EFFECT OF FREEZING RATE AND STORAGE CONDITIONS ON THE DRAINED WEIGHT OF FROZEN PINEAPPLE

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SUMMARY

A standard routine for determining drained weight of frozen pineapple was developed. Increasing the thawing time from 48 to 54 hr had no effect on drained weight. Air-blast freezing at –25°F followed by steady storage temperatures at 0–10°F gave the highest drained weight values.

I. INTRODUCTION

During the early 1950's there was a considerable demand in England for bulk packs of quick-frozen pineapple for further processing and much attention was paid in that country to the drained weight of fruit obtained from each can. Wide variations were reported to Queensland canners and as a result the Queensland Department of Agriculture and Stock was asked to investigate the effect of freezing rates and storage conditions on the drained weight of pineapple.

Although numerous workers (Joslyn and Marsh 1932; Anon. 1932; Caldwell, Lutz, Moon, and Myers 1933; Woodroff 1938; Jacobs 1944) had varying opinions as to the effect of the rate of freezing of various fruits on their quality, little work appeared to have been carried out with pineapples. However, Joslyn and Hohl (1948) indicated that the loss in weight of frozen fruits after thawing was not only dependent on the handling of the product during thawing and draining but also on freezing, storage conditions and time of storage. To determine the weight loss on thawing they drained for a standard time of 2 min over a ⅛-in. mesh screen. Morris (1944) also pointed out that the drained weight of various fruits (which did not include pineapple) was affected by the rapidity of freezing as much higher drained weights were obtained by freezing in dry ice than by freezing at 0°F. Kethley, Cown, and Bellinger (1950) reported losses in the drained weight of strawberries varying from 8 to 25 per cent. as freezing rates were decreased; the drained weight also decreased with time of storage.

The experiment reported here was designed to utilize existing commercial facilities with particular reference to air-blast freezing.

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II. FACILITIES AND MATERIALS

The following commercial freezing facilities were used in the experiment:

(*a*) An air-blast freezer operating at –25°F.

(*b*) A cold room fitted with fans where the air temperature averaged –12°F but fluctuated from 0° to –25°F.

(*c*) A cold room without fans with a steady air temperature of 0°F.

(*d*) A cold room without fans with an average temperature of +10°F with fluctuations varying from +8° to +14°F.

Storage facilities used were the rooms described above under (*b*), (*c*), and (*d*). In selecting these, due consideration was given to normal carriage temperatures on shipboard, which were understood to vary from –10°F to +12°F.

The normal 30 lb cans measuring 14 in. x 9¼ in. x 6¼ in. and packed in a fibreboard carton were used throughout the trial. In order that the effects of the treatments would be as obvious as possible, pineapple pieces were used in preference to slices, since pieces have a greater surface area per unit weight and therefore probably lose more juice during thawing. Even though Joslyn and Marsh (1933) and Jacobs (1944) reported that the loss in drained weight is partly dependent upon the concentration as well as the type of sugar present, it was decided that a 43° Brix sucrose syrup would be used entirely as this was the composition required overseas. The cans were packed with 17½ lb of pineapple pieces and 12½ lb of 43° Brix syrup at normal temperature.

III. PRELIMINARY THAWING PROCEDURE INVESTIGATIONS

It was felt that the thawing temperature of 68°F reported by Joslyn and Marsh (1933) and Kethley, Cown, and Bellinger (1950) was rather high for a bulk pack as it might permit some microbial development during the long thaw, which was expected to take about two days. Preliminary experiments were therefore carried out to determine the rate of thawing at 50 and 68°F and to observe any difference in drained weight. Two uncartoned cans of fruit were frozen in rooms at –15°F and after remaining there for a week they were removed to thawing rooms which were fitted with fans to keep heat transfer rates at a maximum.

Three copper-constanton thermocouples were inserted in each 30 lb can in the positions indicated in Figure 1. The first can was placed in the room at 68°F and temperature measurements taken at frequent intervals. The recordings are tabulated in Table 1 and shown graphically in Figure 2. As expected, there was a more rapid increase in temperature in the external portion than in the centre of the can. After 20 hr, when the centre temperature was approximately 27°F (i.e. melting point), the temperature on the outside of the can was 34–35°F higher. This outside temperature then dropped, presumably owing to convection currents set up in the liquifying centre of the can and possibly the

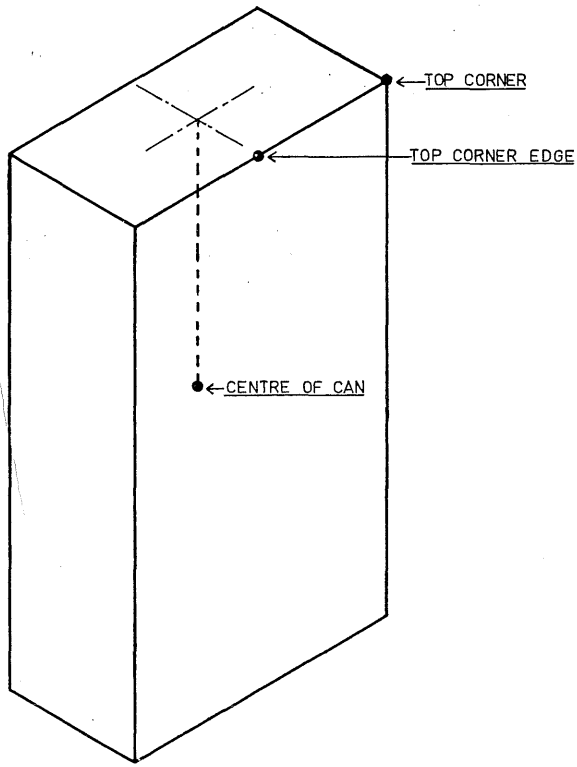

Fig. 1.—Positions of thermocouples in 30 lb can.

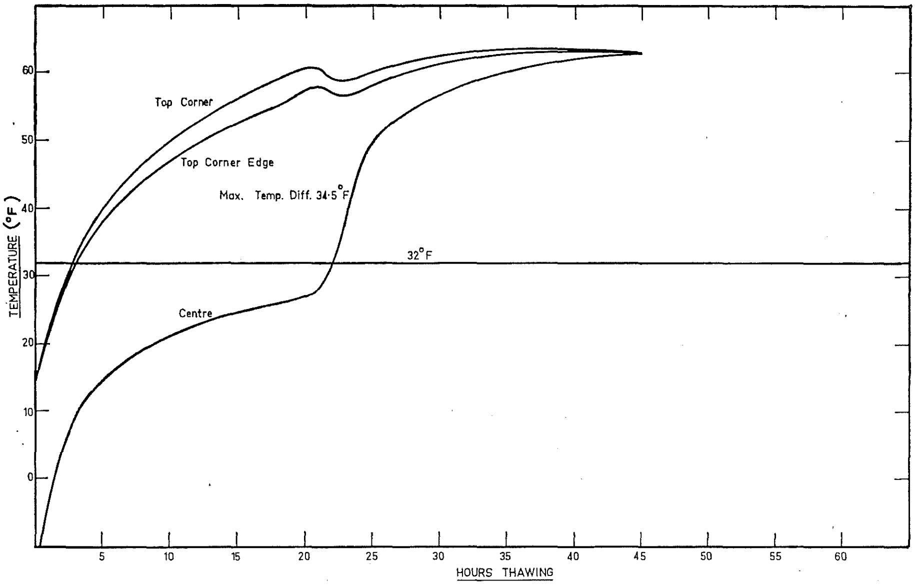

Fig. 2.—Thawing curves for 30 lb frozen pineapple; room 68°F.

rising of the remaining frozen portion to the top of the liquid. This would also account for the rapid rise in temperature in the centre of the can between the 22 and 25 hr periods. The temperature gradient between the thermocouples gradually decreased until an equilibrium was reached after about 45 hr, when the temperature was about 5°F lower than the room temperature.

TABLE 1

TEMPERATURE CHANGES IN 30 LB CANS OF FROZEN PINEAPPLE WHEN THAWED AT 68°F

Time of Day	Hours Thawing	Temperature (°F)		
		Centre	Top Corner Edge	Top Corner
3.00 p.m.	0	−15·5	11·3	11·1
3·30 p.m.	½	−8·7	19·0	19·2
4.00 p.m.	1	−4·5	23·3	22·7
4.30 p.m.	1½	0·4	27·1	27·0
5.00 p.m.	2	4·0	29·6	29·0
8·00 p.m.	5	15·2	39·3	40·2
8.00 a.m.	17	25·6	55·3	58·7
9.00 a.m.	18	26·1	56·3	59·9
10.00 a.m.	19	26·3	57·2	60·8
11.00 a.m.	20	27·0	58·7	61·5
12.00 noon	21	28·2	58·5	60·8
1.00 p.m.	22	32·8	56·5	58·5
3.00 p.m.	24	47·0	58·3	60·0
4.15 p.m.	25¼	50·5	59·2	60·5
4.30 p.m.	25½	51·2	59·5	60·7
8.45 p.m.	29¾	57·2	62·2	62·5
9.15 a.m.	42¼	63·2	63·2	63·1
11.30 a.m.	44½	63·5	63·0	63·1

NOTE.—A delay of ½ hr occurred between removal from cold rooms at −15°F and first reading.

The same thawing procedure was adopted with the second can, using a room temperature of 50°F. The results are tabulated in Table 2 and represented graphically in Figure 3. Temperature differences were generally smaller, the maximum gradient being 17°F. Since equilibrium was reached in about 45 hr also, it was decided to standardize on a 50°F thawing temperature.

Because the determination of the drained weight would be time-consuming for bulk packs and some delay might occur after cans had reached equilibrium, a further preliminary experiment was conducted to determine the effect of thawing for periods longer than 45 hr. Twelve cans were packed with fruit and syrup and frozen at 0°F in an air-circulated room. Cartons were not used. A week later the cans were removed to the thawing room at 50°F and stacked at least 9 in. apart to ensure adequate air movement. During the thawing period, temperature measurements by means of thermocouples were taken at the centre of each can to ensure that all cans were rising in temperature at an equal rate. Four cans were removed after each of the following thawing times:—45 hr, 58 hr, and 62½ hr.

TABLE 2

Temperature Changes in 30 Lb Cans of Frozen Pineapple when Thawed at 50°F

Time of Day	Hours Thawing	Temperature (°F)		
		Centre	Top Corner Edge	Top Corner
12.00 noon	0	−15·2	4·2	7·6
12.30 p.m.	½	−10·8	8·8	11·9
1.00 p.m.	1	−6·3	12·2	16·0
1.30 p.m.	1½	−2·0	15·2	18·5
2.00 p.m.	2	2·5	17·3	20·9
2.30 p.m.	2½	4·5	19·4	22·0
3.00 p.m.	3	6·5	21·3	22·9
3.30 p.m.	3½	7·9	21·8	23·4
4.30 p.m.	4½	11·0	23·6	25·3
8.30 a.m.	20½	23·9	35·8	40·0
9.00 a.m.	21	24·0	36·3	40·0
9.30 a.m.	21½	24·1	36·5	40·2
11.30 a.m.	23½	24·7	37·7	41·5
12.00 noon	24	24·8	37·8	41·6
1.00 p.m.	25	24·9	38·2	42·0
2.00 p.m.	26	25·2	39·0	42·9
2.30 p.m.	26½	25·7	39·5	43·4
8.30 a.m.	44½	45·2	46·0	47·5
9.30 a.m.	45½	45·2	45·6	46·2

Note.—A delay of ½ hr occurred between removal from cold room and first reading.

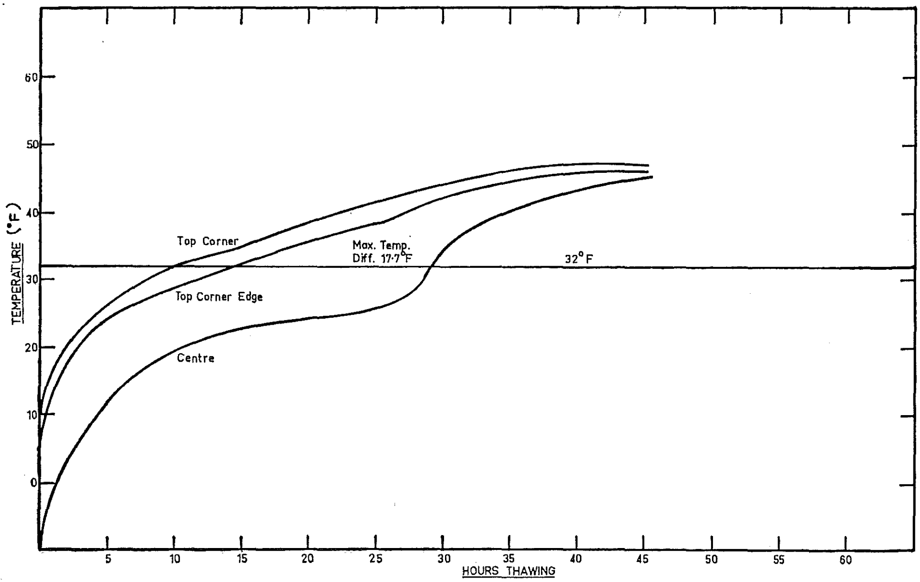

Fig. 3.—Thawing curves for 30 lb frozen pineapple; room 50°F.

The drained weight was determined by the following method, which was subsequently adopted for the remainder of the investigations:—

The whole top was removed from the can and the contents emptied quickly into two $\frac{1}{8}$ in. mesh stainless steel screens each 18 in. in diameter. The pieces of fruit were spread out evenly as the fruit was being poured from the can, and exactly 2 min after spreading was complete the screen contents were tipped into a bucket and weighed, the net weight being the drained weight. It was noted that within 5 min of completing the 2 min draining, sufficient juice had been exuded from the drained fruit to cover the pieces again. This indicated the desirability of a minimum pressure on the fruit, and this could only be obtained by having a thin layer of pieces on the screen during draining. The results are shown in Table 3. There was no significant difference in drained weight between any of these thawing times ranging from 45 to 62½ hr and it was therefore decided that for the principal experiment a thawing time of 48–54 hr would be used.

TABLE 3

Drained Weight of 12 Cans used to Determine Importance of Time of Thaw

Can No.	Weight	Hours Thawing	Centre Temperature (°F)	Syrup Temperature (°F)	Mean for Each Set of 4
	lb oz				lb oz
1	15 5	45	33·5	51	
2	15 12½	45	33·5	51	15 7⅛
3	15 4	45	33·5	51	
4	15 10	45	33·5	51	
1	15 5	58	44·5	53·6	
2	15 7	58	44·5	53·6	15 7
3	15 8	58	44·5	55·4	
4	15 8	58	44·5	56·5	
1	15 10	62½	48·5	55·4	
2	14 14	62½	48·5	55·4	15 3¾
3	15 3	62½	48·5	57·2	
4	15 0	62½	48·5	57·2	

Note.—The centre temperature was the temperature at the centre of the can just prior to draining, and the syrup temperature was taken immediately after draining.

IV. MAIN EXPERIMENT

Seventy-two cans were packed in late August with pineapple pieces from the winter crop and then cartoned and wired in accordance with the normal commercial procedure. Six replications were used for each of the 12 treatments listed in Tables 4 and 5. As the minimum time delay between packing and freezing was about 1 hr due to the disposition of preparation and freezing facilities, a further variable was introduced into the blast-freezing trial by allowing half the cans to stand for another 2 hr before freezing. A thermocouple was

TABLE 4

DRAINED WEIGHTS, CENTRE TEMPERATURES AND SYRUP TEMPERATURES OF 72 CANS USED IN FREEZING AND STORING EXPERIMENT

Freezing Method	Storage Conditions	Code No.	Drained Weight	Mean Drained Weight	Centre Temperature (°F)	Syrup Temperature (°F)
			lb. oz.	lb. oz.		
Air-blast	—15°F	A1	16 13	16 9·3	47	55
		2	16 10		49	56
		3	16 3		50	56
		4	16 14		49	56
		5	16 7		50	54
		6	16 9		49	55
Air-blast	0°F	B1	16 11	10 10·3	48	54
		2	16 12		48	54
		3	16 11		48	53
		4	16 11		48	53
		5	16 9		46	53
		6	16 8		48	53
Air-blast	10°F	C1	16 12	16 15·1	47	53
		2	17 0		46	51
		3	17 1		45	49
		4	17 0		45	50
		5	16 14		45	50
		6	17 0		45	50
Air circulated ..	—15°F	G1	16 9	16 7·5	45	51
		2	16 7		47	49
		3	16 6		41	51
		4	16 6		47	53
		5	16 4		48	54
		6	16 13		45	53
0°, still air ..	0°F	H1	16 6	16 5·1	48	53
		2	15 12		46	52
		3	16 6		47	53
		4	16 4		48	53
		5	16 10		46	53
		6	16 9		46	51
10°, still air ..	10°F	J1	16 4	16 1·3	47	58
		2	15 13		47	56
		3	15 15		46	52
		4	16 2½		46	53
		5	16 1		48	55
		6	16 5		45	55

Freezing Method	Storage Conditions	Code No.	Drained Weight	Mean Drained Weight	Centre Temperature (°F)*	Syrup Temperature (°F)†
			lb. oz.	lb. oz.		
Air-blast, 2 hr. stand	—15°F	D1	16 6	16 6·5	46	52
		2	16 7		48	53
		3	16 3		45	51
		4	16 8		45	53
		5	16 7		46	52
		6	16 8		46	52
Air-blast, 2 hr. stand	0°F	E1	16 12	16 3·3	45	51
		2	16 13		45	51
		3	16 13		46	52
		4	16 10		39	51
		5	17 1		45	48
		6	17 1		38	46
Air-blast, 2 hr. stand	10°F	F1	17 0	16 10·5	48	50
		2	16 12		46	50
		3	16 7		46	51
		4	16 10		45	51
		5	16 12		45	50
		6	16 0		46	50
10°, still air ..	10°F (for 8 weeks then 0°F)	M1	16 1	16 2	47	56
		2	16 1		48.	55
		3	16 3		47	53
		4	16 3		48	53
		5	16 0		47	53
		6	16 4		47	53
O°, still air ..	0°F (for 8 weeks then 10°F)	K1	16 6	16 4·8	45	54
		2	16 4		45	55
		3	16 5		46	54
		4	16 6		46	54
		5	16 4		44	52
		6	16 4		47	55
10°, still air ..	10°F	L1	16 5	16 1	45	54
		2	15 10		45	55
		3	16 1		46	54
		4	16 4		46	54
		5	15 15		46	54
		6	16 3		46	55

* Centre temperature of can just prior to draining.
† Syrup temperature immediately after draining.

put in an extra can placed in the blast freezer to observe when freezing was complete. Although the product had passed through the freezing zone in 15–20 hr, the cans were left in the blast freezer for a total of 48 hr, by which time the centre of the can had reached –20°F. The cans of frozen pineapple were then transferred to the storage rooms.

In each freezing chamber the cans were spaced several inches apart to allow plenty of air circulation, thereby ensuring that all cans in each room received equal treatment.

After storage for 22–23 weeks the cans were placed in storage at −15°F for 7 days to ensure that they were all the same temperature. They were then promptly removed to the room, held at 50°F, and thawing commenced under the controlled conditions set out. Thermometers were placed in about 25 per cent. of the cans to check temperatures. Between 48 and 54 hr after removal from frozen storage the drained weights were determined. The results are set out in Table 4 and the mean values in Table 5.

TABLE 5

Summary of Mean Values on Table 4

Freezing Method	Storage Conditions	Mean Drained Weight lb	oz
Air-blast	11° fluct.	16	15·2
Air-blast (2 hr stand)	0° fluct.	16	13·7
Air-blast (2 hr stand)	11° fluct.	16	10·5
Air-blast	0° fluct.	16	10·3
Air-blast	−15° fluct.	16	9·3
Air circulated (−15°)	−15° fluct.	16	7·5
Air-blast (2 hr stand)	−15° fluct.	16	6·5
0° still air	0° fluct.	16	5·2
0° still air	8 weeks 0° fluct. 14 weeks 11° fluct.	16	4·8
11° still air	8 weeks 11° fluct. 14 weeks 0° fluct.	16	2·0
11° still air	11° fluct.	16	1·4
11° still air	11° fluct.	16	1·0
Necessary differences for significance	5% level	3	5
	1% level	4	7

There was no significant difference between the two methods of air-blast freezing. This finding gave the processors a certain amount of latitude in the time delay before freezing provided quality was not overlooked by permitting unnecessary delays and subsequent loss in flavour due to the effect of micro-organisms or enzymes. At that time, freezing facilities were some miles from the canneries and some delay was inevitable.

Losses in drained weight varied from 3·2 to 8·2 per cent. depending on freezing and storage conditions. These losses were considered quite satisfactory and contrasted sharply with results reported from England, where an average loss of 15 per cent. was claimed. It was considered that manufacturers in that country were not taking due care to ensure that juice was not expressed from the fruit during draining. The results for pineapple compared very favourably with other fruits reported by Jacobs (1944), who indicated that some fruits had drip losses as high as 44 per cent. Little or none of the original texture of the pineapple was lost and this observation corresponded with the findings of Eckart and Cruess (1931).

Air-blast freezing, regardless of storage conditions, resulted in higher drained weights than freezing in still air at 0°F or +10°F. This result indicated that the slight extra expense of air-blast freezing was probably warranted and that the installation of such freezers in canneries was desirable. Fair results were obtained by freezing in a room at –15°F with air circulation and this method was considered to be the best expedient if air-blast freezing facilities were not available.

With the air-blast frozen samples, storage at temperatures of 0° and +10°F gave significantly higher drained weights than storage at –15°F. This result was unexpected, but the greater loss at the lower temperature was probably due to severe fluctuations in product temperature due to air circulation and the wide temperature range of the room. Very little product temperature change would have occurred at 0° and + 10°F because there was no forced air circulation and air temperature fluctuations were small. The variation in individual can weights when stored at + 10°F tended to be greater than when stored at 0°F, suggesting that 0°F was the best storage temperature.

These experiments were conducted on winter pineapples, which are normally slightly firmer than summer fruit. The drained weight of summer pineapples could therefore be expected to be slightly less. No effort was made to consider maturity aspects as each can contained a blend of all maturities. It is possible, however, that variation within treatments may have been partly due to maturity differences.

V. CONCLUSIONS

To obtain the highest drained weight after thawing, pineapple pieces in syrup should be air-blast frozen at temperatures of about –25°F or lower. There should be a minimum delay between packing and placing in the freezer in order to maintain the best quality, but delays up to 3 hr do not significantly affect the drained weight. Under carefully controlled thawing conditions the loss in drained weight of quick-frozen pineapple stored at a steady temperature of +10°F or lower should not exceed 10 per cent. Steady air temperatures at about 0°F are conducive to high drained weight values (as well as quality). Large changes in product temperatures tend to adversely affect drained weight. Maturity is expected to have some effect on drained weight.

VI. ACKNOWLEDGEMENTS

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