.7 μm Clysar 50-EHC-F film (E.I. DuPont de Nemours, Wilmington, Dela.) and subjected to heat treatment prior to storage at 4°C. Clysar shrink-film has a permeability of 1.82×10^{-4} liters·$(m^2)^{-1}$·s^{-1} and 4.56×10^{-7} kg·$(m^2)^{-1}$·s^1 for 0_2 and H_20, respectively.

Muskmelon fruit were harvested at full-slip from a commercial field at Weslaco, Texas, in May 1986. The experiment was designed as a 2 × 2 × 4 factorial with three replications (melons) per treatment. There were two wrap treatments (wrapped vs. not wrapped), followed by two heat treatments (no heat and 3 hr at 45°C, 100% RH), and four storage times (0, 6, 12, and 18 days at 4°, 90% RH).

Four cylinders of tissue 2.5 cm long were taken from the equatorial region of each melon using a 1.9-cm-diameter cork borer. These cylinders represented tissue from all sides of the melon. The outer 0.5 cm was discarded, and the inner edible mesocarp tissue was bulked, weighed, and frozen at −80°C until

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Table 1. Mean squares for sucrose (Suc), glucose (Glc), and fructose (Fru) contents and activities of acid invertase (Acid), neutral invertase (Neut.), sucrose-phosphate synthase (SPS), and sucrose synthase (SS) as affected by wrapping, heating, and storage treatments.

Source of variation	df	Mean squares							Error term
		Suc	Glc	Fru	Acid	Neut.	SPS	SS	
Wrap (W)	1	52.73	12.85	0.25	0.07	1.47	1.76	1.12	W x S
Heat (H)	1	22.40	42.83*	0.60	0.02	1.29**	2.95	2.85	H x S
W x H	1	2.11	62.33	13.58	0.00	0.93	0.34	0.10	W x H x S
Store (S)	3	109.07*	22.85**	21.06**	0.06**	0.69	15.62**	1.69**	Error
W x S	3	5.73	2.64	7.70	0.02	4.45**	4.21	0.69*	Error
H x S	3	162.62*	3.94	1.40	0.06*	0.07	3.95	0.21	Error
W x H x S	3	15.97	18.95**	3.64	0.02	0.18	3.34	0.35	Error
Error	32	37.48	2.15	2.76	0.01	0.48	1.76	0.18	

*,**Significant at the 5% and 1% levels, respectively.

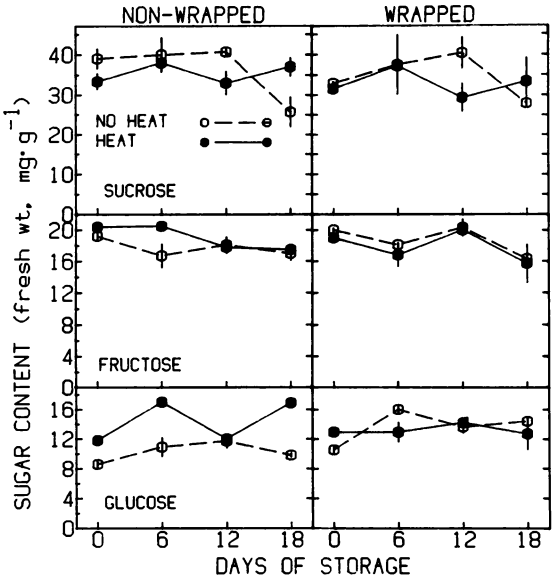

Fig. 1. Sucrose, glucose, and fructose content of mesocarp tissue of 'Magnum 45' muskmelon fruit shrink-wrapped and/or heated to 45°C for 3 hr prior to storage at 4°. Bars represent ± SE.

needed for sugar analysis. Four additional samples were taken for enzyme analysis. Extraction of tissue and assay of sugars and enzymes were performed as described by Lingle and Dunlap (9).

After 18 days of storage, all nonwrapped fruit were soft but still marketable. Nonheated fruit had lost 4.3% of their moisture. Prestorage heating to 45°C accelerated water loss; after 18 days of storage, nonwrapped, heated fruit had lost 5.1% moisture (G.E.L., unpublished data). Wrapping with polyethylene film inhibited the water lost to 0.8% after 18 days of storage.

The data were analyzed by analysis of variance using a mixed model, with the wrap and heat treatments as fixed effects and the storage treatment as a random effect. The mean squares from this analysis are presented in Table 1. Storage was a significant factor for all variables except neutral invertase activity. Heat treatment was significant for glucose content and the activities of neutral invertase and sucrose synthase. By itself, wrapping did not have a significant effect on any variable.

Sucrose is the major free sugar found in the mesocarp of mature netted muskmelon fruit (2, 8, 10). Sucrose content has been variously reported as increasing after harvest at the expense of glucose and fructose (8), and remaining constant, with decreases in glucose and fructose (2, 10). In the present study, the sucrose content of nonwrapped, nonheated fruit declined between 12 and 18 days of storage at 4°C (Fig. 1). Wrapping nonheated fruit did not prevent this decline, suggesting that water loss during storage did not induce the loss of sucrose. However, heating the fruit prior to storage inhibited the decline in sucrose content at the end of the storage period. Thus, it appears that some of the processes responsible for sucrose degradation in the mesocarp may have been heat-sensitive.

There are three classes of enzymes known to be involved in the direct metabolism of sucrose in plant tissue (5): invertase, sucrose synthase, and sucrose-phosphate synthase (SPS). The two forms of invertase, acid and neutral, and sucrose synthase are primarily cleavage enzymes. SPS synthesizes sucrose.

Acid invertase activity in the mesocarp of all fruit in this study was very low (0.24 ± 0.15 μmol sucrose cleaved per gram fresh wt per hour), and the data are not presented here. Acid invertase activity is high in very young fruit, but declines prior to maturation (9). The lack of significant increase in the activity of this enzyme during storage indicates that it was not responsible for the decline in sucrose content in unheated fruit (Fig. 1). There was no significant correlation between acid invertase activity and sucrose content in this experiment (Table 2).

The activity of neutral invertase (Fig. 2) was not consistently influenced by storage. There was a significant interaction between the effects of wrapping and storage (Table 1), which makes interpretation of the data difficult. However, the activity of neutral invertase was not correlated with the content of any sugar in this experiment (Table 2). Therefore, neutral invertase did not appear to play a large role in sucrose metabolism under the conditions of this experiment.

Sucrose synthase activity in mesocarp tissue of wrapped and nonwrapped, nonheated fruit increased gradually during storage (Fig. 2). In nonwrapped, heated fruit, sucrose synthase activity increased between 6 and 18 days of storage, and in wrapped, heated fruit this activity increased between 0 and 6 days of storage. Although these increases in activity suggest a role for sucrose synthase in the loss of sucrose from nonheated fruit between 12 and 18 days of storage (Fig. 1), activity of this enzyme was not inhibited in heated fruit. Also, activity of sucrose synthase was not correlated with the content of any sugar (Table 2).

Storage was a main effect for SPS activity (Table 1). Although there was no significant change in SPS activity in nonwrapped, nonheated fruit (Fig. 2), there was a decline in SPS in nonwrapped, heated fruit between 6 to 12 days of storage, in wrapped, nonheated fruit between 0 and 18 days of storage, and in wrapped, heated fruit between 6 and 12 days of storage.

There are several possible explanations for the lack of correlation between the activity of the enzymes assayed and the content of any sugar in the mesocarp of muskmelon during storage (Table 2). There can be major differences between in vitro activity and in vivo activity, since enzymes are assayed in vitro under optimum conditions, while many factors such as compartmentation and metabolite levels control activity in vivo. Enzyme activities at 4°C presumably would be very slow, so that changes in the levels of sugars influenced by those enzymes also

Table 2. Correlation coefficients across all treatments of sucrose (Suc), glucose (Glc), and fructose (Fru) content and activities of acid invertase (Acid), neutral invertase (Neut.), sucrose-phosphate synthase (SPS), and sucrose synthase (SS) in mesocarp tissue of 'Magnum 45' muskmelon fruit.

	Variable					
Variable	Neut.	SPS	SS	Suc	Glc	Fru
Acid	0.547**	0.217	0.258	−0.078	0.074	−0.024
Neutral		−0.137	−0.052	−0.208	−0.042	−0.089
SPS			−0.395**	0.120	−0.143	0.093
SS				−0.022	0.198	−0.250
Suc					0.211	0.381*
Glc						0.314*

*,**Significance is indicated at the 5% or 1% levels, respectively.

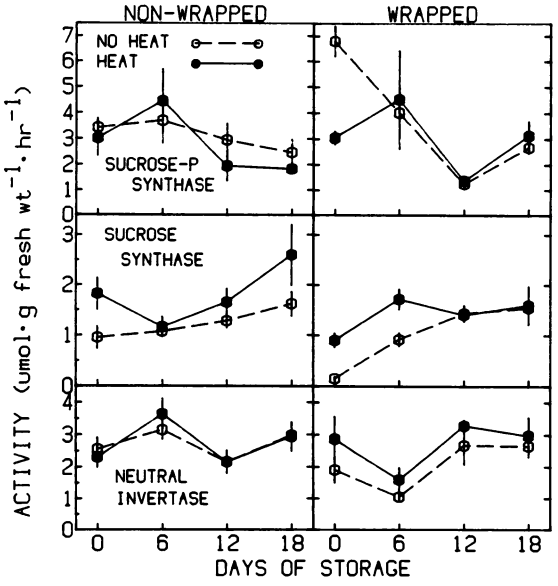

Fig. 2. Activity of neutral invertase (neutral), sucrose-phosphate synthase (SPS), and sucrose synthase (SS) in mesocarp tissue in 'Magnum 45' muskmelon fruit shrink-wrapped and/or heated to 45°C for 3 hr prior to storage at 4°. Bars represent ± SE. Activity of acid invertase was low and not reported here.

would be very slow. Additionally, changes in sugars, such as the decline in sucrose content in nonheated fruit between 12 and 18 days of storage, may be more directly related to changes in other metabolic pathways such as respiration.

Heat and storage had the greatest effect on sugar content in the mesocarp tissue of 'Magnum 45' muskmelon fruit. Water loss does not seem to play a role in controlling the sugar content of the fruit. Both heat treatment and storage caused increased electrolyte leakage from the hypodermis (G.E.L., unpublished data), suggesting disruption of cellular membranes. Such disruption in vivo would be expected to have a major effect on cellular activity, but it is uncertain how deep into the tissue the increased leakage was manifested. It is unlikely that activities of sensitive enzymes, such as SPS, would persist in the event of cellular disruption. It seems more likely that the effects of heat and storage may have been induced by some other factor, as yet undetermined.

Although wrapping muskmelon fruit with polyethylene film maintains the appearance of the fruit during storage (7), wrapping did not prevent a small loss of sucrose in the mesocarp between 12 and 18 days of storage at 4°C. This loss was apparently not directly attributable to the action of sucrose-metabolizing enzymes. The detrimental effects of high temperatures on melon quality were not manifested when the fruit were stored at 4°.

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