RESPIRATION AND CHEMICAL CHANGES OF THE PAPAYA FRUIT IN RELATION TO TEMPERATURE[1]

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(WITH TWO FIGURES)

Since the modification of the quarantine laws (**11**) to permit the shipment of fresh fruit from Hawaii to Pacific coast markets and the adaptation of the quarantine treatments to the papaya (**4, 5, 6, 7**) the problem of delivering high-quality fruit to these markets now depends largely on the proper storage temperature. It has been established (**8**) that a temperature below 50° F. "chills" the papaya after which the fruit will not ripen normally. There has been very little work on the nature of this chill effect, work on the cold storage of the papaya having been confined largely to a study of the proper temperature to apply during transportation. STAMBAUGH (**9**) found that unripe papayas would not ripen after any appreciable time below a temperature of 60° F., while JONES and KUBOTA (**8**) showed that a temperature of 32° to 34° F. for a period of 11 days prevents ripening and that the fruits quickly decay at room temperature. This decay is largely initiated by a latent infection of anthracnose (**7**). WARDLAW *et al.* (**12**) pointed out that the natural resistance of the fruit to the development of latent infection is destroyed by "chill" and by certain chemical treatments. The present paper deals with the nature of the "chill effect" as revealed by the respiratory activity and chemical changes at various temperatures.

Materials and methods

The fruits used in this study were all of the Solo variety and were harvested firm-ripe as needed. Each treatment was run in duplicate at least twice and in some cases four times using 12 fruits for each treatment. The storage temperatures used were 40°, 45°, 50°, 55°, and 60° F. (maintained ± 1° F.) for the 5-day storage period. The 5-day storage period was selected as being equivalent to the time required for the fruit to reach Pacific coast markets from Honolulu. The fruits used for chemical studies were treated as follows: (1) Analyzed immediately after harvest; (2) allowed to ripen at room temperature; (3) held 5 days at a specified temperature; and (4) held 5 days in cold storage and then allowed to ripen at room temperature or until the fruit from the low temperature first showed signs of decay.

Methods of analysis were standard. Sugars were determined by the method of STILES, PETERSON, and FRED (**10**). Soluble pectin was determined

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by precipitation with $CaCl_2$ of a cold water extract (7 extractions) of the finely ground residue from an alcoholic extraction. Carbon dioxide was found by absorption in LiOH and, after precipitation of the bi-carbonates and carbonates with $BaCl_2$, titration of the excess alkali with 0.1 N HCl to phenolphthalein.

Results and discussion

Respiration in relation to temperature

Work on the storage of the papaya has shown that the critical temperature lies slightly below 50° F. This is shown more clearly in figures 1 and 2.

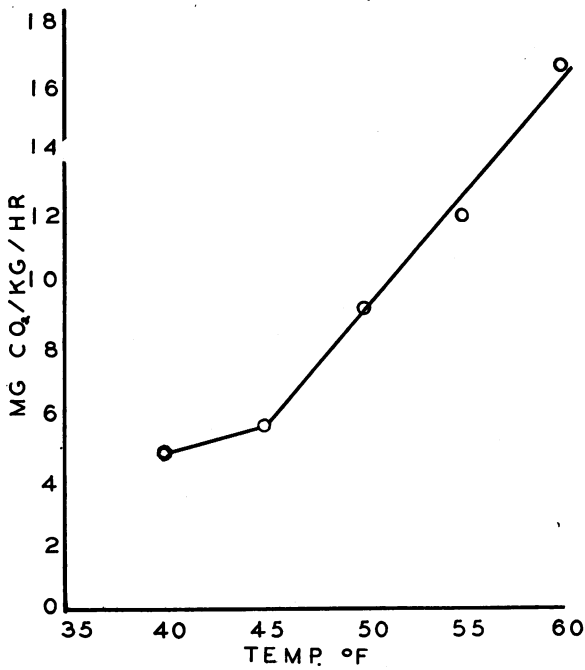

Fig. 1. The influence of temperature on carbon dioxide production of papaya fruit.

The production of carbon dioxide in milligrams per kilogram of fruit at the different temperatures was as follows: 40° F. – 4.8; 45° F. – 5.5; 50° F. – 9.0; 55° F. – 12.0; 60° F. – 16.0. The temperature coefficient over the same temperature range was 1.5 between 40° and 45° F., 3.3 between 45° and 50° F., 2.2 between 50° and 55° F., and 2.2 between 55° and 60° F. This does not agree with the findings by Haller *et al.* (**2**) for strawberries, peaches, lemons, oranges, and grapefruit in which they report a higher Q_{10} for the lower temperature range. Thus there is a marked break in the nature of the processes having to do with the production of carbon dioxide in the papaya between the temperatures of 45° and 50° F. The critical

nature of the temperature between these two points is further shown in the chemical changes as will be discussed later, and in the ripening of the fruit after a period at this temperature. On removal to room temperature after 5 days at 45° F. the papaya fruits ripen unevenly, with poor quality, and are subject to the development of anthracnose, while after a like storage period at 50° F. the fruits ripen evenly, with high quality and no decay.

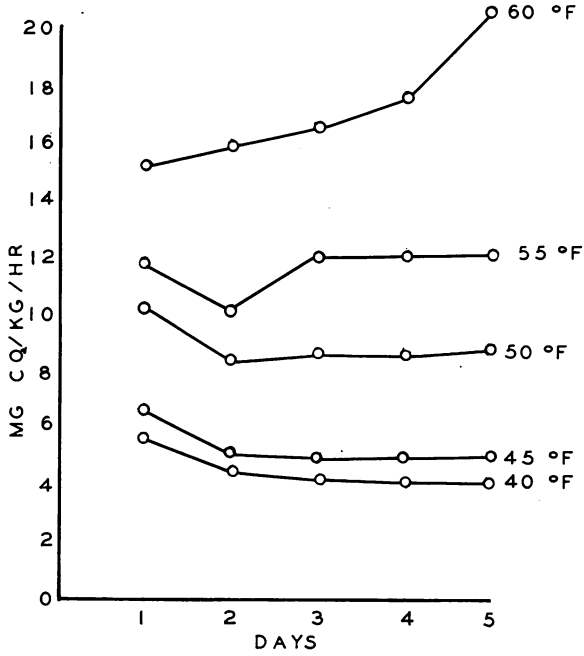

FIG. 2. Carbon dioxide production of papaya fruit for a period of five days at the temperatures indicated.

CHANGES IN CHEMICAL COMPOSITION IN RELATION TO TEMPERATURE

It has been shown (**8**) that the most marked changes in chemical composition during ripening of the papaya are the reducing sugar-sucrose relations, a reduction in structural materials (acid hydrolyzable materials), and an increase in soluble solids. Further, a temperature of 32° to 34° F. stops these changes and they are not resumed on removal to room temperature. Table I shows the chemical changes occurring during storage over the temperature range of 40 to 60° F. and during subsequent ripening.

An examination of table I shows that there is very little hydrolysis of sucrose during storage at the lower temperatures and on removal to room temperature the hydrolysis of the sucrose does not proceed as far in the chilled fruit as in the check fruit. At the higher temperatures (50° F. and above) there is a slow hydrolysis of sucrose. This hydrolysis is continued

TABLE I

CHANGES IN COMPOSITION OF THE PAPAYA FRUIT DURING STORAGE AND SUBSEQUENT RIPENING. PERCENTAGE OF FRESH WEIGHT

STORAGE TEMPERATURE	FRUIT TREATMENT	SOLUBLE SOLIDS	INSOLUBLE SOLIDS	REDUCING SUGAR	SUCROSE	TOTAL SUGAR	SOLUBLE PECTIN*	ACID HYDROLYZABLE
°F.		%	%	%	%	%	%	%
	Analyzed immediately	10.01	2.97	4.77	2.95	7.72	0.49	0.64
	Ripened at room temperature	10.22	2.52	7.21	0.76	7.97	0.58	0.52
40°	5 days at 40° F.	10.05	2.76	5.71	2.20	7.91	0.47	0.67
	5 days at 40° F. ripened at room temperature	10.82	3.09	7.52	1.46	8.98	0.65	0.65
	Analyzed immediately	11.34	2.82	6.16	3.40	9.56	0.46	0.72
	Ripened at room temperature	11.62	2.89	8.54	1.09	9.63	0.65	0.63
45°	5 days at 45° F.	12.08	3.00	5.46	4.65	10.11	0.49	0.82
	5 days at 45° F. ripened at room temperature	12.15	2.87	7.84	1.92	9.76	0.62	0.69
	Analyzed immediately	9.25	2.41	4.88	2.34	7.22	0.35	0.66
	Ripened at room temperature	9.65	2.77	6.98	0.68	7.66	0.67	0.66
50°	5 days at 50° F.	9.74	2.34	5.96	1.92	7.88	0.48	0.60
	5 days at 50° F. ripened at room temperature	10.04	2.87	7.25	0.59	7.84	0.67	0.66
	Analyzed immediately	9.63	2.97	4.34	3.46	7.80	0.39	0.75
	Ripened at room temperature	10.98	2.92	7.71	1.09	8.80	0.65	0.59
55°	5 days at 55° F.	9.61	2.94	4.61	3.11	7.72	0.40	0.83
	5 days at 55° F. ripened at room temperature	10.46	3.36	6.78	1.43	8.21	0.77	0.76
	Analyzed immediately	9.43	3.66	4.21	2.92	7.13	0.53	1.08
	Ripened at room temperature	10.50	3.19	6.47	1.90	8.37	0.71	0.77
60°	5 days at 60° F.	9.57	3.23	5.32	2.65	7.97	0.52	0.87
	5 days at 60° F. ripened at room temperature	10.63	2.91	6.79	2.09	8.88	0.59	0.60

* As calcium pectate.

to completion on removal to room temperature as compared to check fruits. Even though the temperature effect is obvious on the sucrose changes, none of the chemical changes is so markedly affected as is respiration.

This indicates that the basic metabolism of the fruit has been upset rather than simple enzymatic changes. The nature of the basic upset is not clear but on the basis of a temperature coefficient of 1.5 between 40° and 45° F. it is probable that some physical phase of respiration has become limiting. Tropical fruits such as banana and papaya (**3, 8, 13**) are subject to this temperature "chill" at temperatures below 50° F. as contrasted to temperature climate fruits, such as the apple (**1**), which are not "chilled" by temperatures even as low as 32° F. Does this signify a fundamental difference in the basic metabolism of tropical and temperate climate fruits? This question should be carefully investigated.

The results presented show clearly that in the transport and marketing of the papaya the temperature should not be allowed to drop below 50° F. Thus special care will be required in handling papayas on northern markets during the winter months.

Summary

1. Papaya fruit are "chilled" when stored for a period of 5 days at a temperature of 45° F. or lower.

2. The temperature coefficient was found to be 1.5 between 40° and 45° F., 3.3 between 45° and 50° F., 2.2 between 50° and 55° F., and 2.2 between 55° and 60° F.

3. Ripening changes, especially sucrose changes, are retarded by all temperatures studied.

4. It is suggested that there is a difference between the basic metabolism of tropical climate and temperate climate fruit.

5. In the transport and marketing of papayas the temperature should not be allowed to go below 50° F.

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