

The freezing of mango slices (*Mangifera indica* var. Kensington)

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'Kensington' mango slices were frozen with sucrose syrup, with dry sucrose and without sugar addition, using blast freezing at -30°C , and still air freezing at -18°C . According to taste panel assessment, slices frozen in syrup were best. A syrup strength of 200 g/L was sufficient to produce a high quality product. The blast-frozen slices had a higher texture score than the still air-frozen slices.

The annual production of 'Kensington' mangoes (*Mangifera indica* var. Kensington) in Queensland, currently at 3100 t, is expected to rise to 31 000 t by 1996 (Luxton 1981). Currently, 20% of the crop is processed as purée (Bradley, pers. commun.) and this proportion is likely to remain constant. Frozen mango slices may well find a good market, utilising the expected increased production.

Mango slices have been frozen in syrup, with dry sugar, and without sugar addition. Orr and Miller (1955) compared the freezing quality of 19 Hawaiian mango varieties in sucrose syrup (200–350 g/L), with dry sucrose, and as purée, with and without added ascorbic acid. The syrup packs had the best quality, with 200 g/L being preferred to higher concentrations, although the ratio of fruit to syrup was not reported. Ascorbic acid addition did not affect quality. Leverington (1957) compared 'Kensington' mangoes frozen in a heavy sucrose syrup (500 g/L) with a 2:1 ratio of fruit to syrup, in dry sucrose (3:1), and as mango purée with added sugar and gelatine. All products were found to be attractive. Gorgatti Netto, Bleinroth & Lazzarini (1973) froze 'Haden' mango slices in sucrose and glucose syrups (250–450 g/L), with a fruit to syrup ratio of 2:1. Syrup concentration had no effect, but sucrose was preferred to glucose, and calcium chloride addition (700 mg/L) marginally improved quality. Brekke *et al.* (1975) froze five Hawaiian mango varieties in sucrose syrup (350 g/L), with dry sucrose, and as purée. The syrup packs had the best flavour, but textural differences between the syrup and dry sugar packs were only slight. Cooke *et al.* (1976) reported that 'Alphonso' mango slices frozen in 400 g/L sucrose syrup had a better flavour than those frozen in 200 g/L syrup.

Several mango freezing methods have been reported. In comparing plate freezing, air-blast freezing and polyphase freezing, Leverington (1957) noted that the last method resulted in the best appearance and texture. Cooke *et al.* (1976) compared domestic deep freezing, air-blast freezing, and cryogenic freezing, and found quality was unaffected by freezing rate.

Despite these studies, information about the optimum freezing technique for 'Kensington' mangoes is incomplete. No recent research on Queensland fruit has been published. The aim of this work was to study the effect of pack style, syrup concentration and freezing method on the sensory quality of frozen 'Kensington' mango slices.

Materials and methods

Harvesting

Unripe 'Kensington' mangoes were harvested at weekly intervals over 2 seasons (December 1980, and November and December 1981) from the Bowen Horticultural Research Station in north

Queensland. Packed in cardboard cartons the fruit were transported by rail to the laboratory in Brisbane.

Ripening

The fruit was dipped in the fungicide *Benomyl* (1 g/L) at 52°C for 5 min to prevent anthracnose development (Muirhead 1976) and then ripened in an ethylene gas atmosphere (100 $\mu\text{L/L}$) (30°C , 90% relative humidity) according to Bradley and Scudamore-Smith (pers. commun.). Ripeness was judged subjectively by assessing softness of individual fruit twice daily. Ripe fruit were removed and stored at 30°C until processed.

Pack styles and syrup concentration

The fruit were washed and the broad sides (cheeks) cut from the seed with a sharp knife, sliced longitudinally (20 mm width) and peel removed. Fruit were packed in three styles: as slices in sucrose syrups, slices with dry sugar, and as individually quick-frozen (IQF) slices.

Slices in syrups were packaged in rectangular PVC trays (500 g capacity). Fruit fill weights for the syrup packs were 313 g and 400 g to give 5:3 and 4:1 fruit to syrup ratios respectively. Sufficient sucrose syrup (300 g/L in the 1980 trial, and 100, 200, 300 or 400 g/L in 1981) was added to give a total fill weight of 500 g. The fruit to syrup ratio was constant at 5:3 in the 1981 experiment.

The dry-sugar packs (500 g fill weight) were prepared from fruit slices gently mixed with sugar in the ratio 7:1 or 15:1.

IQF slices

IQF slices were frozen without sugar or syrup addition on wire mesh trays, before packaging in PVC trays. Packs were closed with PVC lids.

Freezing methods

Fruit were frozen in both still and moving air. The slices in syrups and slices with dry sugar were frozen after packaging, while IQF slices were frozen before packaging. Still freezing was carried out at -18°C for 2 h (IQF packs) and 7 h (all other packs). Blast-freezing was carried out in a pilot-scale cross-draft blast freezer (-30°C , air velocity 5 m/sec). The residence times were 20 min (IQF packs) and 1 h (all other packs). The samples were transferred to a room at -18°C and stored for 3 months before assessment.

Statistical designs

Optimal pack style

This experiment was designed as a randomised block layout comprising 10 treatments replicated over 3 harvest times. The treatments were partitioned factorially with 5 pack styles (5:3 syrup, 4:1 syrup, 7:1 dry-sugar, 15:1 dry-sugar and IQF), and 2 freezing methods (still freezing at -18°C and blast-freezing at -30°C).

Optimal syrup concentration

This experiment was also a randomised block layout with 8 treatments replicated over 4 harvest times. The treatments were

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partitioned as a factorial of 4 syrup concentrations (100, 200, 300 and 400 g sugar/L) and 2 freezing methods (still-freezing at -18°C and blast-freezing at -30°C).

Organoleptic assessments

The frozen slices were thawed overnight at 5°C and evaluated for appearance, flavour, texture and general acceptability. A taste panel of 15 adults selected from laboratory staff rated the samples on a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. The panelists were familiar with taste panel techniques but were not trained in mango quality assessment. At each session, 4 samples (served at ambient temperature) were evaluated by the panel. Taste panel data were interpreted by analysis of variance, followed by least significant difference testing at the $P < 0.05$ level.

Results

There were no significant interactions between freezing method and pack style or freezing method and syrup concentration. Main effects only have been tabulated.

Effect of pack style

Mean scores for the various pack styles are shown in Table 1.

General acceptability

The 4:1 syrup pack received a higher general acceptability score than the dry-sugar and IQF packs ($P < 0.05$).

Appearance

The syrup packs and IQF packs received significantly higher scores ($P < 0.05$) than the dry sugar packs for appearance.

Flavour

The dry-sugar packs and syrup packs received significantly higher flavour scores ($P < 0.05$) than the IQF pack.

Texture

The 4:1 syrup pack was scored significantly above the dry-sugar packs ($P < 0.05$) for texture. The IQF pack also received a higher texture score than the 15:1 dry-sugar pack ($P < 0.05$).

Effect of freezing method

Taste panel means for freezing methods are shown in Table 2.

General acceptability and appearance

Freezing method did not significantly affect general acceptability and appearance scores.

Flavour

The flavour scores of treatments frozen in still air were significantly higher ($P < 0.05$) than the blast frozen packs in 1981 but not in 1980.

Texture

The texture scores of the blast-frozen packs were significantly higher than those of the still-frozen samples ($P < 0.05$).

Effect of syrup concentration

Taste panel means for the various sugar syrup concentrations are shown in Table 3.

General acceptability, flavour and texture

The 100 g/L syrup treatment received significantly lower flavour, texture and general acceptability scores ($P < 0.05$) than the other syrup treatments.

Appearance

Syrup strength had no significant effect on appearance scores ($P < 0.05$).

Discussion and conclusions

The results indicate that mango slices frozen in syrup yielded a product of higher general acceptability than slices packed with dry-sugar and IQF slices. This agrees with the findings of Orr and Miller (1955), Leverington (1957) and Brekke *et al.* (1975). The results also show that 100 g/L syrup concentration is too low, 200 g/L is satisfactory and 300 and 400 g/L give no improvement on 200 g/L syrup. These findings agree with earlier work (Orr & Miller 1955) but differ from the results of Cooke *et al.* (1976) who reported a flavour preference for 400 g/L syrup concentration. The discrepancy is possibly due to varietal or ripeness differences or varying taste panel preference.

The dry-sugar packs had a ragged slice appearance

Table 1. Scores* of the effect of pack style on frozen mango slices

Pack Style	Appearance	Flavour	Texture	General acceptability
Slices in syrup (5:3)	7.4a	6.1bc	5.9ac	6.0ab
Slices in syrup (4:1)	6.6ab	6.3ac	6.4a	6.3a
Slices with sugar (7:1)	4.3c	6.7ab	5.6bc	5.7ab
Slices with sugar (15:1)	4.1c	6.8a	5.3c	5.5b
IQF slices	6.0b	5.3d	6.1ab	5.4b
Standard error	0.3	0.2	0.2	0.2

* Mean scores of 15 panelists

Means followed by a common letter are not significantly different ($P < 0.05$)

presumably because of the effect of mixing the slices with sugar causing physical damage and osmotic changes. Orr and Miller (1955) reported a similar finding and concluded that osmotic effects were responsible for the inferior appearance of fruit frozen with dry sugar. The ratio of fruit slices to syrup or sugar was not shown to have any effect on quality in this work, although Orr and Miller (1955) found adverse textural changes with a high rate (32:1) of fruit to dry-sugar, compared to lower ratios (8:1 and 10:1). The IQF slices had a low flavour score which may have been caused by the lack of cover syrup protection. Woodroof and Luh (1975) pointed out that packing fruit in syrup excludes air, and had beneficial effects on colour, flavour and texture.

Freezing methods affected texture and flavour scores, although the magnitude of the differences was small. The overall effect on general acceptability was not significant. This is in general agreement with the findings of Cooke *et al.* (1976). The higher flavour scores of the still-frozen packs (in the 1981 trial) may have been due to better equilibration of the fruit with the syrup during the slow freezing. Overall, this work indicates that Queensland 'Kensington' mango slices should be frozen as slices in sucrose syrup (200 g/L) for optimum sensory quality and that still-freezing and blast-freezing are equally acceptable.

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Table 2. Scores* of the effect of freezing method on frozen mango slices

Freezing method	Appearance		Flavour		Texture		General acceptability	
	1980	1981	1980	1981	1980	1981	1980	1981
Still freezing	5.5a	6.2a	6.3a	6.5a	5.6a	5.9a	5.7a	6.1a
Blast freezing	5.9a	6.1a	6.2a	6.1b	6.2b	6.4b	5.9a	5.9a
Standard error	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1

* Mean scores of 15 panelists

For each year means followed by a common letter are not significantly different ($P < 0.05$)

Table 3. Scores* of the effect of syrup concentration on frozen mango slices

Syrup concentration	Appearance	Flavour	Texture	General acceptability
100	6.2a	5.4b	5.9b	5.3b
200	6.1a	6.5a	6.2a	6.2a
300	6.2a	6.6a	6.2a	6.2a
400	6.2a	6.7a	6.3a	6.4a
Standard error	0.2	0.2	0.1	0.2

* Mean scores of 15 panelists

Means followed by a common letter are not significantly different ($P < 0.05$)

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