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Thermal Degradation of Pigments and Relative Biochemical Changes in Cherries and Apricots

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THERMAL DEGRADATION OF PIGMENTS AND RELATIVE BIOCHEMICAL CHANGES IN CHERRIES AND APRICOTS

by

K..B..Dalal

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K. B. Dalal

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INTRODUCTION

The extent and nature of biochemical changes that take place in canned fruits during storage temperatures above freezing have been reviewed and discussed by Pederson, *et al*. (1947). These changes include loss in nutritive value, e.g. ascorbic acid, thiamine (Brenner, *et al*., 1948) and deterioration of color (Tressler, *et al*., 1955). Bauernfeind (1953) reported that canned peaches, apricots, and sweet cherries, after a few months of storage at 70° F, frequently undergo changes such as destruction of anthocyanin and carotenoid pigments with the subsequent formation of brown colored compounds. Darkening of fruit-color eventually results in their unacceptability at consumer level. Preference for fruit is mainly based upon the attractive appearance of the products. Thus, color is an important factor governing the quality of fruits and fruit products.

In earlier studies, conducted elsewhere, emphasis was placed on effects of low storage temperatures on the quality of canned apricots and cherries. Paucity of scientific literature on the stability of processed apricots and cherries gave impetus to a study of the comparative influence of high storage temperatures and their duration, as such tests will have considerable economic bearing upon storing and shipping processed products to tropical countries.

This thesis presents the effects of storage temperatures (40, 70, 100, and 120° F) and their duration (16 weeks) on colors (anthocyanins and carotenoids), total titratable acidity, pH, viscosity, carbohydrates (total and free reducing sugars, pectins), volatile reducing substances, hydroxymethyl furfural, and organoleptic quality of canned apricots and cherries.

REVIEW OF LITERATURE

A review of pertinent literature was made for information concerning biochemical changes that take place in canned fruits during storage at varied temperatures. Pederson, _et al_. (1947) reported that canned fruits stored at temperatures above freezing often undergo chemical degradation, such as destruction of anthocyanin and carotenoid pigments, formation of brown colored compounds, possible intramolecular oxidations, loss of ascorbic acid, and others, all of which may affect the quality of products. Alteration in flavor and appearance brought about by contact of processed food with oxygen and high temperatures occupy prominent positions among the causes of food deterioration (Coulter and Jenness, 1946). Livingston, _et al_. (1953) reported that apple sauce when held at elevated temperatures or over a prolonged storage period caused the diffused non-enzymatic darkening of the sauce, which is thought to be due to a number of non-oxidative reactions. Among these, sugars and pigments degradation are considered to be possible darkening mechanisms.

Disadvantages of high temperature storage have been widely discussed by Brody, _et al_. (1960). According to their investigation, many biochemical quality factors are not storage stable in most conventional canned food under ambient temperature conditions. It would be expected that equal or greater instability will be found in high temperature short time processed products due to the greater concentration of unstable reactants, and high storage temperatures might cause loss of these qualities. Canned sour cherries and pitted sweet cherries have been found to undergo deterioration of color and other chemical change due to initial damage caused by scalding and oxidation (Labelle, *et al*., 1958, Loufti, *et al*., 1952).

MATERIALS AND METHODS

Apricots (Variety—Moorpark), sweet cherries (Variety—Lambert), and sour cherries (Variety—Montmorency) were harvested at optimal maturity based on visual appearance, for canning. These fruits were then processed under commercial conditions using the following proportion of fruit and sugar solution. Moorpark: 505 g. of fruit and 300 ml. of 40 percent sugar solution per can. Lambert: 430 g. of fruit and 400 ml. of 40 percent sugar solution per can. Montmorency: 367 g. of fruit and 300 ml. of 40 percent sugar solution per can. Canned fruits were stored in four chambers of 40, 70, 100, and 120° F. At weekly intervals random samples of canned products were removed from each storage condition and evaluated for the following subjective and biochemical attributes:

Color measurements

Anthocyanins and carotenoids were determined colorimetrically using procedures outlined by Sondheimer, et al. (1948), and McCollum (1953), respectively.

Total pectins

Pectins as calcium pectate were determined according to the method described by Ruck (1956).

Total and free reducing sugars

These were determined by the Shaffer-Somogyi micromethod, (AOAC, 1960).

Total titratable acidity and pH

These were determined with a Beckman pH meter. Ten grams of fruit was homogenized with 100 ml. distilled water and then titrated to pH 8·1 with 0·1N sodium hydroxide.

Viscosity

It was determined by employing Zahn viscosimeter and was expressed in terms of seconds required to empty out the syrup from the cup.

Hydroxymethyl furfural, volatile reducing substances and organoleptic quality evaluation

These evaluations were made on the terminal samples (at the end of the sixteenth week of storage duration). HMF and VRS were determined by the procedures outlined by Luh, et al. (1958), and Luh (1961), respectively. Organoleptic quality, using a hedonic scale (Peryam and Pilgrim, 1957), was evaluated by a laboratory panel of ten judges.

Summary of the chemical analysis conducted is presented in Appendix Tables 2 to 17, inclusive.

RESULTS AND DISCUSSION

When processed apricots, sweet and sour cherries were stored at temperatures of 40, 70, 100 and 120° F for 16 weeks, the colors of the fruits darkened progressively with the storage time. According to Markakis, et al. (1957), breakdown of anthocyanins at high temperatures ranging from 113 and 230° F involves the hydrolytic opening of the pyrylium ring with the formation of substituted brown insoluble polyphenolic compounds. Sondheimer, et al. (1948) suggested that entrapped oxygen in the headspace of the can, together with high temperatures, is responsible for the breakdown of the anthocyanins through the hydrolysis or polymerization of pseudobase pigment to insoluble red-brown and soluble brown compounds. In both the reactions red-brown compounds may arise from sugars, chiefly glucose. Browning in the case of apricots is reported to be due to Maillard type of reaction (Liggett, et al., 1959) involving chemical interaction of a sugar with acid or may be due to the carmelization of sugar itself. It may also be assumed that acid-base catalyzed thermal decomposition of reducing sugars could cause non-enzymatic browning in apricots. Figures 1 and 6 show progressive deterioration of anthocyanin pigments with the increase in time and temperature of storage. Samples stored at 40° F also indicated an increased trend of browning in the later storage periods. The degree of browning in both sweet and sour cherries was much greater at 70, 100 and 120° F than at 40° F. For each 10° F rise in temperature the rates of deterioration of pigments increased two to three-fold becoming almost constant during the later storage periods.

In apricots, the rate of darkening was not so pronounced as in the case of cherries. It can be seen from Figure 11 that samples stored at 40° F showed very little formation of hydroxymethyl furfural, even after the sixteenth week. Temperatures of 70, 100, and 120° F caused progressive browning of color, but at a considerably slower rate. This striking difference in the rate of deterioration of anthocyanin and carotenoid pigments at high temperatures may be attributed to the fact that anthocyanins, being water soluble compounds, are considerably degraded by the increase in acidity, while fat soluble carotenoids are not susceptible to increased acidity to such an extent.

Rapid decrease in the pectin content of stored fruits with time and temperatures might be attributed to the conversion of protopectin to water soluble uronic acids. Figures 2, 7, and 12 show the progressive loss of pectins in all three fruits along with increased temperatures. The degree of softening (which is due to percent loss of pectin) varied from extremely high (94 percent) in the case of Montmorency cherries, high (75 percent) in Lambert cherries to moderate (52 percent) in apricots.

Higher temperatures together with acid content favored the hydrolysis of sucrose into its component monosaccharides. Figures 4, 5, 9, 10, 14, and 15 indicate increases of both total and free reducing sugars of all three fruits. A uniform increase (45 percent) in total reducing sugars along with time and temperatures was observed in all three fruits. The percentage increase of free reducing sugars as compared to total reducing sugars was almost double in both apricots and cherries.

High temperatures favor the catalytic oxidation of monosaccharides to sorresponding acids. Results of the effects of storage temperatures and duration on total titratable acidity of canned fruits are manifested in Figures 3, 8, and 13. A slow rate of increase was observed at 40° F, as compared to rapid acceleration at 70, 100, and 120° F.

Hydroxymethyl furfural can be formed by interaction of hexoses with acids. Luh, et al. (1963) reported that when canned fruits were stored at high temperatures, a slow chemical reaction between acids and reducing sugars were responsible for the formation of HMF. Effects of time and temperatures (40, 70, 100, and 120° F) on the HMF formation in the terminal samples stored for 16 weeks are shown in Table 1. Steady increase of HMF along with temperatures indicate lowering of keeping quality of fruits during storage. Table 1 also shows the progressive decrease of volatile reducing substances (responsible for flavor in fruits) with

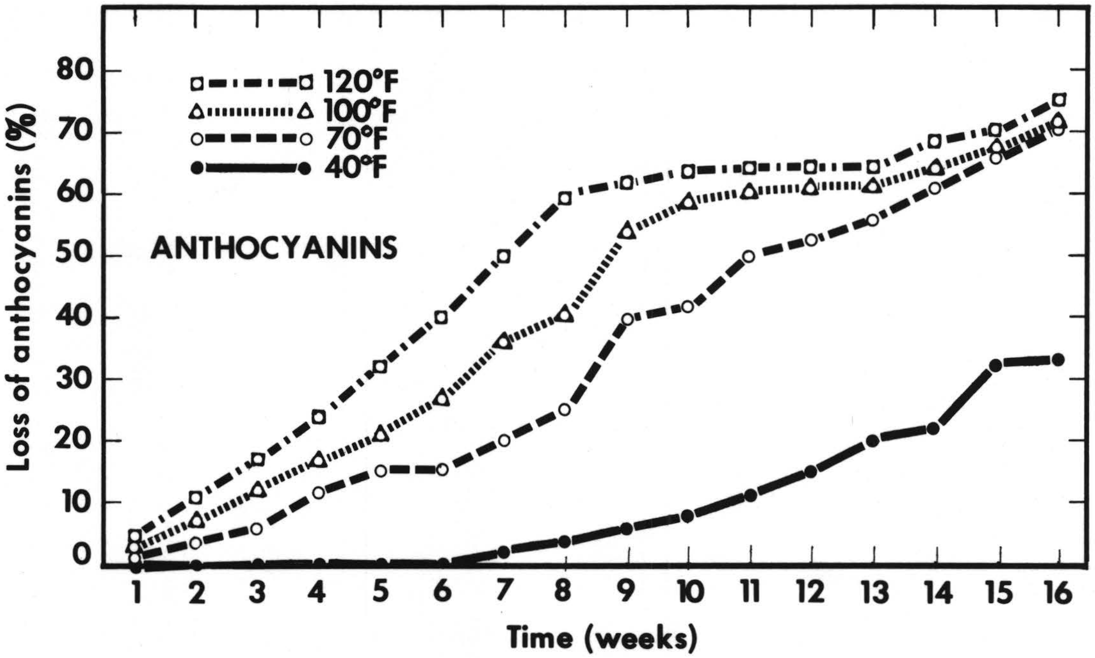

Figure 1. Effects of storage temperatures and their duration on anthocyanins of Lambert cherries

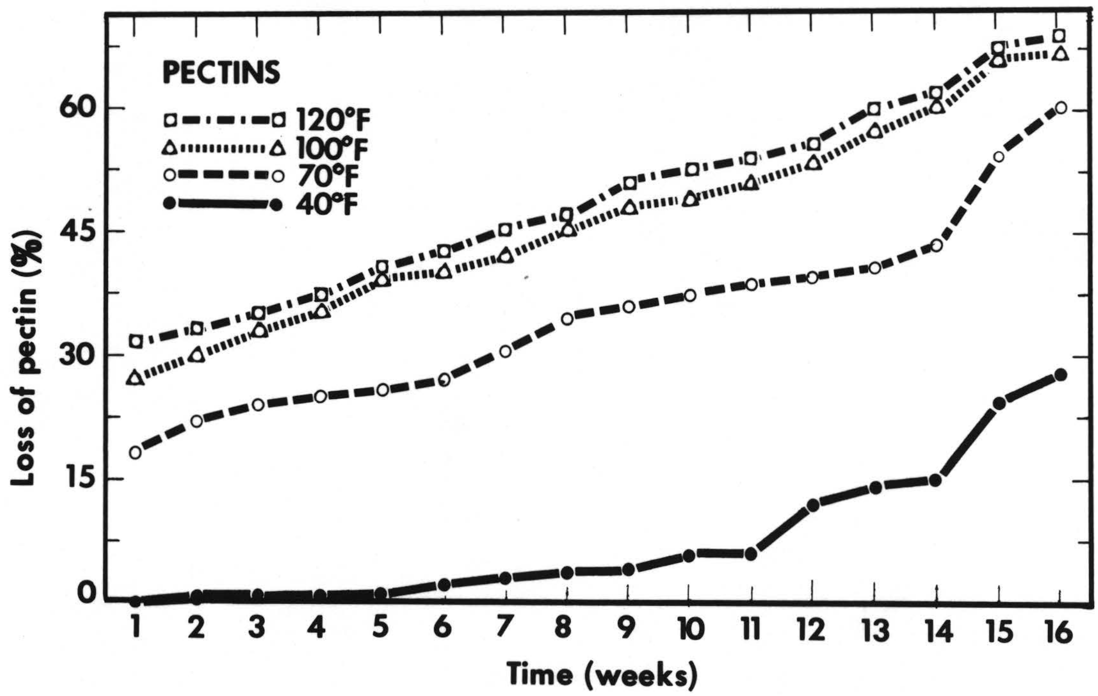

Figure 2. Effects of storage temperatures and their duration on pectins of Lambert cherries

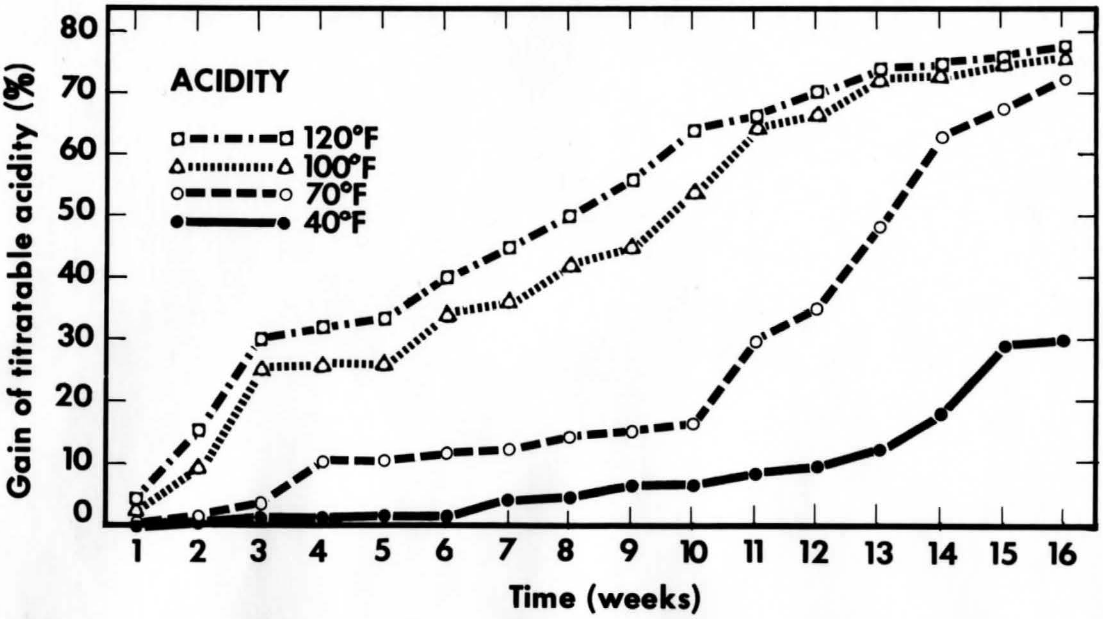

Figure 3. Effects of storage temperatures and their duration on total titratable acidity of Lambert cherries

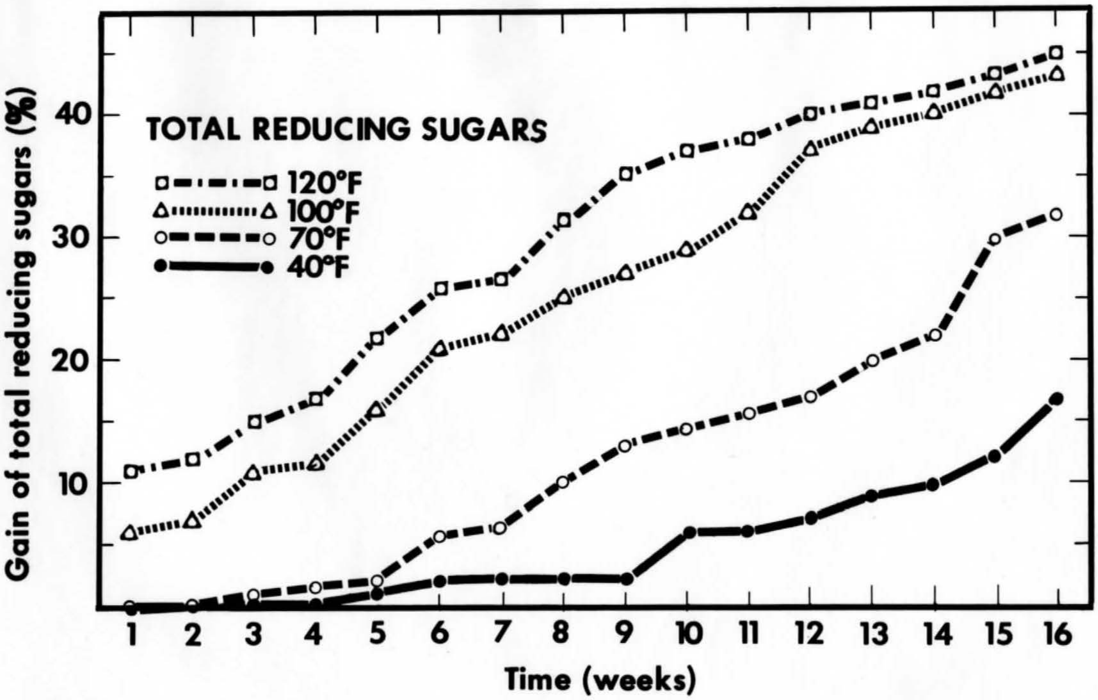

Figure 4. Effects of storage temperatures and their duration on total reducing sugars of Lambert cherries

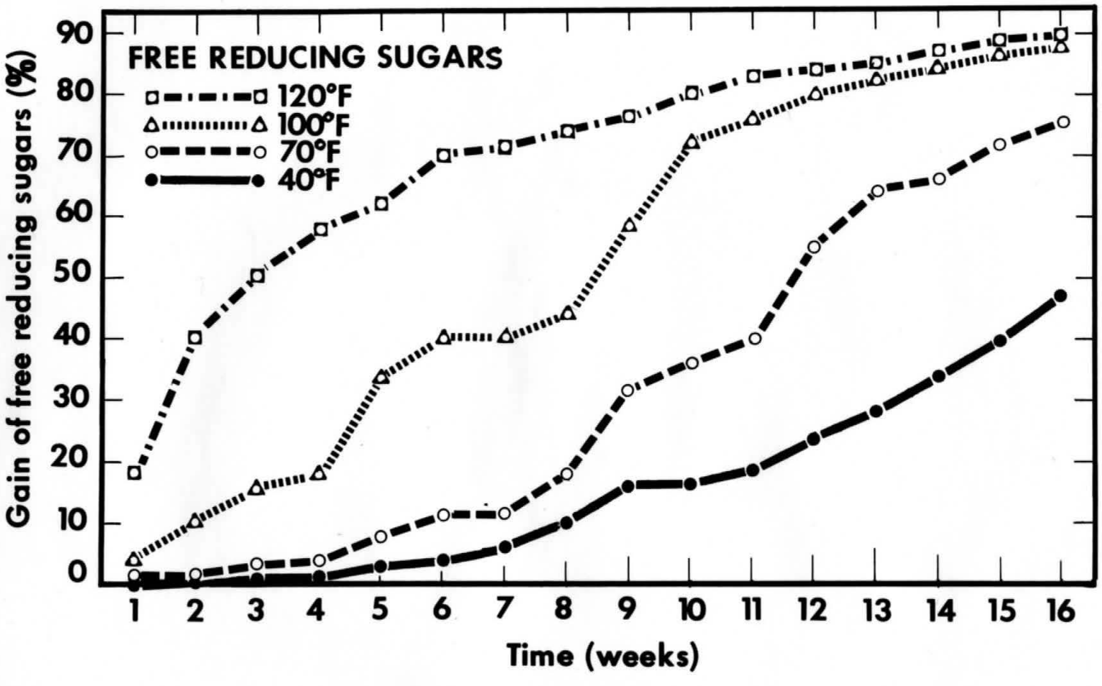

Figure 5. Effects of storage temperatures and their duration on free reducing sugars of Lambert cherries

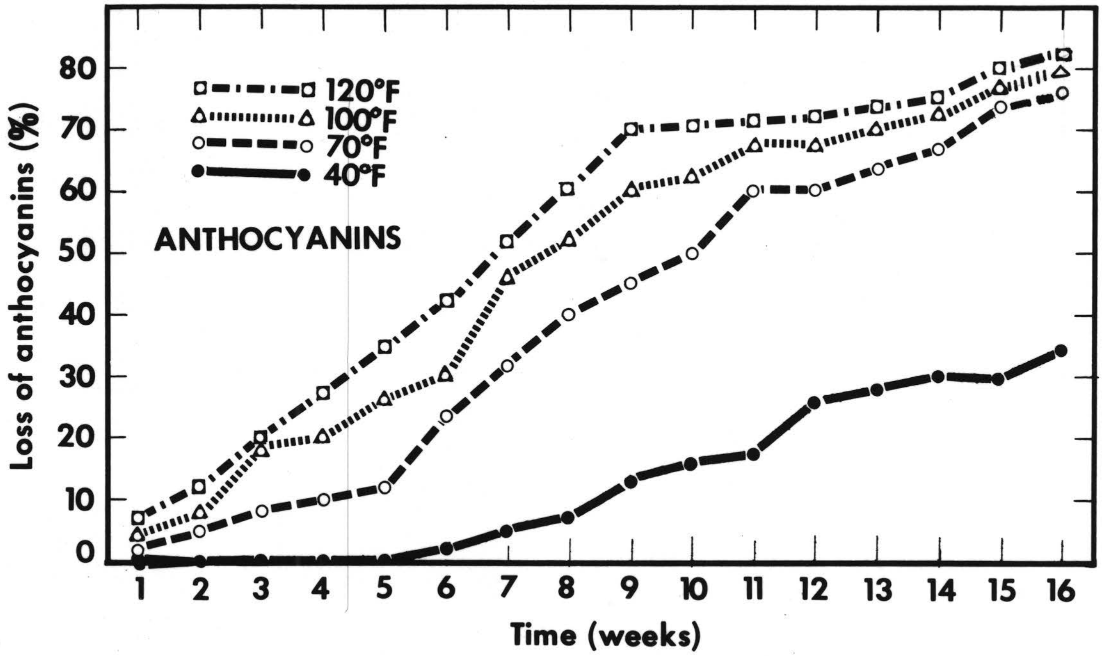

Figure 6. Effects of storage temperatures and their duration on anthocyanins of Montmorency cherries

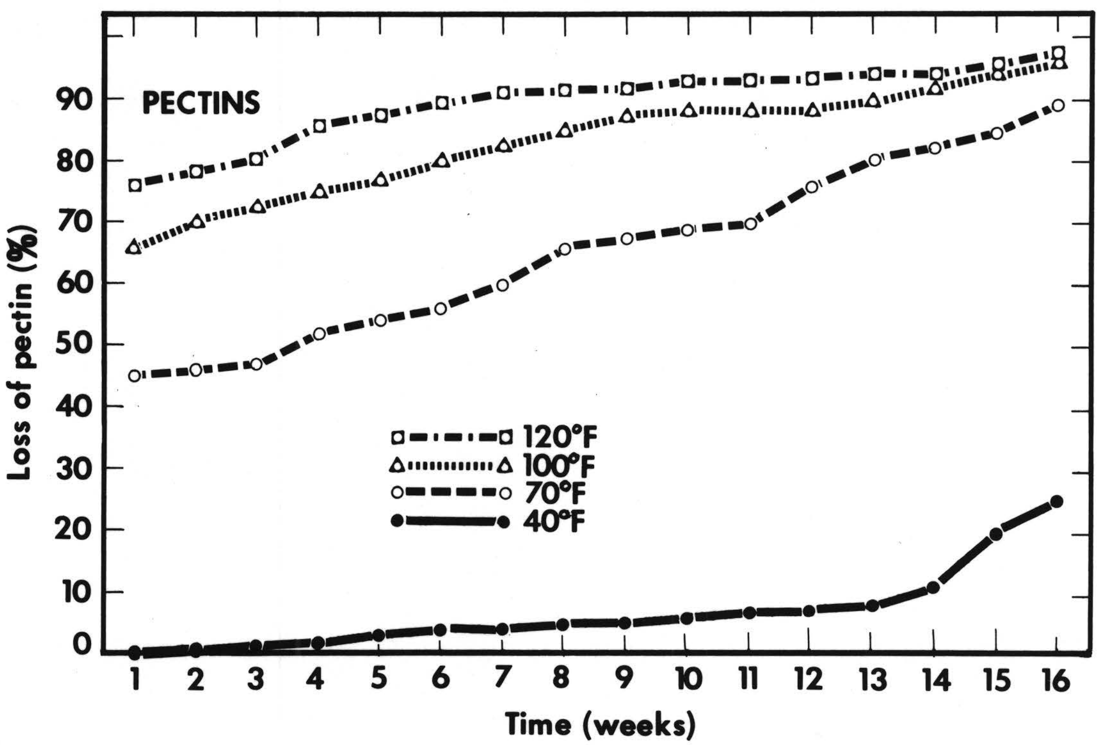

Figure 7. Effects of storage temperatures and their duration on pectins of Montmorency cherries

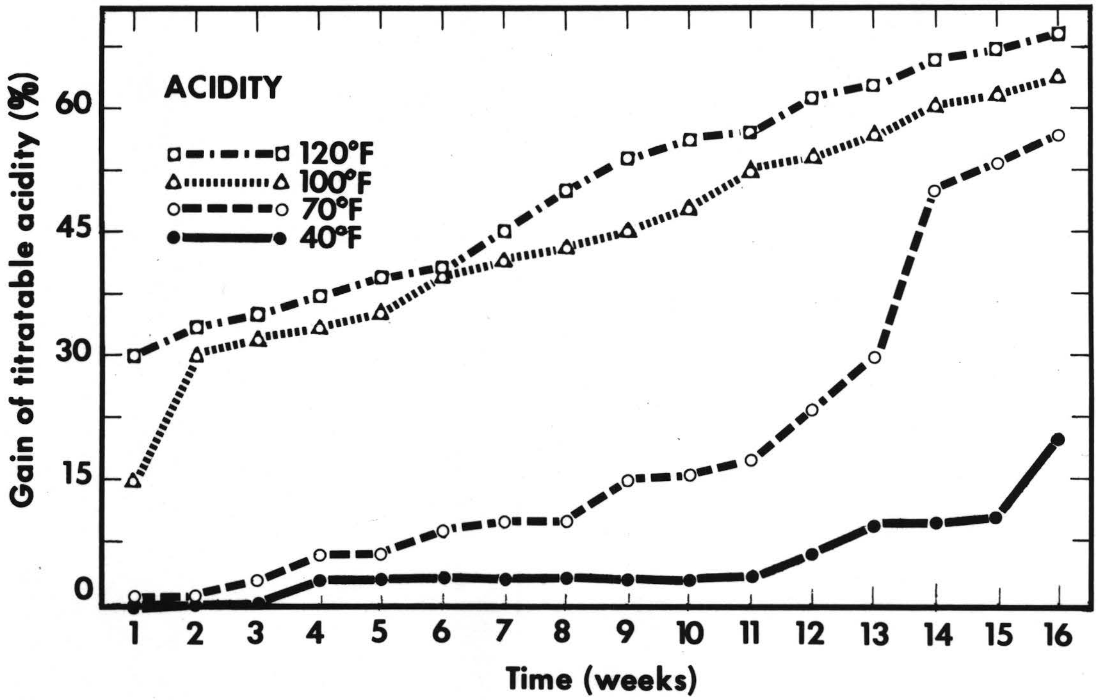

Figure 8. Effects of storage temperatures and their duration on total titratable acidity of Montmorency cherries

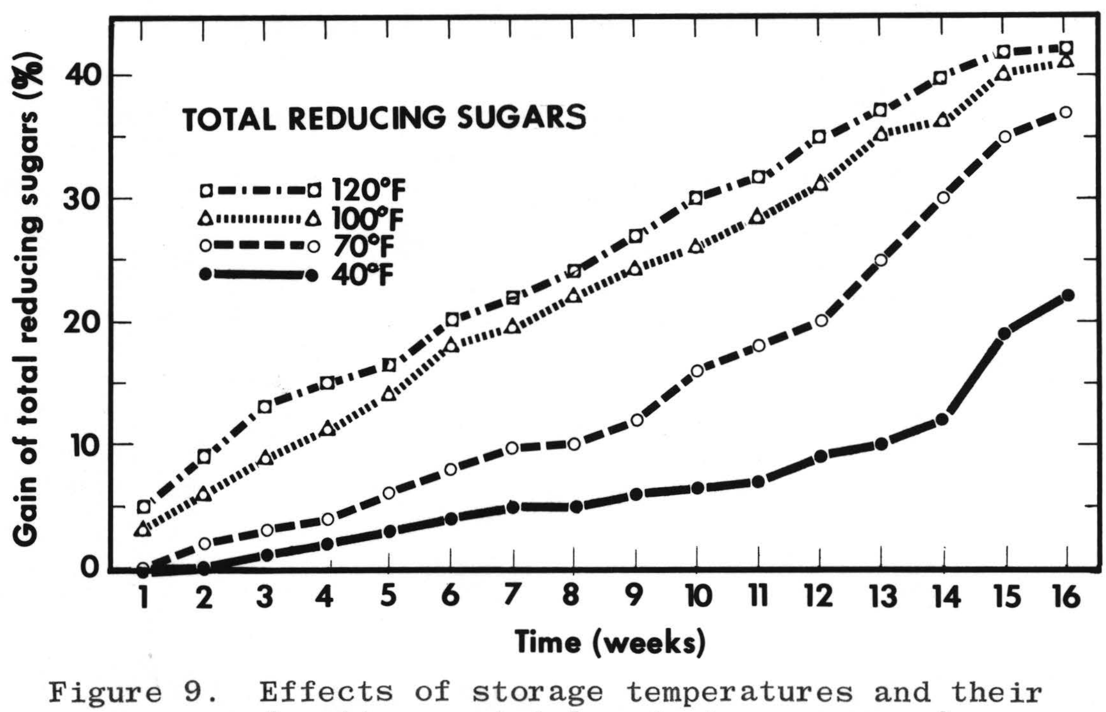

Figure 9. Effects of storage temperatures and their duration on total reducing sugars of Montmorency cherries

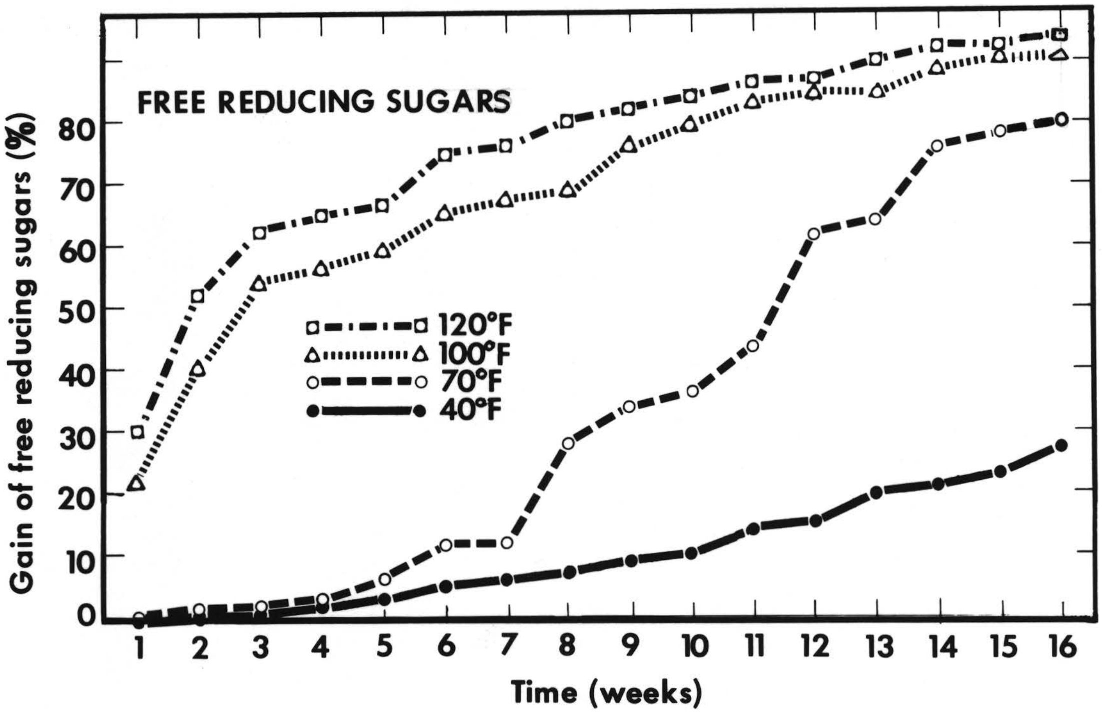

Figure 10. Effects of storage temperatures and their duration on free reducing sugars of Montmorency cherries

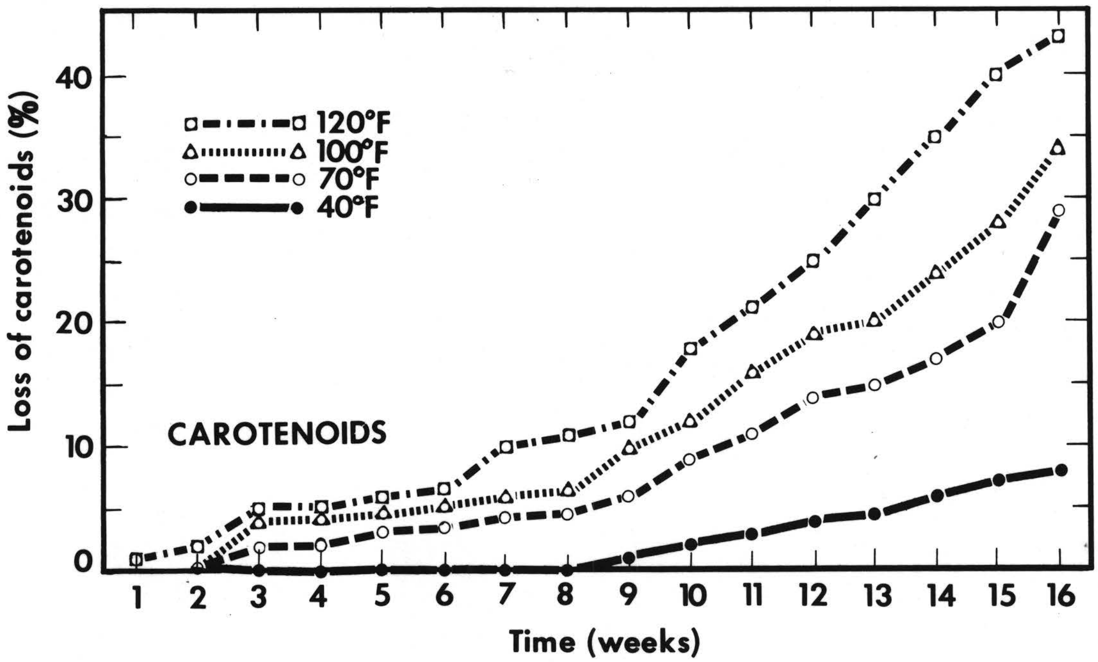

Figure 11. Effects of storage temperatures and their duration on carotenoids of Moorpark apricots

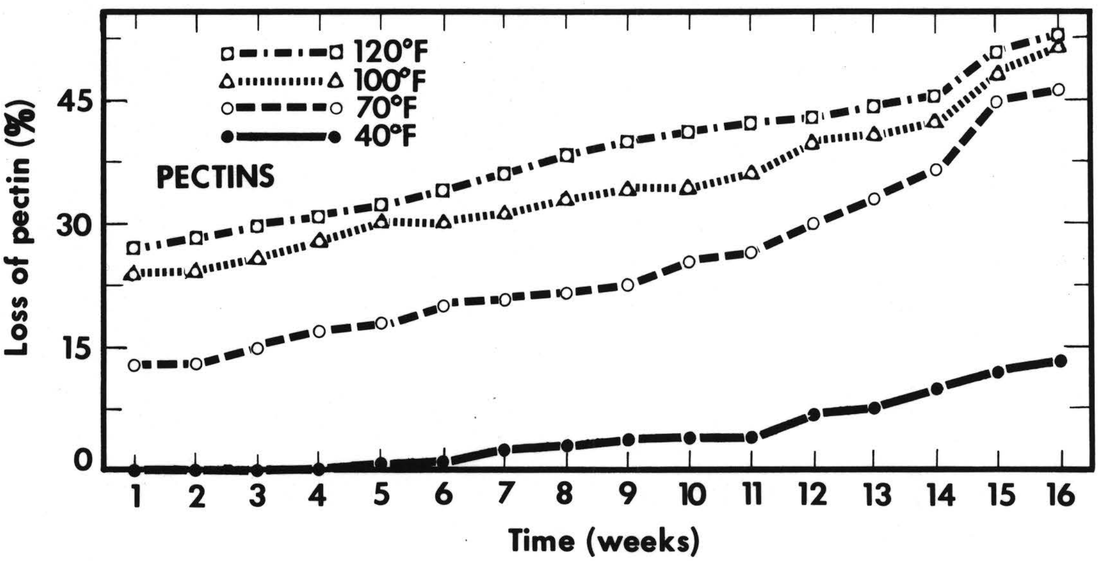

Figure 12. Effects of storage temperatures and their duration on pectins of Moorpark apricots

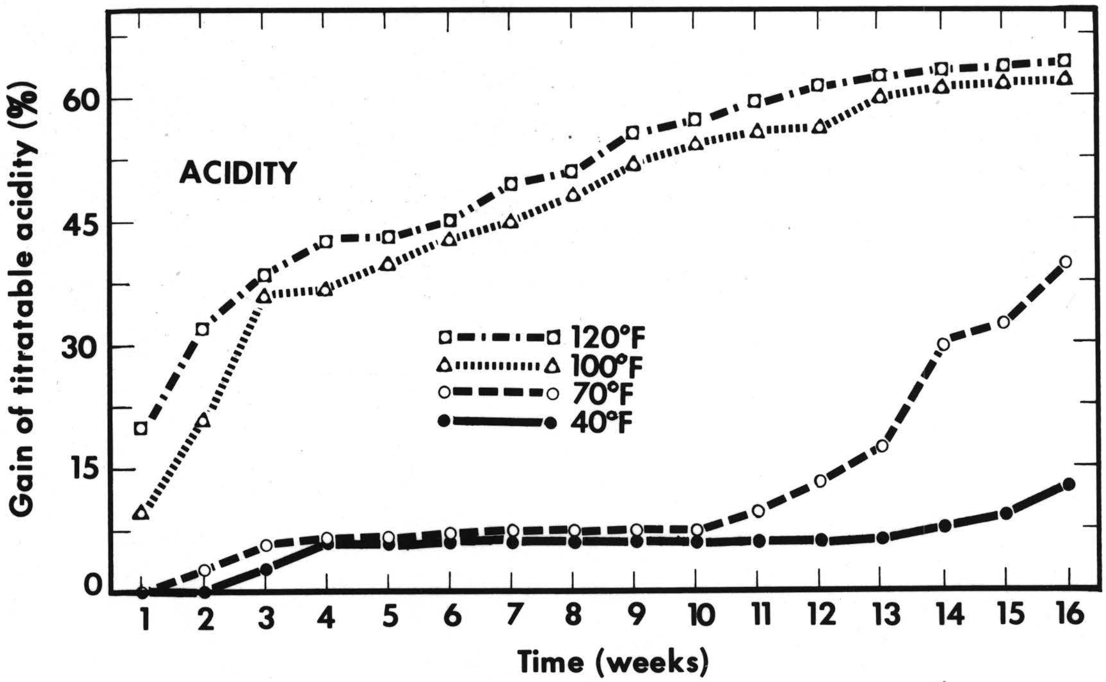

Figure 13. Effects of storage temperatures and their duration on total titratable acidity of Moorpark apricots

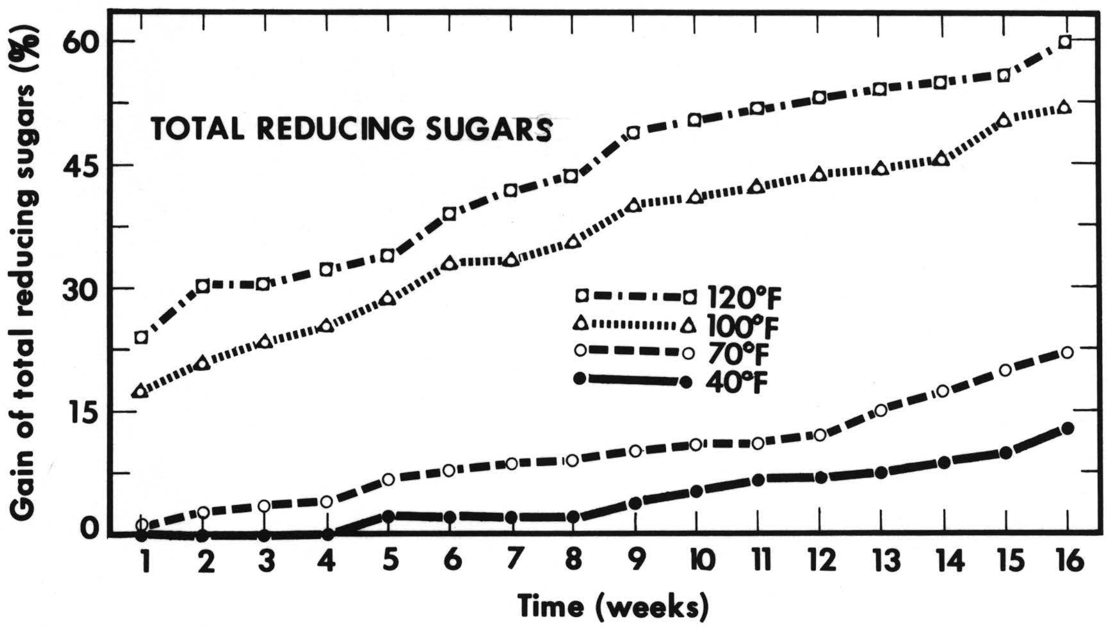

Figure 14. Effects of storage temperatures and their duration on total reducing sugars of Moorpark apricots

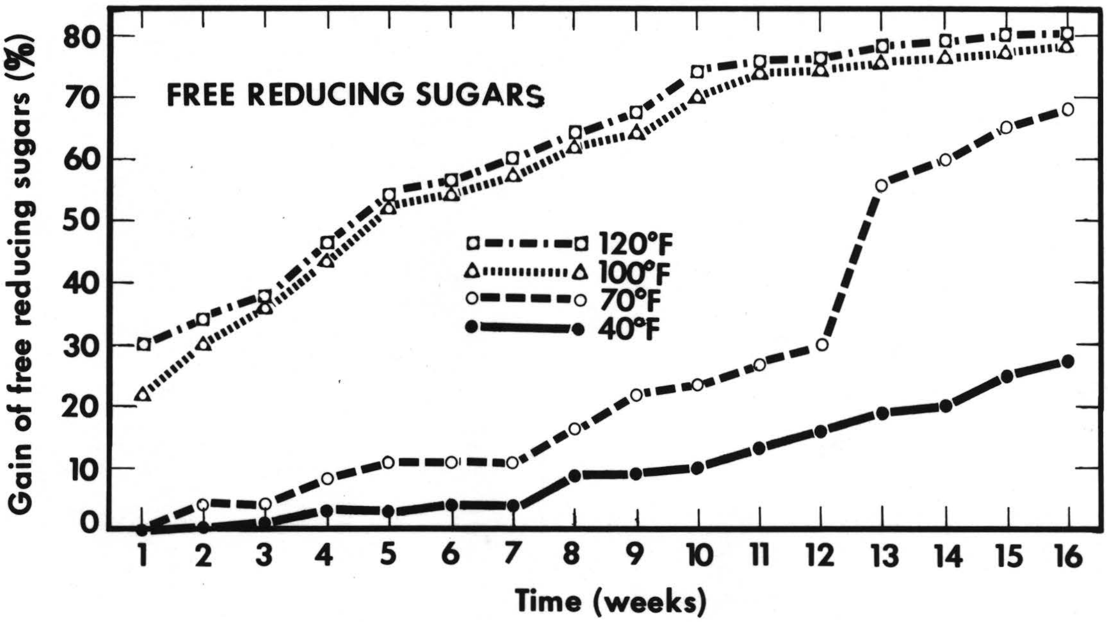

Figure 15. Effects of storage temperatures and their duration on free reducing sugars of Moorpark apricots

Table 1. Effects of storage temperatures on the volatile reducing substances (VRS) hydroxymethyl furfural (HMF), and organoleptic quality scores of canned apricots, and sweet and sour cherries after sixteen weeks

Storage temperature °F	Moorpark apricots					Lambert cherries					Montmorency cherries				
	VRS mu/100 g	HMF mu/100 g	Color score	Flavor score	Texture score	VRS mu/100 g	HMF mu/100 g	Color score	Flavor score	Texture score	VRS mu/100 g	HMF mu/100 g	Color score	Flavor score	Texture score
40	120.0	23.0	8.2	8.0	8.0	133.0	38.0	8.6	8.6	8.2	93.3	50.0	9.0	8.6	8.0
70	106.0	65.0	8.0	7.7	7.0	120.0	100.0	8.3	8.0	8.0	93.0	166.0	7.9	7.8	7.1
100	100.0	115.0	7.5	6.7	6.0	106.0	190.0	5.6	5.8	5.0	86.6	220.0	4.4	5.2	4.9
120	93.3	140.0	7.4	3.4	3.0	100.0	250.0	2.8	3.6	3.0	80.0	340.0	1.9	3.2	2.1

time and temperatures. All fruits acquired a "burnt" flavor at 70, 100, and 120° F. Off-flavor was not found in the samples stored at 40° F. Organoleptic quality scores are also included in the Table. The average scores on terminal samples (sixteenth week) indicate "unacceptability" of fruits stored at highest temperatures of 100 and 120° F. No significant change in viscosity of cover syrup was observed.

It was observed that loss or gain of all chemical attributes manifested a direct linear correlationship with time and temperature. A first order reaction (increasing) was observed in the early stages of storage periods, which slowly changed to zero order (constant) with the advancement of storage periods.

SUMMARY AND CONCLUSIONS

Apricots (Variety—Moorpark), sweet cherries (Variety—Lambert) and sour cherries (Variety—Montmorency) were processed with 40 percent sugar solution as cover syrup. The processed fruits were stored at 40, 70, 100, and 120° F and were analyzed for colors, pectin, sugar (both total and free reducing), acidity, pH, and viscosity at weekly intervals for 16 weeks. At the end of storage duration the terminal samples were also analyzed for hydroxymethyl furfural, volatile reducing substances, and organoleptic quality scores for color, flavor, and texture. It was observed that as the storage duration and temperature increased, sugars (total and free reducing), acidity, and hydroxymethyl furfural increased, whereas anthocyanins, carotenoids, pectin, volatile reducing substances, syrup viscosity, and organoleptic quality decreased.

In order to maintain high quality of canned fruit products, storage temperatures at or below 40° F are preferable. The lower the temperatures, the slower will be the rate of deterioration of fruits.

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APPENDIX

Table 2. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the first week of storage

Fruit Variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.346	4.10	2.30	0.2479	4.1	15.50
"	70	-	4.60	0.208	4.13	2.30	0.2479	4.1	15.40
"	100	-	4.60	0.263	4.91	2.80	0.2747	4.0	15.16
"	120	-	4.60	0.252	5.01	3.00	0.3017	3.9	15.00
Sweet Cherries									
(Lambert)	40	4.53	-	0.180	3.92	1.62	0.1340	4.0	15.10
"	70	4.53	-	0.147	3.92	1.63	0.1340	4.0	14.80
"	100	4.48	-	0.130	4.10	1.92	0.1340	3.9	14.70
"	120	4.32	-	0.121	4.30	2.10	0.1400	3.8	14.56
Sour Cherries									
(Montmorency)	40	3.94	-	0.088	3.10	1.35	0.2345	3.8	14.56
"	70	3.90	-	0.048	3.10	1.36	0.2345	3.7	14.56
"	100	3.74	-	0.028	3.20	1.40	0.2680	3.7	14.50
"	120	3.66	-	0.020	3.25	1.80	0.3082	3.6	14.40

[a]Determined by employing Zahn viscosimeter number 2

Table 3. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the second week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.346	4.10	2.30	0.2480	4.00	15.50
"	70	-	4.60	0.296	4.20	2.39	0.2546	4.00	15.50
"	100	-	4.60	0.260	5.00	3.00	0.3018	3.95	15.20
"	120	-	4.56	0.253	5.32	3.10	0.3230	3.90	14.90
Sweet cherries									
(Lambert)	40	4.53	-	0.181	3.92	1.64	0.1340	4.00	14.90
"	70	4.32	-	0.140	3.92	1.64	0.1340	4.00	14.70
"	100	4.20	-	0.127	4.20	2.28	0.1470	3.90	14.66
"	120	4.03	-	0.120	4.40	2.45	0.1540	3.70	14.50
Sour cherries									
(Montmorency)	40	3.94	-	0.087	3.10	1.35	0.2345	3.80	14.56
"	70	3.74	-	0.046	3.18	1.37	0.2345	3.80	14.50
"	100	3.50	-	0.025	3.30	1.50	0.3082	3.65	14.43
"	120	3.40	-	0.018	3.40	1.90	0.3149	3.60	14.40

[a]Determined by employing Zahn viscosimeter number 2

Table 4. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the third week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca-pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.346	4.10	2.32	0.2546	4.00	15.20
"	70	-	4.50	0.293	4.20	2.40	0.2013	4.00	14.80
"	100	-	4.44	0.255	5.10	3.11	0.3300	3.90	14.70
"	120	-	4.40	0.246	5.38	3.23	0.3390	3.90	14.50
Sweet cherries									
(Lambert)	40	4.53	-	0.179	3.92	1.65	0.1350	4.00	14.50
"	70	4.28	-	0.137	3.94	1.66	0.1580	3.90	14.50
"	100	3.98	-	0.120	4.35	2.51	0.1670	3.80	14.20
"	120	3.66	-	0.116	4.51	2.66	0.1740	3.70	13.80
Sour cherries									
(Montmorency)	40	3.94	-	0.087	3.16	1.36	0.2412	3.80	15.20
"	70	3.60	-	0.045	3.19	1.39	0.2412	3.80	15.20
"	100	3.24	-	0.025	3.40	1.57	0.3149	3.70	15.00
"	120	3.12	-	0.016	3.52	2.01	0.3150	3.70	14.80

[a]Determined by employing Zahn viscosimeter number 2

Table 5. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the fourth week of storage

Fruit variety	Storage temperature ^{o}F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.345	4.10	2.33	0.2613	4.00	15.10
"	70	-	4.50	0.286	4.25	2.48	0.2613	4.00	14.70
"	100	-	4.44	0.250	5.20	3.30	0.3400	3.80	14.60
"	120	-	4.36	0.238	5.41	3.39	0.3551	3.80	14.50
Sweet cherries									
(Lambert)	40	4.53	-	0.179	3.98	1.66	0.1350	4.00	15.40
"	70	3.98	-	0.136	3.98	1.68	0.1474	3.85	14.80
"	100	3.78	-	0.116	4.40	2.58	0.1680	3.80	14.60
"	120	3.39	-	0.111	4.59	2.70	0.1760	3.65	14.40
Sour cherries									
(Montmorency)	40	3.94	-	0.087	3.17	1.37	0.2412	3.80	14.10
"	70	3.34	-	0.042	3.21	1.40	0.2490	3.75	13.80
"	100	3.19	-	0.021	3.46	1.60	0.3182	3.70	13.70
"	120	2.88	-	0.011	3.57	2.13	0.3216	3.60	13.50

[a]Determined by employing Zahn viscosimeter number 2

Table 6. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the fifth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.345	4.20	2.38	0.2613	4.00	15.00
"	70	-	4.46	0.282	4.32	2.57	0.2614	4.00	14.80
"	100	-	4.40	0.246	5.30	3.40	0.3460	3.75	14.65
"	120	-	4.36	0.233	5.49	3.50	0.3560	3.70	14.60
Sweet cherries									
(Lambert)	40	4.53	-	0.178	3.94	1.69	0.1350	4.00	14.50
"	70	3.74	-	0.132	4.00	1.75	0.1480	3.80	14.30
"	100	3.54	-	0.110	4.60	2.63	0.1700	3.70	14.00
"	120	3.09	-	0.106	4.85	2.78	0.1800	3.60	13.90
Sour cherries									
(Montmorency)	40	3.94	-	0.086	3.18	1.39	0.2413	3.80	13.80
"	70	3.18	-	0.040	3.30	1.46	0.2498	3.75	13.80
"	100	2.88	-	0.019	8.53	1.80	0.3190	3.70	13.70
"	120	2.55	-	0.010	3.60	2.21	0.3245	3.60	13.60

[a]Determined by employing Zahn viscosimeter number 2

Table 7. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the sixth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.344	4.22	2.40	0.2614	4.00	14.90
"	70	-	4.44	0.280	4.40	2.64	0.2615	3.90	14.81
"	100	-	4.40	0.241	5.46	3.50	0.3560	3.70	14.50
"	120	-	4.30	0.228	5.74	3.61	0.3580	3.70	14.42
Sweet cherries									
(Lambert)	40	4.53	-	0.176	3.98	1.71	0.1360	4.00	14.40
"	70	3.66	-	0.130	4.20	1.80	0.1490	3.80	14.30
"	100	3.31	-	0.106	4.75	2.70	0.1790	3.70	13.90
"	120	2.70	-	0.103	4.98	2.85	0.1900	3.60	13.70
Sour cherries									
(Montmorency)	40	3.90	-	0.086	3.22	1.41	0.2413	3.80	13.80
"	70	3.05	-	0.038	3.36	1.50	0.2500	3.70	13.70
"	100	2.80	-	0.017	3.65	1.89	0.3200	3.60	13.50
"	120	2.30	-	0.009	3.73	2.30	0.3299	3.60	13.40

[a]Determined by employing Zahn viscometer number 2

Table 8. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the seventh week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.343	4.22	2.41	0.2616	3.90	14.80
"	70	-	4.40	0.276	4.41	2.66	0.2617	3.80	14.65
"	100	-	4.40	0.236	5.49	3.55	0.3575	3.60	14.40
"	120	-	3.22	0.220	5.80	3.66	0.3630	3.60	14.28
Sweet cherries									
(Lambert)	40	4.46	-	0.175	3.98	1.72	0.1400	4.00	14.35
"	70	3.39	-	0.124	4.23	1.81	0.1490	3.70	14.35
"	100	2.88	-	0.101	4.80	2.74	0.1830	3.70	13.84
"	120	2.37	-	0.100	5.00	2.88	0.1940	3.55	13.60
Sour cherries									
(Montmorency)	40	3.78	-	0.085	3.23	1.45	0.2416	3.70	13.65
"	70	2.71	-	0.035	3.36	1.51	0.2560	3.70	13.50
"	100	2.10	-	0.015	3.70	1.92	0.3290	3.50	13.38
"	120	1.92	-	0.008	3.79	2.32	0.3460	3.45	13.22

[a]Determined by employing Zahn viscosimeter number 2

Table 9. Effects of storage temperatures on the chemical changes of canned apricots, sweet and sour cherries after the eighth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.60	0.339	4.25	2.45	0.2617	3.90	14.76
"	70	-	4.40	0.272	4.48	2.70	0.2618	3.75	14.62
"	100	-	4.30	0.231	5.59	3.61	0.3600	3.60	14.36
"	120	-	4.20	0.215	5.91	3.70	0.3700	3.50	14.23
Sweet cherries									
(Lambert)	40	4.39	-	0.173	4.00	1.75	0.1410	3.90	14.33
"	70	3.16	-	0.120	4.30	2.10	0.1510	3.65	14.25
"	100	2.47	-	0.099	4.87	2.77	0.1900	3.60	14.21
"	120	2.20	-	0.097	5.21	2.91	0.1990	3.50	13.75
Sour cherries									
(Montmorency)	40	3.66	-	0.084	3.25	1.50	0.2417	3.70	13.60
"	70	2.66	-	0.033	3.40	1.60	0.2600	3.60	13.45
"	100	1.80	-	0.013	3.79	2.05	0.3350	3.50	13.33
"	120	1.53	-	0.007	3.85	2.35	0.3520	3.40	13.18

[a]Determined by employing Zahn viscosimeter number 2

Table 10. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the ninth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.50	0.337	4.30	2.50	0.2617	3.80	14.73
"	70	-	4.32	0.269	4.51	2.80	0.2620	3.70	14.60
"	100	-	4.20	0.229	5.75	3.70	0.3790	3.55	14.30
"	120	-	4.10	0.210	6.00	3.79	0.3860	3.50	14.15
Sweet cherries									
(Lambert)	40	4.24	-	0.170	4.10	1.80	0.1420	3.85	14.30
"	70	2.70	-	0.115	4.45	2.20	0.1600	3.65	14.20
"	100	2.06	-	0.930	4.99	2.90	0.2000	3.55	14.15
"	120	1.90	-	0.090	5.31	3.00	0.2100	3.40	13.95
Sour cherries									
(Montmorency)	40	3.42	-	0.083	3.30	1.55	0.2425	3.75	13.55
"	70	2.37	-	0.031	3.51	1.78	0.2711	3.55	13.40
"	100	1.53	-	0.011	3.85	2.15	0.3390	3.50	13.29
"	120	1.16	-	0.006	3.93	2.40	0.3600	3.35	13.15

[a]Determined by employing Zahn viscosimeter number 2

Table 11. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the tenth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.50	0.334	4.32	2.52	0.2620	3.75	14.68
"	70	-	4.18	0.260	4.56	2.87	0.2612	3.60	14.50
"	100	-	4.08	0.225	5.80	3.79	0.3830	3.50	14.20
"	120	-	3.80	0.205	6.19	3.83	0.3900	3.45	14.05
Sweet cherries									
(Lambert)	40	4.11	-	0.179	4.18	1.84	0.1420	3.80	14.20
"	70	2.64	-	0.113	3.50	2.27	0.1680	3.60	14.10
"	100	1.90	-	0.091	5.13	2.94	0.2100	3.50	13.60
"	120	1.70	-	0.087	5.41	2.99	0.2190	3.40	13.50
Sour cherries									
(Montmorency)	40	3.27	-	0.083	3.33	1.58	0.2430	3.60	13.50
"	70	2.16	-	0.030	3.60	1.83	0.2726	3.50	13.40
"	100	1.50	-	0.011	3.92	2.34	0.3410	3.45	13.20
"	120	1.15	-	0.006	3.99	2.45	0.3621	3.35	13.10

[a]Determined by employing Zahn viscosimeter number 2

Table 12. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the eleventh week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.44	0.332	4.33	2.60	0.2628	3.70	14.65
"	70	-	4.08	0.256	4.58	2.93	0.2710	3.65	14.50
"	100	-	3.86	0.221	5.82	3.90	0.3880	3.50	14.15
"	120	-	3.60	0.203	6.23	4.01	0.3960	3.40	14.00
Sweet cherries									
(Lambert)	40	3.99	-	0.167	4.16	1.88	0.1430	3.80	14.20
"	70	2.30	-	0.110	4.56	2.35	0.1730	3.55	14.05
"	100	1.81	-	0.087	5.20	2.99	0.2190	3.40	13.55
"	120	1.70	-	0.84	5.42	3.04	0.2240	3.35	13.50
Sour cherries									
(Montmorency)	40	3.24	-	0.081	3.34	1.60	0.2440	3.60	13.50
"	70	1.94	-	0.029	3.62	1.90	0.2840	3.45	13.35
"	100	1.25	-	0.010	3.98	2.38	0.3510	3.40	13.15
"	120	1.15	-	0.006	4.10	2.48	0.3690	3.30	13.06

[a]Determined by employing Zahn viscosimeter number 2

Table 13. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the twelfth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.40	0.323	4.37	2.68	0.2636	3.70	14.60
"	70	-	4.00	0.245	4.63	3.00	0.2800	3.60	14.45
"	100	-	3.74	0.215	4.88	4.00	0.3900	3.45	14.10
"	120	-	3.42	0.200	6.29	4.03	0.4000	3.35	14.00
Sweet cherries									
(Lambert)	40	3.75	-	0.157	4.27	1.90	0.1450	3.75	14.20
"	70	2.10	-	0.106	4.64	2.46	0.1820	3.50	14.00
"	100	1.74	-	0.083	5.39	3.03	0.2240	3.40	13.50
"	120	1.64	-	0.078	5.45	3.05	0.2290	3.35	13.45
Sour cherries									
(Montmorency	40	2.90	-	0.081	3.40	1.68	0.2500	3.55	13.43
"	70	1.63	-	0.026	3.73	2.10	0.2900	3.40	13.30
"	100	1.24	-	0.010	4.15	2.43	0.3580	3.35	13.10
"	120	1.08	-	0.005	4.23	2.50	0.3710	3.25	13.00

[a]Determined by employing Zahn viscosimeter number 2

Table 14. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the thirteenth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.40	0.320	4.40	2.72	0.2640	3.70	14.50
"	70	-	3.90	0.220	4.71	3.60	0.2910	3.55	14.40
"	100	-	3.68	0.200	5.93	4.02	0.3960	3.40	14.00
"	120	-	3.28	0.193	6.34	4.04	0.4024	3.35	14.00
Sweet cherries									
(Lambert)	40	3.60	-	0.193	4.30	1.95	0.1500	3.75	14.15
"	70	1.98	-	0.155	4.70	2.66	0.1990	3.45	14.00
"	100	1.64	-	0.100	5.44	3.03	0.2300	3.35	13.36
"	120	1.52	-	0.075	5.51	3.05	0.2320	3.35	13.30
Sweet cherries									
(Montmorency)	40	2.83	-	0.080	3.43	1.75	0.2550	3.50	13.41
"	70	1.56	-	0.020	3.90	2.22	0.3010	3.35	13.25
"	100	1.22	-	0.009	4.21	2.46	0.3620	3.30	13.00
"	120	1.05	-	0.005	4.26	2.45	0.3815	3.25	13.00

[a]Determined by employing Zahn viscosimeter number 2

Table 15. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the fourteenth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.32	0.309	4.43	2.76	0.2670	3.65	14.10
"	70	-	3.80	0.207	4.80	3.68	0.3205	3.50	14.00
"	100	-	3.50	0.192	5.98	4.04	0.4008	3.35	13.83
"	120	-	3.00	0.180	6.39	4.10	0.4039	3.35	13.80
Sweet cherries									
(Lambert)	40	3.45	-	0.153	4.36	1.97	0.1560	3.70	14.10
"	70	1.70	-	0.097	4.80	2.70	0.2190	3.40	13.90
"	100	1.62	-	0.071	5.48	3.06	0.2320	3.35	13.30
"	120	1.50	-	0.068	5.54	3.08	0.2340	3.30	13.27
Sour cherries									
(Montmorency)	40	2.78	-	0.078	3.49	1.80	0.2600	3.50	13.40
"	70	1.44	-	0.016	4.00	2.28	0.3308	3.30	13.20
"	100	1.20	-	0.007	4.24	2.50	0.3700	3.30	12.90
"	120	1.04	-	0.004	4.32	2.53	0.3832	3.25	12.90

[a]Determined by employing Zahn viscosimeter number 2

Table 16. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the fifteenth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.30	0.300	4.50	2.88	0.2700	3.65	14.10
"	70	-	3.68	0.190	4.89	3.83	0.3290	3.50	14.00
"	100	-	3.30	0.181	6.13	4.07	0.4010	3.35	13.81
"	120	-	2.86	0.175	6.44	4.12	0.4070	3.30	13.80
Sweet cherries									
(Lambert)	40	3.13	-	0.145	4.40	1.99	0.1600	3.70	14.10
"	70	1.51	-	0.080	5.10	2.89	0.2250	3.40	13.92
"	100	1.46	-	0.063	5.57	3.11	0.2340	3.35	13.30
"	120	1.38	-	0.060	5.60	3.12	0.2350	3.30	13.26
Sour cherries									
(Montmorency)	40	2.75	-	0.070	3.69	1.89	0.2620	3.50	13.40
"	70	1.28	-	0.013	4.19	2.33	0.3593	3.30	13.10
"	100	1.11	-	0.006	4.34	2.53	0.3803	3.30	12.85
"	120	1.02	-	0.004	4.36	2.55	0.3897	3.25	12.80

[a]Determined by employing Zahn viscosimeter number 2

Table 17. Effects of storage temperatures on the chemical changes in canned apricots, sweet and sour cherries after the sixteenth week of storage

Fruit variety	Storage temperature °F	Anthocyanin as chloride mg %	Total carotenoids mu/100 g.	Pectin as Ca- pectate %	Total reducing sugars %	Free reducing sugars %	Total titratable acidity %	pH	Viscosity in seconds[a]
Apricots									
(Moorpark)	40	-	4.26	0.294	4.50	2.93	0.2890	3.65	14.10
"	70	-	3.28	0.184	4.99	3.90	0.3470	3.45	13.95
"	100	-	3.04	0.173	6.25	4.10	0.4055	3.30	13.75
"	120	-	2.62	0.169	6.50	4.14	0.4094	3.25	13.70
Sweet cherries									
(Lambert)	40	3.02	-	0.140	4.50	2.10	0.1740	3.70	14.00
"	70	1.46	-	0.070	5.19	2.96	0.2310	3.35	13.85
"	100	1.28	-	0.059	5.60	3.12	0.2340	3.30	13.20
"	120	1.10	-	0.055	5.66	3.13	0.2370	3.40	13.15
Sour cherries									
(Montmorency)	40	2.64	-	0.066	3.80	2.00	0.2800	3.25	13.35
"	70	1.02	-	0.010	4.28	2.39	0.3680	3.25	13.00
"	100	0.94	-	0.005	4.40	2.55	0.3875	3.20	12.80
"	120	0.78	-	0.004	4.43	2.56	0.3900	3.15	12.80

[a]Determined by employing Zahn viscosimeter number 2