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PROCESSING QUALITY OF ORANGES GROWN IN THE NEAR NORTH COAST AREA OF QUEENSLAND

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SUMMARY

A study was made of the influence on processing quality of variety, rootstock, time of picking, seasonal meteorological conditions, farm practices and district.

Joppas were fairly comparable with Valencias in most aspects of processing quality.

Fruit from trees on trifoliate orange and sweet orange rootstocks was superior in processing quality to that from trees on rough lemon rootstock.

Processing quality improved throughout the harvesting season.

Substantial seasonal variation was noted in some processing quality characteristics.

There were large differences between farms within the Palmwoods district in all characteristics studied.

Correlations between tree age, fruit size and some internal quality characteristics were established.

Fruit grown in the Elimbah–Beerwah district was larger and lower in soluble constituents than that grown in the Palmwoods-Maroochy district.

Processing quality was inferior to that of Florida oranges and only a small percentage of the fruit would satisfy the minimum requirements for oranges for processing laid down by Florida processors.

I. INTRODUCTION

The expansion of the orange processing industry in Australia in recent years, although far less spectacular than in the U.S.A., has nevertheless been consistent and about 20% of the Australian orange crop is now processed. With expansion of orange processing comes the need for a detailed study of fruit quality and of the influence which various factors may exert on this quality. Hence orange quality has been the subject of investigations by workers in many of the citrus-growing regions of the world—e.g. in Florida by Harding, Winston, and Fisher (1940) and Miller, Winston, and Fisher (1941); in California by Sinclair and Bartholomew (1944) and Marsh (1953); in India by Siddappa and

Bhatia (1954) and Singh (1954); in Israel by Braverman and Carmi (1937) and Samisch and Cohen (1949); in South Africa by Marloth (1949, 1950); in Italy by Fratoni and Spadoni (1951) and Lisanti and Catalano (1956); and in the southern States of Australia by Kefford and Chandler (1961). Earlier workers include Copeman (1931) in South Africa and Quinn (1932) in South Australia. The studies of these and other workers have shown that fruit quality is extremely variable and may be markedly affected by many different factors.

In Queensland, the industry began a rapid expansion about 1960. Trials were therefore carried out at this Laboratory in 1963 and 1964 to study the influence exerted by variety, rootstock, time of picking, seasonal conditions, farm practices and regional aspects on the processing quality of oranges grown in the Near North Coast area of south-eastern Queensland. This area, which produces about 40% of Queensland's factory intake of oranges, was chosen for the work mainly because of its proximity to the laboratory.

II. EXPERIMENTAL

(a) Variables

Varieties.—Two varieties, Joppa and Valencia, were investigated, as these are the only two varieties utilized in significant quantities for processing in Queensland. The ratio of Joppas to Valencias processed in the State in 1964 and 1965 was approximately 3:7.

Nine of the farms sampled in 1964 had both Joppas and Valencias growing on rough lemon rootstock and the average ages of the trees for the two varieties were approximately equal. Thus it was possible to make a comparison between varieties, treating farms as replicates.

Rootstocks.—Three rootstocks—rough lemon (RL), sweet orange (SO) and trifoliate orange (TRI)—were investigated. These are the only rootstocks used in commercial orange plantings in Queensland; approximately 90% of the Queensland orange crop is grown on rough lemon rootstock.

Only four farms in the area had Joppas growing on more than one rootstock. On three of these farms, the trees on trifoliate orange and sweet orange were much younger than those on rough lemon. Tree age was uniform on only one farm and rootstock comparisons for the Joppa variety were thus limited to one farm, using trees as replicates. There were 10 farms which had Valencias growing on more than one rootstock and the average ages of trees on the three rootstocks were approximately equal. Thus rootstock comparisons were possible, using farms as replicates.

Time of picking.—The fruit was harvested at 3-weekly intervals over 3-month periods which were centred on the respective commercial harvesting seasons for the two varieties. Joppas were sampled over the period from the second week in May to the second week in August, and Valencias from the third week in July to the third week in October. Five pickings were made for each variety. Changes in the various processing quality characteristics during the

1963 and 1964 seasons were plotted against time for each variety and rootstock on each farm and composite graphs were then obtained by first combining the individual farm graphs for each season and then combining the two seasons.

Season.—On eight Valencia farms and four Joppa farms, fruit was picked from the same trees in the 1963 and 1964 seasons. Seasonal variation, which is considered to be due mainly to differences in meteorological conditions, was noted for each of these farms, and the farm means were combined to give overall seasonal means.

Farms.—Valencias were sampled from nine farms in 1963 and 15 farms in 1964. Joppas were sampled from four farms in 1963 and 10 farms in 1964. It has been estimated that the farms sampled in 1964 produced about 70% of the total Near North Coast Joppa and Valencia crops.

Of the farms sampled in 1964, 10 Joppa farms and 10 Valencia farms were located in the Palmwoods district. Differences occurring between these farms in the processing quality of fruit from trees on rough lemon were noted. Since soil and climatic conditions within the Palmwoods district are fairly uniform, these differences are considered to be mainly due to differing farm practices and tree ages.

Districts.—A comparison of processing quality was made between Valencias grown in the Palmwoods-Maroochy district and those grown in the Elimbah-Beerwah district. Eleven farms in the former area and four in the latter were sampled. The average tree ages for the two areas were approximately the same.

General.—In comparing varieties, rootstocks, seasons, farms and districts, averages for the various processing quality characteristics (except those for bitterness ratings) were taken over the 3-month periods of sampling. Bitterness comparisons were made on juice from fruit picked early in the commercial harvesting season, because bitterness is seldom a problem late in the season.

(b) Sampling Technique

Four trees were selected at random for each variety-rootstock combination on each farm. Twenty fruits were picked from each selected tree at each harvest, Appleman and Richards (1939) and Samisch and Cohen (1949) having reported that 20 fruits constitute a representative sample. The selected fruits were judged to be of average size and colour for the tree at that harvest. Picking was evenly distributed around the outside of the tree.

(c) Processing Technique

The juice was extracted with a mechanical hand-reamer and passed through a 0·05-in. perforated metal screen to remove seeds, rag and coarse pulp. After various quality determinations had been made on the fresh juice, the total soluble solids content was brought to 13·5° Brix by the addition of sugar, and pH was adjusted to 3·5 by the addition of either caustic soda or citric acid. The juice was then packed into 15-oz. epoxy-lacquered cans and closed under a 15-in vacuum. The cans were steam heated for 3 min. at 140 r.p.m. in a spincooker

to a can centre temperature of 190°F and then rapidly water-cooled. After being stored at room temperature for 2 months, they were held at 0°F until colour and vitamin C analyses and organoleptic evaluations of bitterness, off-flavours and general acceptability could be carried out.

(d) Processing Quality Determinations

Mean fruit weight for a particular tree at a particular harvest was taken as the mean weight per fruit calculated from the total weight of the 20 fruit in the sample.

Percentage of juice recovery was determined by dividing weight of extracted juice by weight of fruit and expressing the result as a percentage.

Total soluble solids (*T.S.S.*), expressed as °Brix, was measured by a refractometer.

Soluble solids per ton was calculated from T.S.S. and percentage juice recovery and represents the weight (in lb) of soluble solids in each long ton of fruit processed.

Acidity was determined by potentiometric titration of a 10-ml aquilot of juice with N/10 NaOH and is expressed as percentage anhydrous citric (w/v).

T.S.S./acid was calculated by dividing T.S.S. in °Brix by the acidity expressed as percentage anhydrous citric (w/v).

pH was measured with a Pye glass-electrode meter.

Bitterness was determined organoleptically, using 6–8 trained tasters. The canned juice was stored at room temperature for 2 months and then held at 0°F until it was presented to the panel. All samples were canned at the same T.S.S. and pH in order to minimize errors caused by differences in sweetness and sourness. The tasting scale used was:—0, non-bitter; 1, bitterness doubtful; 2–3, slightly bitter; 4–5, moderately bitter; 6–7, bitter; 8–9, strongly bitter; 10, extremely bitter. Three samples were presented at each session and six replications were obtained for each sample.

Off-flavours in the canned and stored juice were evaluated by a consumer panel of about 70 members, selected from a diversity of occupations. The scale used was:—10, indistinguishable from fresh juice; 8–9, approaching fresh juice; 6–7, palatable but departing from fresh flavour; 4–5, noticeable off-flavour or lack of character; 2–3, pronounced off-flavour; 0–1, undrinkable, nauseating.

General acceptability of the canned and stored juice was evaluated by the same consumer panel, using the following scale:—10, like very much; 8–9, like moderately; 6–7, acceptable; 4–5, neither like nor dislike; 2–3, dislike moderately; 0–1, dislike very much.

Ascorbic acid in the canned and stored juice was determined by titration with 2,6-dichlorophenolindophenol to a visual end point.

Colour of the canned and stored juice was determined quantitatively by extracting with a 1:1 alcohol, petroleum-ether mixture and reading the optical density of the extract at 426 mμ with an Optica spectrophotometer. Absorption

curves were obtained for Joppa and Valencia juices from three rootstocks at various stages of maturity and maximum absorption was found to be at 426 mμ in all cases. Optical density was converted to total carotenoids in mg β-carotene/100 ml juice), using the method of Higby (1962). Juice colour was also determined visually, using the U.S.D.A. colour comparator tubes as described by U.S.D.A. (1964) in their standards for grades of frozen concentrated orange juice. A strong correlation was established between the visual and quantitative determinations ($r = +0{\cdot}908$, $P < {\cdot}001$).

III. RESULTS AND DISCUSSION

(a) Varieties

The composite means for the various processing quality characteristics for the nine farms from which both Joppas and Valencias on rough lemon were sampled in the 1964 season are shown in Table 1.

Joppas were higher than Valencias in fruit weight, pH and T.S.S./acid, and Valencias were higher than Joppas in percentage juice recovery, acidity, off-flavour rating, general acceptability and juice colour. Means for T.S.S. per ton and ascorbic acid were higher for Valencias than for Joppas and means for T.S.S. and bitterness were lower for Valencias than for Joppas, but these differences were not significant at $P < 0{\cdot}05$.

The varietal comparison showed that Joppas are fairly comparable to Valencias in most aspects of processing quality. The comparatively high acidity and low pH and T.S.S./acid of Valencias suggests that the present harvesting season for that variety should be delayed somewhat.

Nothing has been found in the literature concerning the processing quality of Joppas. Other mid-season varieties have been studied by various workers, however, and the following observations, which are in agreement with observations made in this trial, have been made. Westbrook and Stenstrom (1957) presented data which showed that Florida mid-season varieties were comparable to Valencias in T.S.S.; Harding, Winston, and Fisher (1940) in Florida and Cohen (1956) in Palestine found no difference in ascorbic acid between mid-season varieties and Valencias; Wenzel *et al.* (1958) reported that colour and flavour of Florida frozen concentrated Valencia juice was better than that of early and mid-season varieties; Samisch and Cohen (1949) reported that Valencias in Palestine were higher in acidity, ascorbic acid, percentage juice recovery and juice colour, but lower in fruit weight and approximately equal in T.S.S. to the mid-season Shamouti (Jaffa) variety.

(b) Rootstocks

Rootstock averages for the 1963 and 1964 seasons for the Maroochy Horticultural Research Station in the case of Joppas and for the 10 farms on which rootstock comparisons were made in the case of Valencias are shown in Table 2. Off-flavours, general acceptability, ascorbic acid and juice colour were not determined in 1963.

TABLE 1

VARIETAL MEANS

——	Fruit Weight (g)	Juice Recovery (%)	T.S.S. (°Brix)	T.S.S. (lb/ton)	Acidity (% anhydrous citric)	pH	T.S.S./Acid	Bitterness Rating	Off-flavour Rating	General Accept-ability Rating	Ascorbic Acid (mg/100 ml)	Juice Colour	
												Total Carotenoids (mg beta-carotene/ 100 ml)	Visual Determina-tions
Joppa	155	46·9	10·09	106	1·23	3·28	8·56	2·39	5·0	4·7	37·3	0·78	39
Valencia	142	51·0	9·86	113	1·47	3·18	7·09	1·84	5·8	5·7	38·5	1·48	40
Significance ..	**	**	N.S.D.	N.S.D.	**	**	**	N.S.D.	**	**	N.S.D.	**	

* Significant at 5% level. ** Significant at 1% level. N.S.D. Not significantly different.

TABLE 2

ROOTSTOCK MEANS

Item	Year	Joppa				Valencia			
		RL	SO	TRI	Significance	RL	SO	TRI	Significance
Fruit weight (g)	1963	167	179	168	NSD ..	182	183	176	NSD
	1964	169	162	164	NSD ..	157	156	167	NSD
Juice recovery (%)	1963	48·0	51·0	51·2	TRI > RL* SO > RL*	51·5	53·2	54·5	TRI > RL* SO > RL*
	1964	50·1	51·1	50·1	NSD ..	51·1	52·7	54·2	TRI > RL*
T.S.S. (°Brix) ..	1963	10·3	10·9	11·2	TRI > RL** SO > RL*	9·3	10·0	10·9	TRI > RL* TRI > RL** SO > RL**
	1964	10·3	10·9	11·5	TRI > RL** SO > RL* TRI > SO*	9·2	10·0	10·7	SO > RL** TRI > RL** TRI > SO**
T.S.S. (lb/ton) ..	1963	111	125	128	TRI > RL** SO > RL**	107	119	133	TRI > RL** SO > RL** TRI > SO*
	1964	116	125	129	TRI > RL* SO > RL*	105	118	130	TRI > RL** SO > RL** TRI > SO*
Acidity (% anhydrous citric)	1963	1·21	1·23	1·24	NSD ..	1·23	1·32	1·36	TRI > RL*
	1964	1·17	1·18	1·26	NSD ..	1·42	1·51	1·58	TRI > RL**
pH	1963	3·40	3·38	3·35	NSD ..	3·33	3·27	3·33	NSD
	1964	3·33	3·34	3·33	NSD ..	3·20	3·16	3·19	NSD
T.S.S./acid ..	1963	8·53	8·82	8·98	NSD ..	7·84	7·93	8·39	TRI > RL*
	1964	8·95	9·30	9·28	NSD ..	6·65	6·79	6·93	NSD
Ascorbic acid (mg 100 ml)	1964	38	34	34	RL > SO** RL > TRI**	39	43	41	TRI > RL* SO > RL**
Juice colour (total carotenoids in mg beta—carotene/100 ml)	1964	0·65	0·76	0·76	TRI > RL** SO > RL**	1·03	1·16	1·25	SO > RL** TRI > SO** TRI > RL**
Bitterness rating	1963	1·11	0·70	0·85	RL > SO*	1·78	1·11	1·25	RL > SO* RL > TRI*
	1964	2·09	1·12	0·47	RL > TRI** RL > SO** SO > TRI**	1·54	0·31	0 29	RL > SO** RL > TRI**
Off-flavour rating	1964	4·9	5·1	5·3	NSD ..	5·5	6·2	5·8	SO > RL** SO > TRI**
General acceptability rating ..	1964	4·9	5·0	5·1	NSD ..	5·2	6·1	5·7	SO > RL** SO > TRI* TRI > RL*

Fruit weight was not affected by rootstock. Percentage juice recovery was higher for trifoliate orange and sweet orange than for rough lemon. Total soluble solids were highest for trifoliate orange, lowest for rough lemon and intermediate for sweet orange. Soluble solids per long ton were highest for trifoliate orange, lowest for rough lemon and intermediate for sweet orange. However, the difference between trifoliate orange and sweet orange was not significant for Joppas. Acidity means also were highest for trifoliate orange and lowest for rough lemon and intermediate for sweet orange, but the only significant difference established was between trifoliate orange and rough lemon for Valencias. pH was not shown to be influenced by rootstock. T.S.S./acid means were generally highest for trifoliate orange and lowest for rough lemon but the differences were small and only significant for the 1963 Valencias. Ascorbic acid for Joppas was higher for rough lemon than for sweet orange and trifoliate orange, but for Valencias the reverse was true.

Juice colour for Valencias was highest for trifoliate orange and lowest for rough lemon, and for Joppas it was higher for trifoliate orange and sweet orange than for rough lemon. Bitterness in both varieties was higher for rough lemon than for sweet orange and trifoliate orange. Also, bitterness in Joppas on sweet orange was higher than that in Joppas on trifoliate orange in 1964. Bitterness at a level of slightly bitter or higher was seldom found in juice from fruit from sweet orange and trifoliate orange even when the fruit was picked early in the harvesting season. During the 1963 and 1964 seasons, bitterness at a level of slightly bitter (rating score 2·0) or higher occurred early in the commercial harvesting season in fruit from 15 different scion-rootstock-farm combinations. In 13 of these, rough lemon was the rootstock involved.

Off-flavours for Valencias were less pronounced in juice from sweet orange than in juice from rough lemon and trifoliate orange. The mean rating scores for Joppas were highest for trifoliate orange and lowest for rough lemon, but the differences were not significant at $P < \cdot 05$. General acceptability for Valencias was highest for sweet orange and lowest for rough lemon. Again no significant difference was established between the rootstocks for Joppas, although mean scores were highest for trifoliate orange and lowest for rough lemon.

Although fruit weight was not shown to be influenced by rootstock in this trial, rootstock effects on fruit weight have been reported by many workers, including Bitters and Batchelor (1951), Harding, Winston, and Fisher (1940) and Hodgson (1947).

Rootstock effects on percentage juice recovery were in agreement with those reported by Kefford and Chandler (1961), Marloth (1949) and Harding, Winston, and Fisher (1940).

Rootstock effects on total soluble solids, soluble solids per ton, acidity, pH and T.S.S./acid were generally in agreement with those reported by Kefford and Chandler (1961), Sinclair and Bartholomew (1944), Richards (1940), Marloth (1949), Harding, Winston, and Fisher (1940) and Hodgson and Eggers (1938).

There is a considerable amount of disagreement in the literature concerning the effect of rootstock on ascorbic acid. The findings for Valencias were in fairly good agreement with those of Harding, Winston, and Fisher (1940) and Bitters (1960, p. 65). The findings for Joppas, however, were similar to those reported for Navels by Kefford and Chandler (1961).

Rootstock effects on juice colour observed in this trial were in agreement with visual observations made in California by Bitters (1960, p. 82). Singh (1948) reported that the blood-red colour in Malta Blood Red orange in India was influenced by rootstock. Miller, Winston, and Fisher (1941), however, stated that they found no effect of rootstock on the pigments of the juice.

Effects of rootstocks on bitterness were in agreement with those reported by Kefford and Chandler (1961), Marsh (1953) and Marsh and Cameron (1950).

The finding that sweet orange was superior to rough lemon with respect to off-flavour development and general acceptability of canned Valencia juice is in agreement with the findings of Kefford, Chandler, and Lynch (1952), Hall (1943), Marsh (1953) and Marsh and Cameron (1950). However, the finding that sweet orange was superior to trifoliate orange with respect to these characteristics is at variance with the findings of these workers. Although no significant difference between rootstocks in consumer panel evaluation of off-flavours was established for Joppas, evaluations carried out by the analytical taste panel showed that, for most farms, trifoliate orange and sweet orange were superior to rough lemon with respect to off-flavours.

(c) Time of Picking

Fruit weight (Figure 1) for Joppas increased slowly until the second or third week of July and then decreased slightly. The trend was similar for all three rootstocks. For Valencias, fruit weight increased at a constant rate during the period for rough lemon and trifoliate orange, but for sweet orange it reached a peak in about the third week of September and then decreased slightly.

A decrease in fruit weight late in the harvesting season was observed in Florida Temple oranges by Harding and Sunday (1953). The trends observed for Valencias on rough lemon and trifoliate orange are in agreement with those reported by Harding, Winston, and Fisher (1940), Bain (1958) and Marloth (1950).

Percentage juice recovery (Figure 2) for Joppas increased until about the second week of June and then decreased for the remainder of the sampling period. The trend was similar for all three rootstocks. For Valencias on rough lemon and sweet orange, juice recovery decreased slowly during the first half of the sampling period, reaching a minimum in about the last week of August, and then increasing slowly for the remainder of the sampling period. For Valencias on trifoliate orange, percentage juice recovery decreased slowly and at a fairly constant rate during the period.

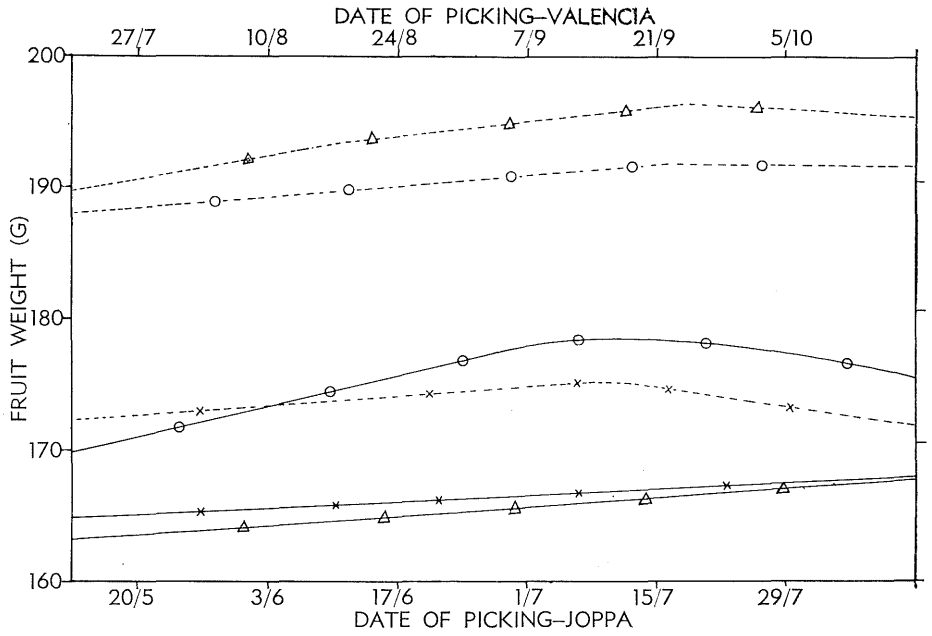

Fig 1.—Fruit weight *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

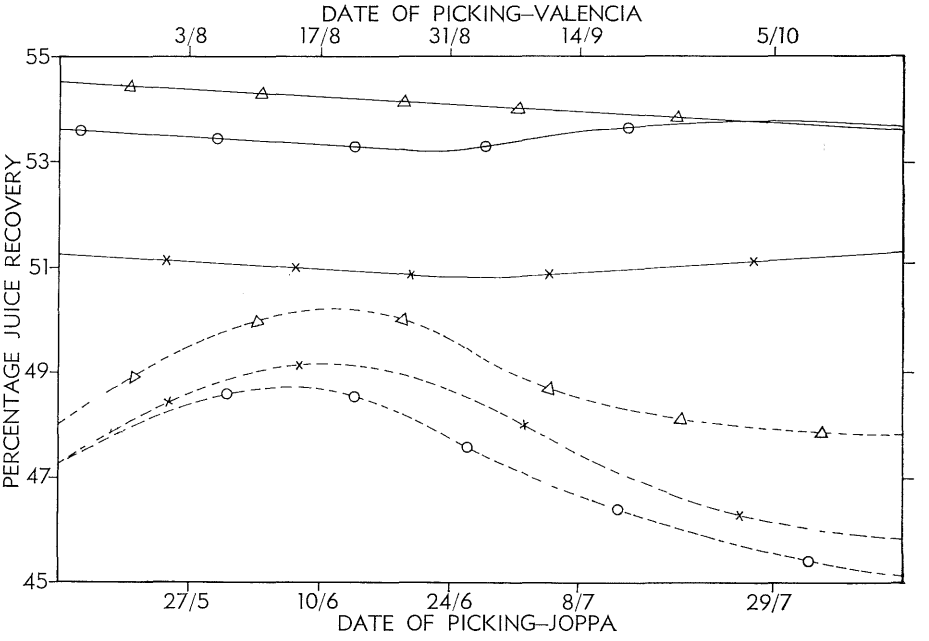

Fig. 2.—Percentage juice recovery *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

The trends observed for Joppas were similar to those reported for early and mid-season Florida oranges by Harding, Winston, and Fisher (1940) and for the mid-season Shamouti (Jaffa) variety by Samisch and Cohen (1949). Marloth (1950) and Harding, Winston, and Fisher (1940) reported that percentage juice recovery for Valencias remained fairly constant during the commercial harvesting period.

Total soluble solids (T.S.S.) (Figure 3) for Joppas increased at a constant rate during the sampling period. For Valencias, T.S.S. increased until about the second or third week of August, remained fairly constant until about the first week of October, and then decreased slowly. The trend was not appreciably influenced by rootstock.

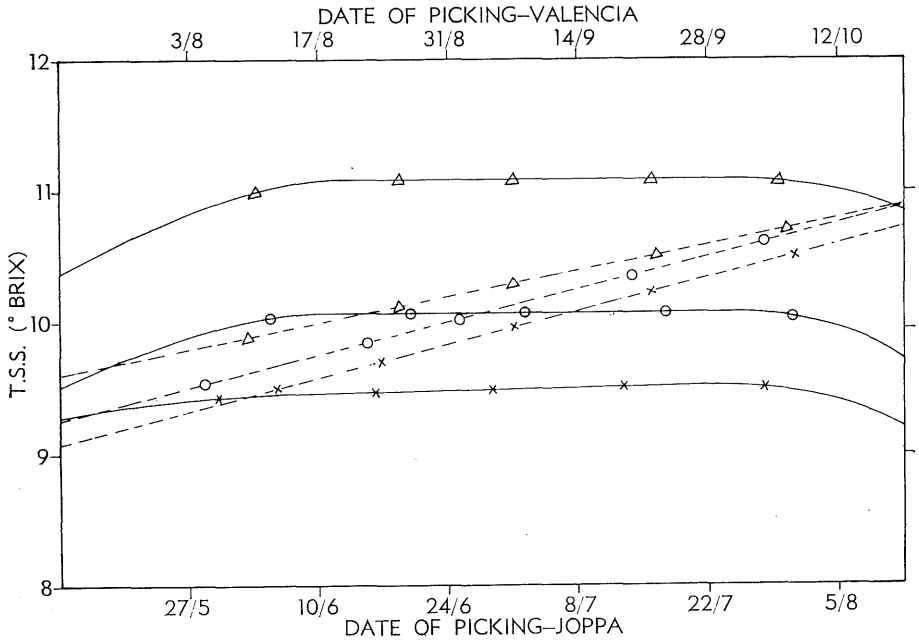

Fig. 3.—Total soluble solids *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

The trends observed for Joppas were similar to those reported for early and mid-season Florida oranges by Harding, Winston, and Fisher (1940) and for Shamouti oranges by Samisch and Cohen (1949). The trends observed for Valencias were similar to those reported by Harding, Winston, and Fisher (1940), Marloth (1950) and Copeman (1931). Sinclair and Bartholomew (1944) Halma (1943), Richards (1940) and Bain (1958) reported a slowing down in the rate of increase in T.S.S. during the later part of the harvesting season, but they did not actually observe a decrease.

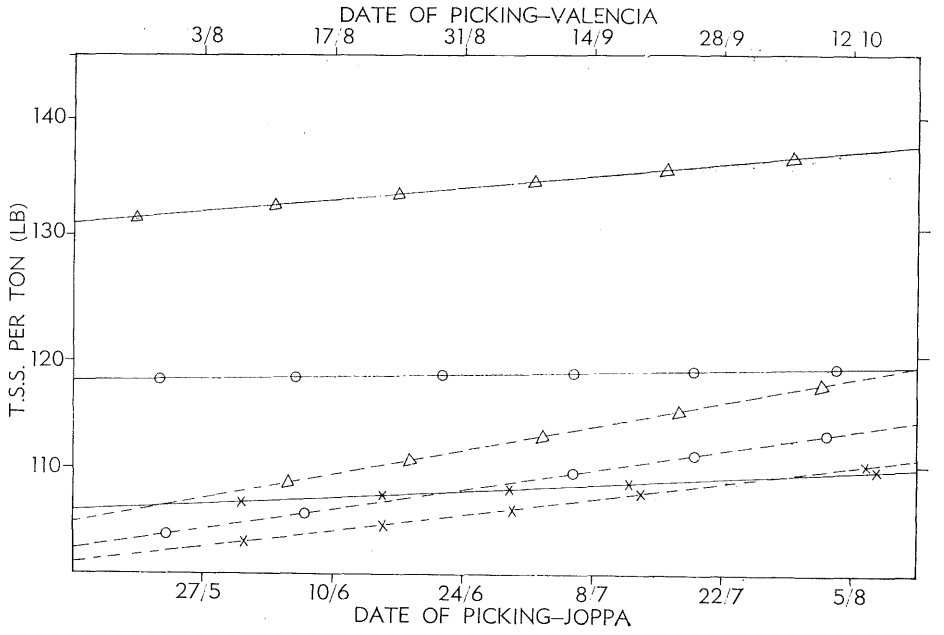

Fig. 4.—Soluble solids per long ton *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

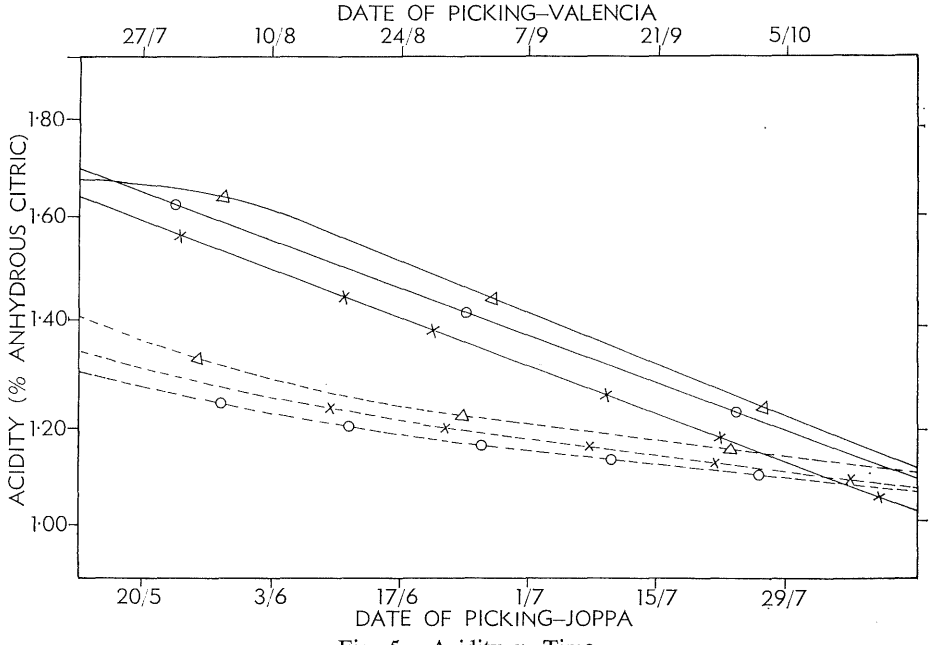

Fig. 5.—Acidity *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

Soluble solids per ton (Figure 4) increased at a constant rate during the period for both varieties, the rate of increase being considerably greater for Joppas than for Valencias. For both varieties, the rate of increase was greater for trifoliate orange than for rough lemon and sweet orange.

Acidity (Figure 5) decreased throughout the period for both varieties. For Joppas the rate of fall decreased slightly during the period, while for Valencias a fairly constant rate of decrease was noted. The rate of decrease was greater for Valencias than for Joppas, and for both varieties the trend was similar for all rootstocks.

pH (Figure 6) increased at a constant rate during the period for both varieties, the rate of increase being slightly greater for Valencias than for Joppas. For Joppas the rate of increase for rough lemon and sweet orange was slightly greater than that for trifoliate orange, while for Valencias the rate of increase for rough lemon was slightly lower than that for trifoliate orange and slightly greater than that for sweet orange.

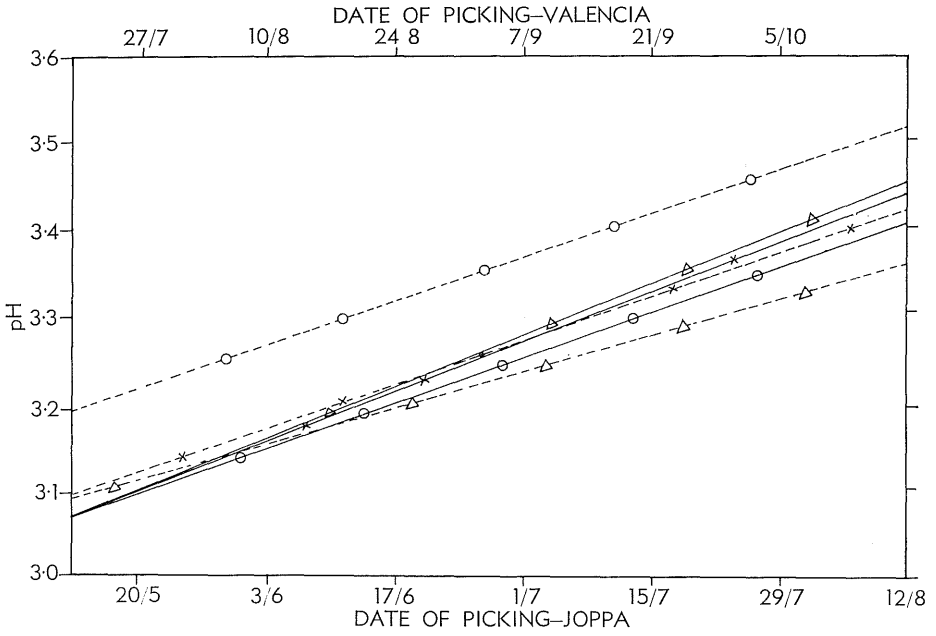

Fig. 6.—pH *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON

– – – JOPPA
—— VALENCIA

T.S.S./acid (Figure 7) increased at a constant rate during the period for both varieties, the rate of increase being slightly greater for Valencias than for Joppas. For both varieties the rate of increase was slightly less for sweet orange than for rough lemon and trifoliate orange.

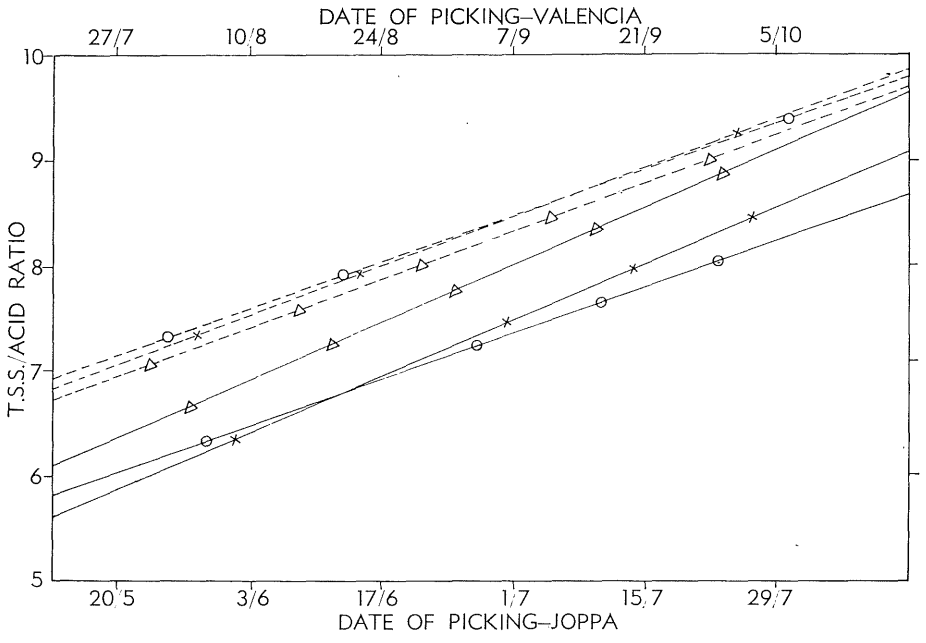

Fig. 7.—T.S.S./Acid ratio *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON

– – – JOPPA
—— VALENCIA

Since new minimum requirements for the marketing of fresh oranges, incorporating a minimum T.S.S./acid ratio of 7·5 for Joppas and 7·0 for Valencias, are under consideration in Queensland, it is noted that in the 1963 and 1964 seasons, T.S.S./acid for Joppas on rough lemon reached 7·5 in the first week of June, and for Valencias on rough lemon the ratio reached 7·0 in the fourth week of August.

Trends observed for acidity, pH and T.S.S./acid are generally in agreement with those reported by Harding, Winston, and Fisher (1940), Samisch and Cohen (1949), Marloth (1950), Copeman (1931), Sinclair and Bartholomew (1944), Halma (1943), Richards (1940), Bain (1958) and Swift and Veldhuis (1957).

Ascorbic acid (Figure 8) for Joppas increased until about the third week of June, decreased until about the second or third week of July, and then remained fairly constant. For Valencias on all rootstocks, ascorbic acid remained fairly constant until about the second week of August, and then decreased during the remainder of the period. These trends are fairly similar to those reported by Harding, Winston, and Fisher (1940) and Swift and Veldhuis (1957). Samisch and Cohen (1949) found that ascorbic acid in Shamouti oranges remained fairly constant during the harvesting season.

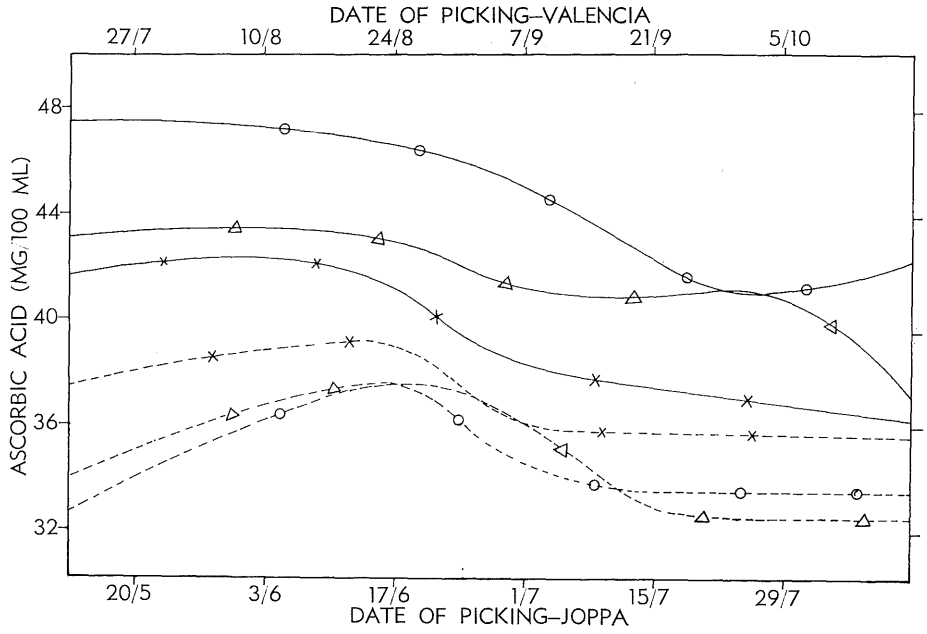

Fig 8.—Ascorbic acid *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

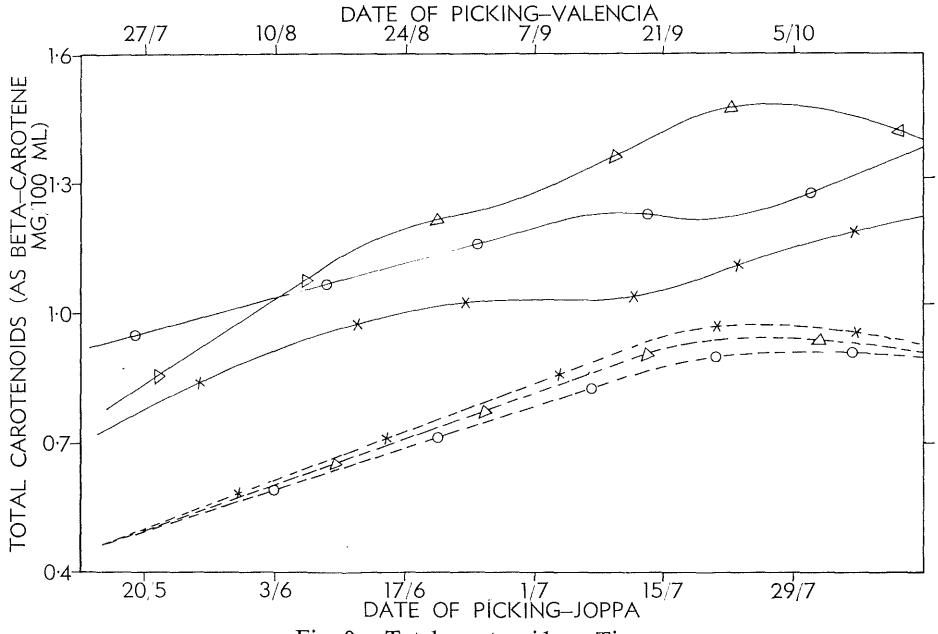

Fig. 9.—Total carotenoids *v.* Time.

△ TRIFOLIATA
O SWEET ORANGE
X ROUGH LEMON
– – – JOPPA
—— VALENCIA

Juice colour (Figure 9) for Joppas increased at a constant rate until about the fourth week of July, after which it decreased slightly. For Valencias, juice colour increased throughout the whole of the sampling period and the rate of increase was approximately the same as that for Joppas. The trend was not appreciably influenced by rootstock for either of the two varieties.

The trends for Joppas were similar to those reported for early and mid-season Florida oranges by Miller, Winston, and Fisher (1941) and for Shamouti oranges by Samisch and Cohen (1949). Trends observed for Valencias, however, differed from those reported by Miller, Winston, and Fisher (1941), who found that juice colour of Valencias increased to a peak and then decreased towards the end of the harvesting period.

Bitterness (Figure 10) decreased during the period for both varieties, the rate of decrease being somewhat variable. The graphs in Figure 10 were obtained by studying changes in the bitterness levels during the 1964 sampling period of juice from fruits which, when picked early in the commercial harvesting season, had been found to yield juice containing bitterness at a level of slightly bitter or greater. For Joppas, bitterness in these fruit reached the slightly bitter range (rating score 2–3) about the end of June and fell below that range about the end of July. For Valencias, bitterness reached the slightly bitter range in about the second week of August and fell below that range early in October. Since in 1964 bitterness at the level of slightly bitter or greater was not present in juice from fruit from sweet orange or trifoliate orange, even when the fruit was picked early in the season, the graphs represent rough lemon only. These trends are in agreement with those reported by Kefford and Chandler (1961), Marsh (1953), Marsh and Cameron (1950), Emerson (1949), Samisch and Cohen (1949) and Samisch and Ganz (1950).

Off-flavours (Figure 11), which were studied for Valencias only, became less pronounced during the period, as indicated by the increase in rating scores. For rough lemon and sweet orange, rating scores increased throughout the whole of the sampling period. For trifoliate orange, however, rating scores decreased slightly until about the second week of August, increased until about the third week of September, and then remained fairly constant for the remainder of the period.

General acceptability trends (Figure 12) were almost identical with those for off-flavours, indicating that off-flavours were the major factor influencing general acceptability.

Thus T.S.S./ton, T.S.S./acid, pH, juice colour, bitterness, off-flavours and general acceptability were found to improve during the period of sampling for both varieties and the decrease in ascorbic acid was not considered large enough to be of any practical importance. Therefore, processing quality was improved by leaving the fruit on the tree for a longer time. Joppas picked in late July or early August were considerably better in processing quality than those picked in early or mid June and Valencias picked in late October were considerably better than those picked in early or mid August. It should be noted that

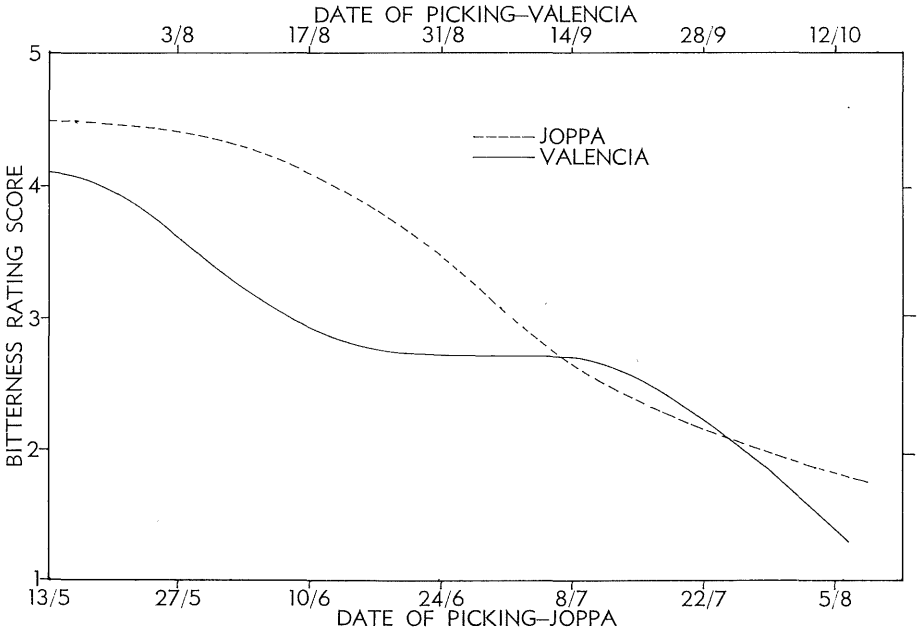

Fig. 10.—Bitterness *v.* Time.

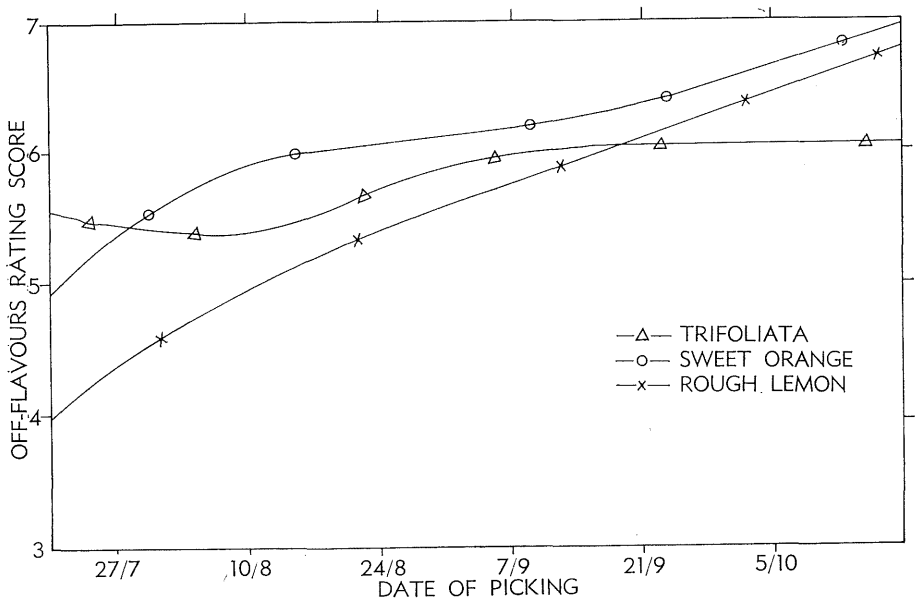

Fig. 11.—Off-flavours *v.* Time.

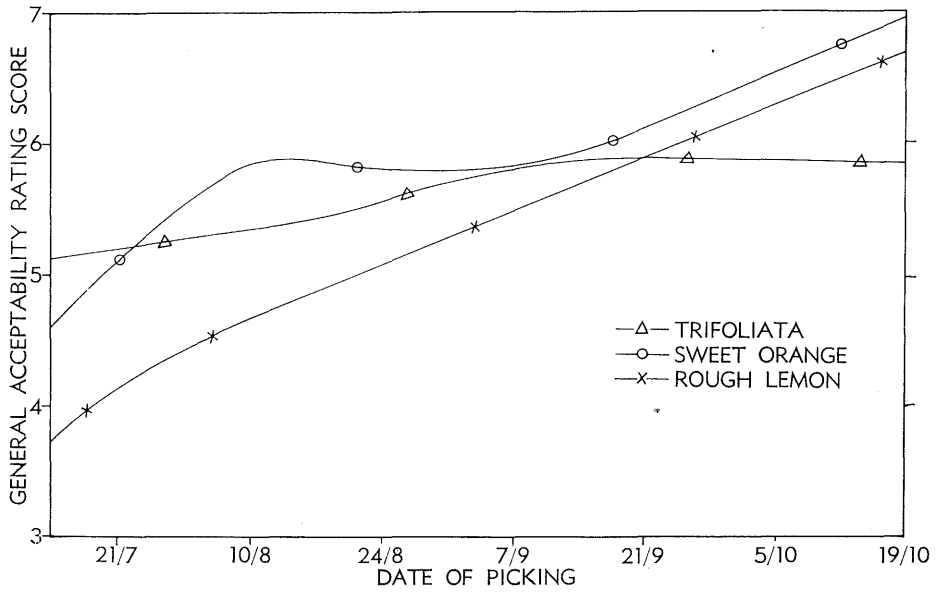

Fig. 12.—General acceptability *v.* Time.

apparent differences between varieties and rootstocks with respect to the processing characteristics represented by Figures 1–12 are not necessarily meaningful, since the graphs are representative of all farms sampled, whereas the number of farms for which valid statistical variety and rootstock comparisons could be made was restricted, for reasons mentioned previously.

(d) Seasonal Differences

Means for the various processing quality characteristics of Joppas and Valencias taken from the same trees in the 1963 and 1964 seasons are shown in Table 3. Off-flavours, general acceptability, ascorbic acid and juice colour were not determined in 1963 and therefore no seasonal comparisons could be made for these characteristics. From Table 3, it can be seen that fruit weight, pH and T.S.S./acid for both varieties, percentage juice recovery for Joppas and bitterness for Valencias were higher in 1963 than in 1964, while acidity for both varieties and T.S.S. and bitterness for Joppas were higher in 1964 than in 1963. No significant seasonal differences were found in soluble solids per ton for either of the two varieties or in percentage juice recovery and T.S.S. for Valencias.

The differences between seasons established in this trial are considered to be due mainly to climatic conditions. The differences in acidity, pH and T.S.S./acid indicate that both varieties matured later in 1964 than in 1963. The most important single factor affecting time of ripening is total available heat (Sinclair and Bartholomew 1944).

TABLE 3

SEASONAL MEANS

Variety and Year	Fruit Weight (g)	Juice Recovery (%)	T.S.S. (°Brix)	T.S.S. (lb/ton)	Acidity (% anhydrous citric)	pH	T.S.S. / Acid	Bitterness Rating
Joppa								
1963	198	48·8	9·9	110	1·16	3·37	8·6	1·1
1964	160	47·3	10·3	110	1·31	3·27	7·9	2·1
Significance	**	**	**	N.S.D.	**	**	**	*
Valencia								
1963	181	52·9	10·0	119	1·32	3·31	7·8	2·0
1964	160	52·7	9·9	116	1·53	3·19	6·8	1·1
Significance	**	N.S.D.	N.S.D.	N.S.D.	**	**	**	*

Fruit quality is also affected by the soil moisture content (Sites, Reitz, and Deszyck 1951; Jones and Embleton 1956) and therefore seasonal rainfall would be an important factor influencing quality, particularly on non-irrigated or poorly irrigated farms.

Fruit quality can be adversely affected by extremely low temperatures (Bartholomew, Sinclair, and Horspool 1950) and extremely high temperatures (Parker 1948), but such conditions are unlikely in the Near North Coast area.

(e) Farm Differences

Table 4 shows the highest and lowest farm means for various processing quality characteristics for Joppas and Valencias on rough lemon grown in the Palmwoods district in the 1964 season. It can be seen that the between-farm differences were large and highly significant for every characteristic studied. Averages for the other farms sampled in the district were generally fairly evenly distributed between the extremes.

In compiling Table 4, one farm was excluded in the extremes for acidity, pH and T.S.S. because fruit from this farm had been fairly heavily treated with lead arsenate. Acidity was considerably lower and pH and T.S.S./acid were considerably higher for this farm than for any of the other farms. These effects of lead arsenate sprays are well known and have been reported for oranges by Miller, Bassett, and Yothers (1933) and for grapefruit by numerous workers, including Deszyck and Ting (1958) and Harding and Fisher (1945).

On two farms sampled in the 1963 season, the fruit had been treated with lime-sulphur sprays about 2 weeks before harvesting, and for these farms the processed juice was found to have a strong hydrogen sulphide smell and taste, even though the lime-sulphur had been washed thoroughly from the skins of these fruit before the juice was extracted. Thus the lime-sulphur was absorbed through the skin; so oranges for processing should not be treated with lime-sulphur spray during or immediately prior to the harvesting season.

In 1964, 50% of the Joppa farms and 33% of the Valencia farms sampled yielded juice which had a bitterness level of slightly bitter or greater early in the commercial harvesting season. For all of these except one Joppa farm, bitterness had fallen below the slightly bitter level by the end of the sampling period.

It is considered that the large differences between farms in the Palmwoods district were due mainly to differing farm practices and tree ages. Tree age was found to be correlated with fruit weight, percentage juice recovery, T.S.S., soluble solids per ton, acidity, pH, T.S.S./acid and juice colour, and regression coefficients for these relationships are shown in Table 5. The relationship between tree age and the soluble constituents in the juice is considered to be due at least in part to the effect of tree age on fruit weight, since fruit weight was found to be correlated with T.S.S., soluble solids per ton, acidity, pH and juice colour. Regression coefficients of these characteristics on fruit weight are shown in Table 6. Similar relationships between fruit weight and the soluble constituents of the juice have been reported by Joslyn and Marsh (1937), Bartholomew and Sinclair (1939) and Samisch and Cohen (1949).

TABLE 4

MAXIMUM AND MINIMUM FARM MEANS

——	Fruit Weight (g)	Juice Recovery (%)	T.S.S. (°Brix)	T.S.S. (lb/ton)	Acidity (% anhydrous citric)	pH	T.S.S. / Acid	Bitterness Rating	Off-flavour Rating	General Acceptability Rating	Ascorbic Acid (mg/100 ml)	Juice Colour (total carotenoids in mg beta-carotene/ 100 ml)
Joppa												
Highest	173	50·0	10·8	116	1·64	3·37	9·0	6·0	—	—	44	1·09
Lowest	125	44·8	9·3	97	1·10	3·07	6·6	0·2	—	—	34	0·67
Significance	**	**	**	**	**	**	**	**	—	—	**	**
Valencia												
Highest	189	53·9	11·1	131	1·95	3·23	7·7	3·8	6·5	6·4	48	2·30
Lowest	122	47·8	9·1	100	1·32	3·06	5·4	0·40	3·6	3·0	32	0·77
Significance	**	**	**	**	**	**	**	**	**	**	**	**

TABLE 5

REGRESSION COEFFICIENTS OF PROCESSING QUALITY CHARACTERISTICS ON TREE AGE (YEARS)

—	Fruit Weight (g)	Juice Recovery (%)	T.S.S. (°Brix)	T.S.S. (lb/ton)	Acidity (% anhydrous citric)	pH	Juice Colour (total carotenoids in mg beta-carotene/100 ml)
Regression coefficient	− 1·610	0·170	0·094	0·717	0·023	− 0·014	0·044
	± 0·396	± 0·076	± 0·013	± 0·185	± 0·002	± 0·006	± 0·012
Significance	**	*	**	**	**	*	**

TABLE 6

REGRESSION COEFFICIENTS OF PROCESSING QUALITY CHARACTERISTICS ON FRUIT WEIGHT (G)

—	T.S.S. (°Brix)	T.S.S. (lb/ton)	Acidity (% anhydrous citric)	pH	Juice Colour (total carotenoids as mg beta-carotene/100 ml)
Regression coefficient	− 0·023	− 0·249	− 0·006	0·003	− 0·003
	± 0·004	± 0·051	± 0·001	± 0·001	± 0·001
Significance	**	**	**	**	**

TABLE 7

PROCESSING QUALITY CHARACTERISTICS OF VALENCIA GROWN IN THE ELIMBAH–BEERWAH AND PALMWOODS–MAROOCHY DISTRICTS

District	Fruit Weight (g)	Juice Recovery (%)	T.S.S. (°Brix)	T.S.S. (lb/ton)	Acidity (% anhydrous citric)	pH	T.S.S. / Acid	Bitterness Rating	Off-flavour Rating	General Acceptability Rating	Ascorbic Acid (mg/100 ml)	Juice Colour (total carotenoids as mg beta-carotene /100 ml)
Elimbah–Beerwah ..	185	50·8	8·7	98·3	1·17	3·33	7·7	1·0	6·1	5·9	41	1·10
Palmwoods–Maroochy	159	51·4	9·7	111·5	1·43	3·21	7·0	1·9	5·0	4·6	40	1·44
Significance	**	N.S.D.	**	*	**	**	N.S.D.	N.S.D.	*	*	N.S.D.	**

Processing quality of oranges has been reported by other investigators to be influenced by fertilizer, irrigation and cultural practices and pesticide treatments.

(f) District Differences

The mean values shown in Table 7 are for various processing quality characteristics of Valencias on rough lemon grown in the Elimbah-Beerwah and Palmwoods-Maroochy districts in the 1963 and 1964 seasons. From these figures it may be seen that T.S.S., soluble solids per ton, acidity and juice colour were higher for the Palmwoods-Maroochy district, while fruit weight, pH, off-flavour score and general acceptability were higher for the Elimbah-Beerwah district. A significant difference was not established between the two districts in percentage juice recovery, T.S.S./acid, bitterness or ascorbic acid.

The larger size of the Elimbah-Beerwah fruit could have been due to the fact that soil texture in this district is lighter and sandier than in the Palmwoods-Maroochy district (Vallance and Lewcock 1938; Vallance and Wood 1940). Samisch and Cohen (1949) reported that orange trees grown on heavier soils tend to bear smaller fruit than those on lighter soils. Ludin and Samisch (1962) made similar observations for lemons. It is considered that the differences between the two districts with respect to soluble constituents in the juice were due at least in part to the fruit size difference.

This investigation has shown that the processing quality of Valencias grown in the Near North Coast area of Queensland is inferior to that of Florida and California Valencias, and in fact only a small percentage of fruit from the Near North Coast would satisfy the usual minimum requirements for oranges for the preparation of frozen orange juice concentrate laid down by American processors. The following is a typical American specification (Kefford 1965): minimum Brix 10·5°, maximum acidity 1·3%, minimum acidity 0·75%, minimum Brix: acid ratio 10·0. Westbrook and Stenstrom (1957, 1964), in studies of the degrees Brix and Brix:acid ratios of oranges utilized by Florida processors for the seasons 1952-53 to 1956-57 and for the seasons 1958-59 to 1963-64, showed that T.S.S. usually ranged from 10° to 13° Brix and Brix:acid ratio from 10·5 to 15. Kefford (1963) reported similar figures for American fruit and also stated that bitterness in processed Valencia juice has never been encountered in Florida or California. Tucker and Reuther (1967) reported T.S.S. ranging from 11° to 13° Brix and Brix:acid ratios ranging from 9 to 13 for California and Arizona Valencias.

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