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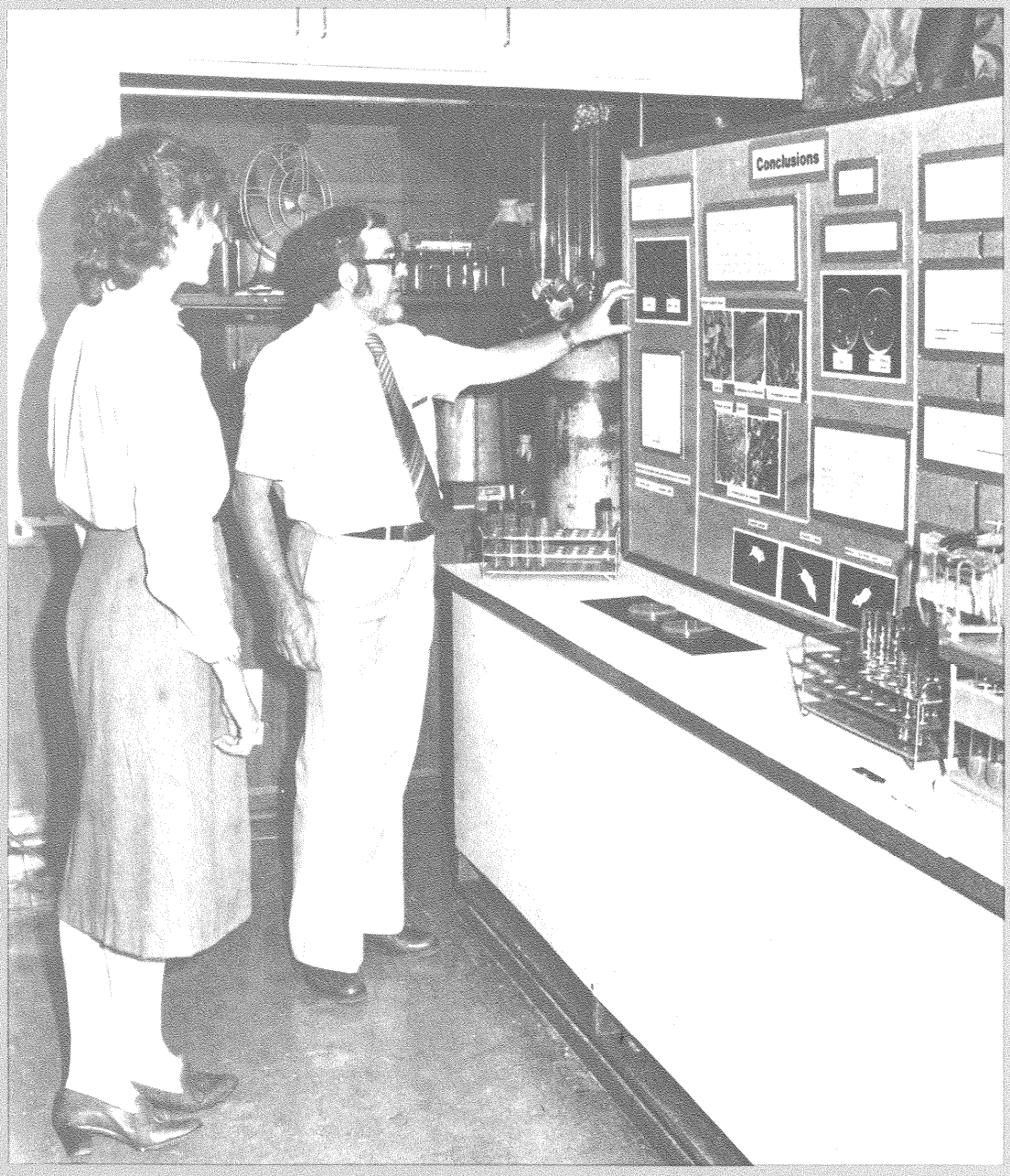

Packaging and cool storage of litchi fruit

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Introduction

One of the best known and highly esteemed fruits of subtropical origin is the litchi (*Litchi chinensis* Sonn). The fruit when mature has a bright red rind enclosing the translucent white flesh (aril), which has a delicate flavour. The harvest season, however, is short and the fruit is highly perishable. For consumer acceptance it is essential that the fruit retains the red colour of the rind, even though the flesh remains acceptable for a time after the rind has turned brown.

Recently, Scott *et al.* (1982) reported that rotting and browning of litchis could be delayed by at least a week at temperatures of 20°–30°C by dipping the fruit in hot benomyl, then packing the fruit in punnets overwrapped with polyvinyl chloride 'cling' film. Production of litchis is increasing in Australia and it is believed that there is a ready market in many countries for fresh red litchis. Refrigerated storage would be required for the maintenance of quality over the longer period needed for an export operation.

This report presents results of preliminary studies on the effect of harvest maturity and storage temperature on litchi fruit. The work was carried out at the CSIRO Food Research Laboratory, North Ryde, while the senior author held an award from the International Development Research Centre of Canada.

Materials and methods

Litchi fruit were harvested from private orchards at Millaroo, Queensland, and at Alstonville, New South Wales. Maturity was arbitrarily classified according to the extent of red colouring in the rind. Fruit were sorted into different maturity classes from a single picking. Three maturities were designated as follows: M_1, green or with trace of pink; M_2, red colouring about 30% of the rind surface, with a distinct green area; M_3, red colouring over 70–80% of the rind and no distinct green coloured area.

The fruit were then treated according to the methods of Scott *et al.* (1982). Fruit were dipped after harvest in an aqueous benomyl fungicide suspension (1000 mg/l of Benlate[R] wettable powder, active constituent – 50% benomyl) at 52°C for 2 min, placed in clear plastic punnets (10 to 12 fruit per punnet), and covered with polyvinyl chloride film (thickness 0.01 mm). The packed fruit were air freighted to Sydney and received at the laboratory 2 days after harvest. The fruit were removed from the punnets and samples of 8–15 fruit, weighing about 200 g, were placed in glass jars. These were held at 20°C and continuously ventilated with saturated ethylene-free air. Gas samples were taken from the jars with a gas-tight hypodermic syringe. An infrared gas analyser or a gas chromatograph with a thermal conductivity detector were used for carbon dioxide analysis and a gas chromatograph with a flame ionization detector for ethylene analysis. Measurements were made daily for 7 to 14 days. Juice samples were obtained by centrifuging samples of homogenized tissue. Total soluble solids (TSS) were measured with a hand refractometer, zeroed with distilled water at room temperature. The pH was measured with a pH meter and titratable acidity was determined by addition of 0.1N NaOH to raise pH of a sample of juice to 8.1.

For the storage trial, three overwrapped punnets of fungicide-treated fruit were placed in cool rooms at 0°, 5°, 7°, 10°, 13° and 20°C. Punnets were subsequently removed from storage for chemical analyses and the determination of weight loss, colour and rotting. Weight loss was determined by weighing punnets of fruit before and after storage. Colour was rated (Campbell 1959)

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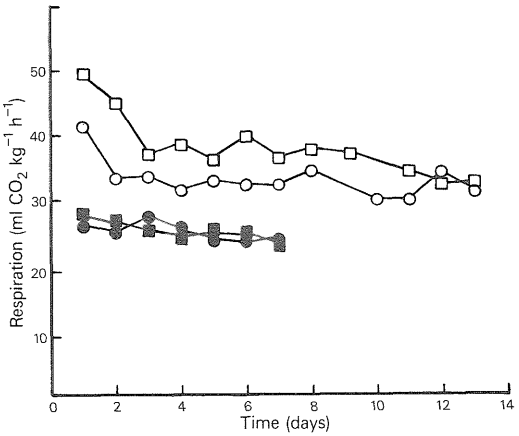

Fig. 1. Rates of respiration of litchis. (□, var. Haak Yip; ○, var. Bengal from New South Wales; ■, var. unnamed, Queensland; ●, var. Bengal, Queensland). Each point represents average of three replicate samples of about 200 g of fruits.

on a numerical scale, as follows: 1, all or almost all red; 2, browning on tips of tubercles; 3, brown spots up to 10 mm diameter; 4, large brown spots of more than 10 mm diameter; 5, all brown. The scale for rot evaluation was as follows; 0, healthy; 1, browning on stem end adjacent to seed, aril unaffected; 2, aril affected but not watery; 3, aril rotted and watery, spots up to 1 cm; 4, more than half fruit rotted. Fungi were isolated from the rind, aril, stem end, membrane and seed of diseased as well as apparently healthy fruit throughout the storage trial. Fruit were surface-sterilized with sodium hypochlorite solution before dissection, and each dissected part was again surface-sterilized before transfer to potato dextrose Vegemite agar. The fungi were identified according to genera.

Results

Respiratory pattern

Litchi fruit from two different localities were used. Carbon dioxide and ethylene production by detached fruit are shown in Figs 1 and 2. Carbon dioxide production decreased slightly during storage and was slightly higher for fruit from New South Wales (Alstonville) than fruit from Queensland (Millaroo). Ethylene production increased from trace levels to about 0.4 μl kg^{-1} h^{-1} after 14 days' storage when fruit treated with hot benomyl were still sound and free from visible infection. The appearance of fungal growth on control samples without fungicidal treatment was associated with a large increase in ethylene production after 3 to 5 days in the jar (upper trace in Fig. 2).

Maturity and maturity indices

Chemical analyses of juice from fruit of the three maturity classes showed an increase in pH and a decrease in titratable acidity as the fruit matured (Table 1). In all three maturity classes a distinct colour change occurred in the juice during the addition of 0.1N NaOH when the pH reached 6.7–7.0. The clear to slightly turbid fruit juice changed to a light yellow colour.

Storage trial

Benomyl-treated fruit in punnets, covered with PVC film and stored at 20 °C, remained in a fresh condition for 11 days with about 3% weight loss, whereas untreated fruit became brown after 1–2 days owing to dehydration (Table 2). After 19 days the colour of treated fruit had deteriorated (mean score 3.6) and some rotting had occurred (mean score 1.4). At lower temperatures rotting remained relatively low even up to 40 days' storage. The mean values at 40 days' storage were: 10 °, 1.1; 7 °, 0.3; 5 °, 0; and 0 °, 0.1. Weight loss was highest at 10 ° (6.4%) and lowest at 0 ° (1.7%). Symptoms of chilling injury were observed after 30 days in fruit held at 0 ° or 5 °C. This

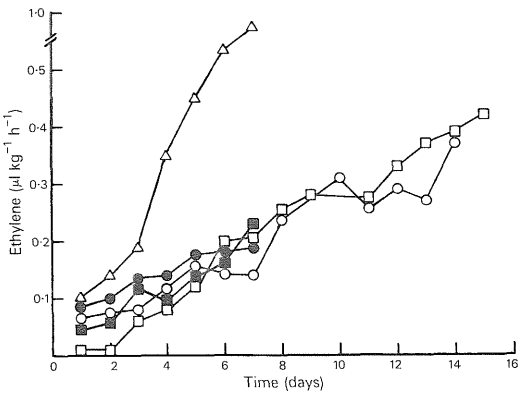

Fig. 2. Rates of ethylene production of litchis. (□, var. Haak Yip; ○, var. Bengal from New South Wales; ■, var. unnamed; Queensland; ●, var. Bengal, Queensland). △, Samples without fungicidal treatment, var. Bengal, New South Wales. Each point represents average of three replicate samples of about 200 g of fruits. The limit of detection of ethylene was 0.02 μ1 kg^{-1} h^{-1}.

Table 1. Composition of Litchi fruit as affected by maturity[A]

Variety	Maturity[B]	Fruit size (g) whole	aril	rind	seed	TSS (%)	pH	$[H^+]$ μM	Titratable acidity[C]
Bengal	M_1	17.2[a]	10.9[a]	3.2[a]	3.1[a]	15.3[a]	3.47	338.8[c]	14[c]
	M_2	18.4[b]	11.8[ab]	3.6[b]	3.1[a]	15.4[a]	3.68	208.9[b]	11[b]
	M_3	19.1[bc]	12.6[b]	3.2[a]	3.4[b]	15.9[b]	4.03	93.3[a]	7[a]
Unnamed	M_1	10.5[a]	6.9[a]	1.8[a]	1.7[a]	16.3[b]	3.67	213.8[c]	11[c]
	M_2	12.0[b]	8.3[b]	2.0[ab]	1.7[a]	16.0[a]	3.97	107.2[b]	7[b]
	M_3	13.6[c]	9.6[c]	2.1[b]	1.8[a]	16.0[a]	4.20	63.1[a]	5[a]

[A] Each value represents average of three replicate punnets.
For each attribute, within varieties values with the same superscript are not significantly different ($P < 0.05$).
[B] Maturity = M_1: green or trace of pink.
Maturity = M_2: 30% colouring, distinct green and red area.
Maturity = M_3: more than 70% colouring, no distinct green area.
[C] Meq/100 ml juice.

injury was in the form of uniform browning of the rind at 0° and irregular brown patches at 5°C. The mean colour ratings at 40 days' storage were: 10°, 3.4; 7°, 2.3; 5°, 2.6; and 0°, 3.5. The texture and flavour of the flesh were apparently not affected. Fruit with chilling injury broke down rapidly and the surface became covered with grey mycelium when held for 5 days at 20°C to simulate marketing. During storage, there was generally a slight decrease in total soluble solids, an increase in pH and a decrease in titratable acidity.

Fungi associated with litchis in storage

The initial browning during storage of tissue at the stem end adjacent to the seed appeared to be a senescent process and not related to microbial deterioration. No fungal growth was obtained when isolations were made from this brown tissue early in storage. As browning progressed, positive isolations resulted. *Stemphylium* sp. was the only fungus consistently isolated from dissected, surface-sterilized tissue from the stem end, rind and aril. Other fungi isolated from surface lesions on intact fruit included *Botryodiplodia* sp., *Colletotrichum* sp., *Fusarium* sp., and *Penicillium* sp. The isolated fungi were not tested for their pathogenicity on the fruit.

Discussion

Maturity indices such as days after fruit set, fruit size, colouring, ratio of component parts, flavour, TSS, acidity and respiration rate or a combination of more than one criterion have been used by various investigators as maturity standards for fruit. Litchis have been found to vary considerably in maturity according to cultivar and

Table 2. Chemical and physical changes in litchis stored at different temperatures[A]

Cultivar	Storage temperature (°C)	Days in storage	TSS	pH	Titratable acidity[B]	Weight loss	Colour rating[C]	Rot rating[D]
Haak Yip	—	0	16.8	5.1	15	—	—	—
	20	19	15.2	5.6	13	4.6	3.6	2.4
	13	19	15.7	5.4	14	2.4	1.6	2.1
	10	40	15.5	5.5	10	6.3	3.4	2.1
	7	40	15.8	6.0	9	2.4	2.3	1.3
	5	40	15.8	5.6	10	2.5	2.6	1.0
	0	40	15.7	5.3	12	1.7	3.5	1.1

[A] Each value represents mean of three replicate punnets.
[B] Meq/100 ml juice.
[C] Mean Score: 1 = red; 5 = brown
[D] Mean Score: 0 = no rotting; 4 = badly rotted.

growing location. Even on the same tree, fruit of various maturity stages exist which could extend harvesting dates from several days to even weeks. Days after fruit set has been suggested by some workers (Gaur and Bajpai 1977) as a desirable criterion for litchi maturity. In this study, we found that titratable acidity fell (and pH rose) as the colouring of the rind developed. An interesting observation was the development of a yellow colour in samples of juice at pH 6.7–7.0 during titration with 0.1 N NaOH. The determination of the volume of titrant required per millilitre of juice to cause the colour change may provide a maturity index which could aid field judgment of optimum maturity.

Akamine and Goo (1973) reported a decrease in respiration and ethylene production in the non-climacteric litchi during the ontogeny of fruit. Prasad and Jha (1979) reported a climacteric-like increase in oxygen uptake of homogenized aril tissue of partially ripe fruit. In the present study, over the limited ranges of maturity stages tested, the fruit exhibited a non-climacteric respiratory pattern. Although ethylene production of detached fruit increased, the rate remained low and was accompanied by a slight decrease in respiratory rate. Rapid deterioration of fruit after harvest was due firstly to the dehydration of rind which resulted in loss of fresh red colouring, and secondly, to the development of brown tissue at the stem end adjacent to the seed. The latter is probably a senescent process. This dead tissue provides a ready access for fungal attack. Other factors contributing to losses include mechanical damage during handling, and preharvest insect damage.

These preliminary results suggest that storage of fresh litchis for more than 30 days below 7 °C is not desirable because of the occurrence of chilling injury. Since the fruit lose acidity, fruit intended for cold storage should probably be harvested at a less mature stage than for immediate consumption provided the skin colour is acceptable.

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Alternative cultivars for orange juice production

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In Australia, where Valencias and navels have always dominated the citrus crop in a ratio of *c.* 6 : 4, other cultivars such as Joppas and Parramattas have decreased from 7% of the crop in 1950 to just over 1% in 1977 (Naylor 1978). Indeed, because of demands for chilled orange juice, for which Valencias are preferred as more reliable sources of non-bitter juice, the dominance of Valencias can be expected to increase; they represented only 52% of young citrus trees in Australia in 1966–72 but 74% in 1976–77. This paper suggests that the industry would gain by planting other cultivars such as Hamlins and Silettas. Such plantings could extend the period when good quality processing oranges are available, and also reduce the present restricting and horticulturally undesirable reliance on Valencias (Turpin 1972).

The need for alternative cultivars

One problem faced by Australian orange juice processors (Chandler 1977) is the limitation in their supply of oranges (*Citrus sinensis* Osbeck) to the Valencia Late, and Washington and Leng navels, hereafter referred to as Valencias and navels respectively. Supply problems are aggravated by the phenomenon of alternate bearing, which particularly affects Valencias, 'off-year' crops being 80–85% of 'on-year' crops, and by the possibility of bitterness developing in juice processed from navels.

Because of this dependence on Valencias and navels, which reach optimum acceptability in November–January and July–September respectively, there are two peak production periods in the Australian citrus industry. The variety of climates under which oranges are grown in Australia results in some spread outside these peak periods. Consequently, there is continuity of juice production on a limited scale from June to March, but the juices produced over much of this period are often too sour, too bland or too flavourless to be acceptable and must be blended with better quality juice before marketing.

Some overseas countries have longer orange-processing seasons than Australia because they use several cultivars which reach acceptable quality at periods spaced more uniformly through the year. In Florida, for example, even without navels which crop poorly there, processing is in progress for 11 months of the year with a peak period from November to July. Over this period, fruit of consistently good quality is readily available, with total soluble solids (TSS) contents of 10–13° Brix, acid contents of 0.60–1.12 g citric acid per 100 ml, and TSS : acid ratios of 11.5–16.5 (FMC Corporation 1976).

The favourable Florida situation arises from the use of four main orange cultivars: Parson Brown, Hamlin, Pineapple and Valencia, which, though all blossoming within the same 6-week period (late February to mid April), reach optimum maturity at different times (Table 1). In this way, good quality juice can be produced for at least 6 months of the year (Table 2), and the quality of juice a month either side of this period would not be greatly inferior. Although Australia, for unidentified horticultural reasons, cannot match the high ratios recorded for Florida juice, there seems no

Table 1. Major orange cultivars processed in Florida[A]

	Hamlin	Parson Brown	Pineapple	Total non-Valencia	Valencia
Period of commercial maturity	Oct.–Dec.	Oct.–Dec.	Jan.–March	Oct.–March	March–July
New commercial plantings					
1947–58 (comparative[B])	27.5	15.8	29.4	68.8	100
1958–70 (comparative[B])	72.3	11.4	44.4	128.1	100
Ratio 1959–70:1947–58	5.64	1.32	2.77	3.42	1.84

[A] Adapted from Cooper and Chapot (1977)

[B] Based on Valencia hectarage = 100, approx. 32 500 and 60 000 ha in 1947–58 and 1958–70, respectively.

reason why this country cannot produce juices of consistent quality over a similar period by using orange cultivars in addition to Valencias and navels.

The Florida industry recognized the benefits of spreading its crop over a number of cultivars during its rapid growth in the 1960s (Cooper and Chapot 1977). Relative expansion was almost twice as great in the non-Valencia cultivars as it was in Valencias over that period (Table 1), and non-Valencias represented 56% of new plantings compared with only 40% in the previous 12 years. Consequently, although Valencias remained the dominant single cultivar, by 1973–74 they were outstripped by non-Valencia cultivars *in toto* (Freeman 1975) with 23% greater production and 9% greater crop value (Table 3). Moreover, although Valencias fetched a higher price on the market, the other cultivars yielded a 2% higher return per hectare.

Previous Australian studies

The possibility of increasing the number of cultivars used for the production of orange juice in Australia was first examined by Cox (1969). Average quality measurements over three seasons were recorded for 19 cultivars grown on *Poncirus trifoliata* (trifoliate orange, TO) rootstock at Somersby, N.S.W., and all sampled during June and August. Cox reported that such fruit would have limited value to processors on the New South Wales central coast simply because it would have to compete with lemons for factory facilities. Early fruit fall and low juice yield presented some problems but no adverse comments were made on juice quality. However, since Cox's report, orange juice production in Australia has increased five-fold (compared with a three-fold increase in lemon juice production), and a re-assessment of alternative cultivars on a broader basis is warranted by this increased demand for oranges for juice processing.

In any such re-assessment, attention must be given to the bitterness and acceptability of the juices after processing, which Cox, though recognizing their importance, could not consider. Such considerations are necessary because orange juice, though acceptable when fresh, may not be sufficiently flavoured to retain flavour after processing, and may also develop bitterness owing to the presence of the bitter principle, limonin (Chandler 1977). Cox, moreover, considered the juices to be acceptable if the acidity was below 1.92 g per 100 ml (as citric acid), at that time the maximum acidity allowed in the definition of mature oranges for the fresh market. However, draft standards currently before the Australian Food Standards Committee limit acid contents to between 0.72 and 1.20 g per 100 ml; only three of the seventeen cultivars examined by Cox yielded juices with mean acid contents below 1.20 g per 100 ml, even as late as August.

Cox's fruit were grown on TO rootstock which is known to induce high acidity in the

Table 2. Mean TSS : acid ratios in frozen orange juice concentrates [A] produced in Florida (1979–80 and 1980–81) [B]

	1979-80	1980-81
December	15.0	14.9
January	14.9	14.4
February	15.6	13.7
March	15.6	14.6
April	15.3	14.1
May	16.0	13.5
June	15.6	14.0
Annual average		
Non-Valencia	15.25	14.40
Valencia	15.58	14.01

[A] Samples taken direct from production runs; 137 samples in 1979–80 and 106 in 1980–81.

[B] From FMC Corporation (1981)

Table 3. Production and utilization of Florida oranges 1973–74 [A]

	Non-Valencia	Valencia
Bearing hectarage ($x10^3$)	128	121
Tonnage produced ($x10^3$)	5359	4362
Yield (tonnes/hectare)	41.9	36.0
Percent processed	93.4	91.7
'On-tree' price ($/tonne)	25.30	28.87
Value of production ($x10^6$)	136	126
Returns per hectare ($)	1062	1041

[A] Adapted from Freeman (1975)

juice (Kefford and Chandler 1961; Chandler *et al.* 1976), and it was considered worthwhile to examine fruit grown on *C. jambhiri* Lush (rough lemon, RL) which has the opposite effect. Usually these rootstocks affect sugar contents in the same direction as acid contents but often the net effect is for RL to give the higher TSS : acid ratio, i.e. to give juice with the better sugar–acid balance. Grown on this rootstock, some cultivars might achieve a low acidity with an acceptable ratio before fruit drop. However, since RL rootstock invariably induces higher limonin contents than other rootstocks (Kefford and Chandler 1961; Maier *et al.* 1977), the processed juice could be unacceptably bitter, although acceptable in sugar-acid balance. On the other hand, cultivars giving juices with little or no bitterness but with unsatisfactorily low ratios when grown on RL would be worthy of subsequent study on other rootstocks to improve the ratio, since these cultivars, having been screened by examination on RL, would present no bitterness problems on other rootstocks.

Recent studies on processed juices

Seven early and mid-season cultivars grown under uniform conditions on RL rootstock were selected for study from the Somersby variety collection of the N.S.W. Department of Agriculture's Horticultural Research Station, Gosford. The cultivars were: Hamlin, Homosassa, Joppa, Mediterranean (sweet), Pineapple, (white) Siletta and St Michael, the selection being based on horticultural performances (Turpin 1972) as well as on Cox's results. Samples were taken between 16 and 23 June and between 20 and 24 August in 1976 and 1978, with an additional pick in late September 1978 from all cultivars except St Michael. The juice was extracted, processed, stored at 1 °C for 6 months and analysed by normal procedures (Chandler *et al.* 1976). A panel of four experienced tasters assessed each juice for bitterness on a continuous 0–10 scale (0, no bitterness; 2, very slight; 4, slight; 6, moderate; 8, strong; 10, extreme bitterness) and for general acceptability on a continuous 0–10 scale (0, completely unacceptable; 2, very slightly; 4, slightly; 6, moderately; 8, strongly; 10, extremely acceptable).

In these preliminary studies, the results were examined for gross differences only, since it was considered that fine differences would not be relevant to industrial operations. The quality of the five juice samples from each cultivar (four in the case of St Michael) was taken as generally indicative of their relative suitability for processing, irrespective of season; and differences between two or more cultivars are only noted in the following discussion when means of the analyses of the four or five samples differed by more than the sum of their standard deviations. The results are summarized in Table 4 which groups the three unpromising cultivars together as 'others'; full details will be made available on request. Noteworthy differences obscured by this condensed presentation will be mentioned in the discussion. To facilitate the overall comparison of the cultivars, Table 4 also includes data from Cox's 1969 study.

Rootstock differences

Although the examinations were made in different years, by different groups and on fruit grown on different rootstocks, there were marked similarities in the results from this and Cox's study (Table 4). Juice yields were very similar and no cultivar gave consistently higher juice yields on one or other of the two rootstocks. Apart from higher concentrations in Joppas and Pineapples on TO, the mean TSS contents were also very similar.

Nevertheless, differences in the maturation processes in fruit on the two rootstocks were apparent and similar to those observed with navels and Valencias (Chandler *et al.* 1976). In fruit on RL, TSS concentrations increased by an average of only 0.3 ± 0.3 °B from June to August whereas the comparable increase in fruit on TO was 1.2 ± 0.2 °B. The biggest differences were in acid contents; fruit on RL were considerably lower in acid. Moreover, the fall in acid concentration from June to

Table 4. Quality parameters for juice from mid-season oranges (N.S.W. Central Coast)

	Hamlin	Siletta (white)	Mediterranean Sweet	St Michael	Others [A]
Juice yield (%)					
TO June-August [B]	44.5 ± 0.2	45.3 ± 0.4	46.3 ± 0.4	44.5 ± 0.2	41.9 ± 0.9
RL June-August [B]	43.8 ± 1.8	43.0 ± 1.2	44.8 ± 2.3	40.9 ± 5.2	40.8 ± 2.3
RL September [C]	44.4	45.1	48.5	—	39.4 ± 2.2
Total soluble solids content (° Brix)					
TO (JA)	10.8 ± 0.7	9.9 ± 0.6	10.5 ± 0.7	9.7 ± 0.7	10.2 ± 0.9
RL (JA)	11.1 ± 1.8	9.7 ± 0.6	10.1 ± 0.5	9.7 ± 0.7	9.3 ± 0.5
RL (S)	13.5	10.6	10.7	—	10.4 ± 0.3
Acid content (g citric acid/100ml)					
TO (JA)	1.10 ± 0.22	1.58 ± 0.18	1.80 ± 0.29	1.55 ± 0.23	1.49 ± 0.20
RL (JA)	0.97 ± 0.22	1.02 ± 0.19	1.23 ± 0.20	1.00 ± 0.17	1.12 ± 0.21
RL (S)	0.80	0.98	0.77	—	0.84 ± 0.11
TSS : acid ratio					
TO (JA)	10.3 ± 2.6	6.4 ± 1.1	6.1 ± 1.4	6.5 ± 1.4	7.1 ± 1.5
RL (JA)	11.7 ± 2.1	9.7 ± 1.8	8.4 ± 1.8	10.0 ± 2.1	8.5 ± 1.8
RL (S)	16.9	10.8	13.9	—	12.6 ± 2.1
Limonin content (mg/litre)					
RL (JA)	4.7 ± 1.7	7.3 ± 2.5	13.6 ± 5.0	11.1 ± 3.1	12.6 ± 4.9
RL (S)	2.0	3.6	9.0	—	11.8 ± 2.4
Bitterness rating [D]					
RL (JA)	2.7 ± 2.7	2.8 ± 1.5	6.0 ± 1.8	3.9 ± 1.7	4.8 ± 1.3
RL (S)	0.0	0.5	1.8	—	2.5 ± 0.9
General acceptability [E]					
RL (JA)	5.1 ± 2.6	5.1 ± 1.1	2.3 ± 1.5	3.4 ± 0.9	2.7 ± 0.8
RL (S)	7.0	5.8	5.0	—	3.0 ± 0.8

[A] Mean values from Homosassas, Joppas and Pineapples.

[B] Mean values (with standard deviations) for fruit on *Poncirus trifoliata* rootstock (TO) from mean values 1966–68 (Cox 1969); for fruit on rough lemon rootstock (RL) from individual 1976–78 data; picks made in June and August each year.

[C] Values for September pick 1978. No pick made of St Michaels.

[D] Bitterness scale from 0 (non-bitter) to 10 (extremely bitter).

[E] Acceptability scale from 10 (extremely acceptable) to 0 (completely unacceptable).

August was only 0.26 ± 0.12 g citric acid per 100 ml in fruit on RL compared with a fall of 0.42 ± 0.09 g citric acid per 100 ml in fruit on TO; nevertheless, in August the mean acid content of fruit on TO was higher than that of fruit on RL (1.29 ± 0.18 and 0.95 ± 0.16 g citric acid per 100 ml respectively).

The difference in acid contents was reflected in large differences in TSS : acid ratios except for Joppas where similar relative differences in TSS and acid contents between fruit on the two rootstocks resulted in very similar ratios. Otherwise, at each comparable pick the ratio for fruit on RL was the higher, with differences of 1.1–4.8 ratio units (mean difference, 2.7 ± 1.0 units). This result justifies the suggestion that some cultivars could give a more satisfactory sugar–acid balance when grown on RL than when grown on TO.

Seasonal differences

Cox's results are available only as means of values obtained over the three seasons 1966–1968, so that no seasonal differences are observable. However, with fruit on RL, there were few consistent differences in the quality characteristics between the corresponding 1976 and 1978 samples, the mean values for each parameter being very similar (Table 5). The TSS contents were generally lower in 1978 than in 1976 by about 1 °B, except for Hamlins which were higher in TSS by about 3 °B. Otherwise, the only consistent difference lay in apparently different maturation rates in the two seasons which,

Table 5. Mean values (with standard deviations) of quality parameters for juices from mid-season oranges [A] over two seasons (N.S.W. Central Coast)

	1976	1978
Juice yield (%)	41.7 ± 2.3	42.5 ± 3.5
TSS content (° Brix)	10.3 ± 1.0	9.2 ± 0.4
Acid content (g/100 ml) [B]	1.06 ± 0.24	1.11 ± 0.16
TSS : acid ratio	9.2 ± 2.3	9.5 ± 1.8
Limonin content (mg/litre)	9.9 ± 5.0	11.4 ± 4.6
Bitterness rating [C]	4.1 ± 1.8	4.1 ± 2.0
General acceptability rating [C]	3.5 ± 1.4	3.4 ± 1.6

[A] Grown on RL rootstock and sampled in June and August.

[B] As citric acid.

[C] See footnotes to Table 4.

nevertheless, resulted in near identical means for each parameter. Acid contents (g citric acid per 100 ml) fell between the June and August picks by 0.32 ± 0.14 in 1976 and by 0.20 ± 0.06 in 1978 and accordingly ratios increased slightly more rapidly in 1976; over the same period, limonin contents also fell more rapidly in 1976, by 7.9 ± 3.9 compared with 3.5 ± 1.6 mg per litre in 1978. The absence of any major overall difference between the two seasons endorsed the decision to treat the juices simply as representative juices from each cultivar, irrespective of the season.

Differences among cultivars

There was less variation in juice yield among cultivars than in any other characteristic: Mediterraneans, Silettas and Hamlins gave the highest yields on both rootstocks, and Homosassas and Pineapples the lowest.

Hamlins were superior to the other cultivars in internal quality characteristics. They had the highest TSS contents on RL and by far the lowest acidity on TO; consequently, their TSS : acid ratios were the highest on both rootstocks. In contrast, Mediterraneans had very high acidities, the highest on TO and the second highest on RL; their TSS contents tended to be only slightly higher than those of the other five cultivars so that their ratios were comparatively low, especially on RL, although considerable improvements were noted at the September pick. Joppas, on the other hand, with highest acidities on RL and hence the lowest ratios, showed only limited improvement at this pick.

Hamlins were also superior to other cultivars in their low limonin contents; Silettas were almost as good as Hamlins in this respect. Since these observations apply to fruit in both seasons and at three maturity levels, these two cultivars are identified as naturally low in limonin, almost as low as Valencias and considerably lower than navels. Homosassas and Joppas were noteworthy in that their limonin contents changed little from June to August in 1976 and from June to September in 1978, whereas Mediterraneans, St Michaels and Pineapples showed considerably reduced limonin contents over these periods. Bitterness scores generally showed the same trends as limonin contents, Hamlins and Silettas giving by far the least bitter juices, with just detectable or no bitterness by August. St Michaels were slightly less satisfactory, the juice being very slightly bitter by August. With other cultivars, the juices were only just detectably bitter by September, except for Joppa juice which was still slightly bitter.

Similarly, Hamlin juice was rated highly acceptable by August, while Siletta juice, though acceptable even in June, was less acceptable than Hamlin juice in August. Juice from St Michaels was acceptable in August and that from Mediterraneans somewhat more acceptable in September. None of the other cultivars gave juices as acceptable as these four cultivars.

Basis for acceptability

With the very notable exceptions of Hamlins and Silettas, processed juices from these sweet orange cultivars, grown on the N.S.W. Central Coast and harvested June–September, were generally unacceptable, as shown by their mean acceptability scores (Table 4). Reasons for this unacceptability varied with the cultivar, being related to TSS : acid ratio, limonin content and another factor, believed to be associated with other flavour characteristics.

With Hamlins, Joppas, Mediterraneans and St Michaels, acceptability (A) increased linearly with increasing ratio (R) (Figure 1), according to the relationship $A = 0.559R - 1.97$ (correlation coefficient = 0.754, number of pairs = 19, significance > 99.9%). From this relationship, these juices would be more than slightly acceptable ($A > 4$) provided $R > 10.7$, in general agreement with the observations recorded above. No such relationship held with the other juices.

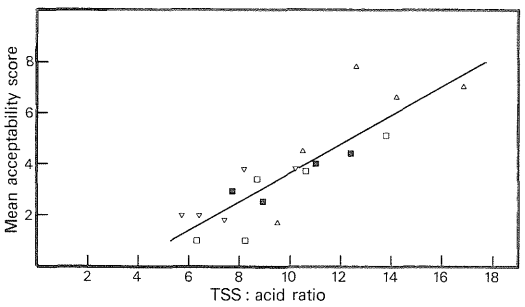

Fig. 1. Plot of mean acceptability score (*A*) against TSS : acid ratio (*R*) for juices from Hamlins (△), Mediterraneans (□), St Michaels (■) and Joppas (▽). The straight line corresponds to the linear regression equation $A = 0.559R - 1.97$.

Silettas gave juices that were always acceptable despite ratios below 10, and Homosassas and pineapples gave juices that were always unacceptable, although some had ratios above 11.

With Joppas, Mediterraneans, Silettas and St Michaels, acceptability (*A*) increased linearly with decreasing limonin contents (L in mgl^{-1}) (Fig. 2), according to the relationship $A = 6.83 - 0.31L$ (correlation coefficient = 0.810, number of pairs = 24, significance > 99.9%). These juices would therefore be more than slightly acceptable ($A > 4$) provided $L < 9.2$, in general agreement with the observations made above. As with ratios, limonin contents had no apparent effect on the acceptability of Homosassa and Pineapple juices; despite some samples with limonin contents below 9.2 mgl^{-1}, these juices were always unacceptable.

In summary, Homosassas and Pineapples did not give satisfactory juices on processing even when the ratios and limonin contents were favourable; unsolicited tasters' comments indicated lack of orange character in the processed juices. Joppas, Mediterraneans and St Michaels were subject to low ratios and high limonin contents; sometimes, when one factor was favourable, the other was not. Mediterraneans and St Michaels gave acceptable juices late in the season, both factors becoming favourable for St Michaels in August and for Mediterraneans in September. Siletta juices, though always acceptable, were most satisfactory in August when limonin contents were low. Hamlin juices were even more satisfactory than Silettas in August, though less satisfactory in June despite the fact that Hamlin juices always contained less limonin and had higher ratios than Siletta juices.

More about the promising cultivars

Although never commercially significant in Australia, the Hamlin (or Norris) is probably the world's principal, very early maturing, common sweet orange, being widely cultivated in Florida and Texas; Brazil and Argentina; Algeria, Morocco and Corsica; South Africa; and the West Indies. In Florida, Hamlin is the most popular of the early-maturing cultivars and the second most important cultivar after Valencia (Hodgson 1967). The trees are moderately vigorous, medium sized, reasonably productive, more cold resistant than most and only slightly susceptible to alternate bearing (Cox 1969; Hodgson 1967). Though thinner skinned, the fruit is comparable in many ways to the Valencia, with similar gross chemical composition when mature, but the Hamlin matures up to 4 months earlier. This trial indicates that Hamlins deserve serious consideration for mid-season processing: when grown on TO or RL and harvested after June, they are capable of providing fruit more acceptable for processing than mature navels and immature Valencias.

Unlike the Hamlin, the Siletta (or Seleta) previously achieved some commercial importance in Australia, being introduced as early as 1824 (Hodgson 1967). Since 1920, its

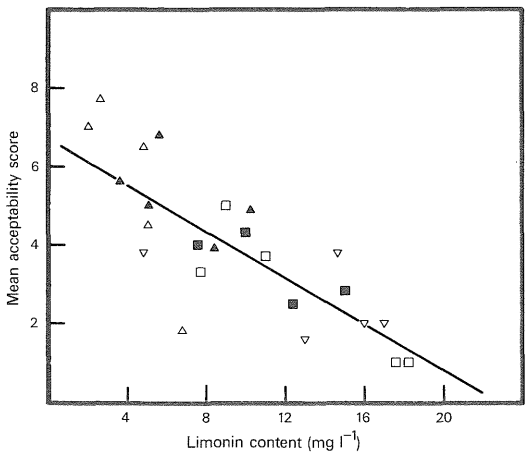

Fig. 2. Plot of mean acceptability score (*A*) against limonin content (*L*) for juices from Hamlins (△), Mediterraneans (□), St Michaels (■), Joppas (▽) and Silettas (▲). The straight line corresponds to the linear regression equation $A = 6.83 - 0.31L$.

plantings have greatly decreased, though it is interesting to note that it was used for juice production in the early days of the industry (Bowman 1956). The trees are similar in horticultural characteristics to Hamlin trees and the fruit is generally similar to the Valencia, apart from a more definite areola, a lack of full orange colour and a tendency to lose green colour before reaching maturity (Cox 1969; Hodgson 1967). Though of commercial importance in Brazil, the Siletta has not received extensive cultivation elsewhere, probably because it tends to drop from the tree after reaching maturity. This was not a major problem at Somersby but if it occurs elsewhere, the use of 'stop-drop' sprays would be justified, as this cultivar, when grown on RL, makes very acceptable processing fruit; the juice of Silettas grown on TO is too acid to be acceptable. Like Hamlins, Silettas would have horticultural advantages in certain areas where RL is the preferred rootstock, and they could be suitable for processing some weeks before Hamlins.

Two other possibly useful cultivars, the Mediterranean (Maltaise oval) and the St Michael (Paperrind), were both important mid-season varieties for the early Californian industry until the dominance of navels and Valencias was established. Though both were widely distributed at one time, the Mediterranean is now cultivated only in North Africa and Mexico and the St Michael only in Mexico (Hodgson 1967). Both trees bear well but are subject to alternate cropping (Cox 1969). The earlier maturing cultivar, the Mediterranean, is pale in both peel and flesh and gives a mild-flavoured juice which, however, retains flavour well on processing, while the St Michael is moderately seedy and has an attractive fresh flavour. Both these cultivars when grown on RL (but not on TO) and harvested later in the season than Hamlins and Silettas (after July for St Michaels and after August for Mediterraneans) could obviate the need for early processing of Valencias; 'stop-drop' sprays may have to be applied, particularly to St Michaels. These cultivars may show more favourable maturation effects (high TSS : acid ratio and low limonin content) on other rootstocks.

Conclusion

On the evidence from the orange plantings at Somersby, both cultivar and rootstock influence the suitability of mid-season cultivars for the production of processed juice. With the notable exception of Hamlins, all cultivars tested on TO rootstock during 1966–68 retained high acidity too long into the season to yield juice acceptable for processing. Hamlins on TO, with low acidity and high TSS content, high TSS : acid ratio and good juice yield, seem satisfactory for juice processing in July–August and possibly later.

In the present trials, Hamlins also performed well on RL with good juice yield, high TSS content, high TSS : acid ratio, low acidity, negligible bitterness and good quality on processing when harvested after June. Silettas on RL also performed well, being suitable for processing a few weeks earlier than Hamlins, though they were not as sweet and had lower TSS : acid ratios. Of the other cultivars, Mediterraneans and St Michaels showed promise; the former gave a very acceptable juice in September and the latter may have done so had the fruit been induced to hang longer on the tree.

The assistance of the N.S.W. Department of Agriculture and its officers at its Somersby orchard in the supply of this fruit is gratefully acknowledged.

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Monitoring the treatment of abattoir wastewaters

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A study of untreated abattoir wastewaters has shown that a good estimate of BOD_5 can be made from COD ($r = 0.92$), and a reasonable estimate from SS ($r = 0.72$). For treated wastewaters, BOD_5 can be predicted reasonably well from SS ($r = 0.86$), with a rough estimate obtainable from COD ($r = 0.69$). The much shorter times required for COD and SS analyses (3 and 1.5 h respectively) compared with the time required for BOD_5 analyses (5 days), should permit COD and SS values to be used for monitoring the performance of plants treating abattoir wastewater. Because of the variability of abattoir wastewaters, a more accurate indication of the BOD_5 would probably be obtained by estimating BOD_5 from a number of COD and SS readings, rather than a single BOD_5 analysis.

Introduction

In Australia, community pressure to minimize water pollution is increasing, and in all States the discharge of wastewater from industrial premises is subject to stringent legal requirements. Although abattoir wastewaters contain only low concentrations of toxic materials, they have an offensive odour and contain large amounts of organic material with high biochemical oxygen demand (BOD). In general, abattoir wastewaters must contain no more than 20 mg l^{-1} BOD_5 (5 day BOD) and 30 mg l^{-1} suspended solids (SS) before discharge to a watercourse, or they must satisfy local authority requirements for BOD_5, SS and fat (grease) before discharge to the sewers.

Treatment plants are installed in abattoirs to give either complete or partial waste water treatment, and regular determinations of BOD_5, SS and fat in wastewaters are required for the assessment of plant performance and for regulatory purposes.

In basic studies of biological oxidation processes, such as reaction kinetics and biomass yields, there is good reason to express the substrate concentration in terms of BOD content. However, procedures for BOD analyses are slow and cumbersome, normally requiring 5 days to complete. This limits the usefulness of BOD_5 results for many aspects of plant control and field work (Sherrard *et al.* 1979). There are obvious advantages in replacing BOD_5 with other measurements

which can be obtained more rapidly and conveniently. These measurements would need to have a known relationship with BOD_5.

Several research workers have attempted, with limited success, to shorten the time required for BOD_5 analyses by the use of mass cultures (Hiser and Busch 1964), or by performing the BOD test at temperatures higher than the normally used 20 °C (Le Blanc 1974). Others (Aziz and Tebbutt 1980; Sherrard *et al.* 1979; Le Blanc 1974; Pipes 1979) have attempted to correlate BOD_5 with SS, chemical oxygen demand (COD), total organic carbon, or other easily measured wastewater parameters. Most have found it difficult to obtain satisfactory correlations, mainly because they have concentrated on municipal sewage, which tends to have a highly variable composition (Kalinske 1976) depending on the quantity and nature of industrial wastewaters discharged into the sewers. In contrast, wastewaters from single-process industries such as abattoirs, or other food processing industries, are generally less variable in composition. BOD_5 is also usually much higher for wastewaters from these industries (abattoir wastewater BOD_5 3000 mg l^{-1} than that for municipal sewage (BOD_5 200–300 mg l^{-1}), thus resulting in much lower percentage errors in analytical results. These factors should improve the chances of obtaining satisfactory correlations between BOD_5, COD and SS for wastewaters in the food industries. Correlations would apply only for samples taken at the same locations in the wastewater systems. The time required for COD and SS analyses are 1.5 and 3 h respectively, thus allowing these measurements to be of use in wastewater treatment plant control.

Although there is debate about the use of BOD_5 as a monitoring parameter (Sherrard *et al.* 1979), BOD_5 and its relationship to COD and SS will remain of interest and importance for design and operation of wastewater treatment plants as long as regulatory authorities continue to specify pollution levels in terms of this characteristic.

Materials and methods

Wastewater samples were obtained from an abattoir (abattoir A) which was slaughtering 700 cattle, 750 pigs, 4000 sheep and 500 calves per day. Wet rendering of inedible offal was also carried out on the premises, but no further meat processing, e.g. boning or smallgoods manufacture, was done. Wastewater flow, which was monitored daily, averaged 4000 m^3 per day.

Samples were taken from the discharge of a dissolved air-flotation unit which was operating ineffectively and removing only the easily-settled or floating suspended solids. Treated effluent was sampled from the overflow of the clarifier of the activated sludge plant. Samples were also taken from other abattoirs to obtain a representation of effluents resulting from a range of operations including smallgoods manufacture. Only untreated wastewater samples were taken in these cases. There was considerable variation in the amount of SS and fat in the latter samples, depending on the type and effectiveness of the primary treatment.

COD and SS were determined according to the methods given in American Public Health Association (1971). BOD_5 analyses for untreated wastewater samples were done in our laboratory and in a commercial analytical laboratory, both using the 'Hach' manometric instrument (Tool 1967). This method involves placing the required volume (usually 95 ml) of diluted (1:10) wastewater in a BOD bottle. A magnetic stirring bar is placed in the bottle and a sealing cap, filled with lithium hydroxide (for carbon dioxide adsorption), is put in position. The bottle is lightly closed and the wastewater stirred. After allowing 10–15 minutes for equilibration, the bottle is sealed and the manometer set to zero. The samples are incubated at 20 °C for 5 days. Readings are recorded every day, the reading on the 5th day being BOD_5. No seed or nitrification inhibitor was used for the untreated samples, as earlier tests had shown they had no effect on the outcome of the test. All BOD_5 analyses for the treated samples were done in our laboratory using the 'Hach' method as described above, except that nitrification inhibitor (Hach Cat. No. 2533-35) was added to all samples.

Results and discussion

Untreated wastewater

The results of the analyses of untreated wastewaters are summarized in Table 1.

BOD_5/COD ratio

An average BOD_5/COD ratio of 0.57 (i.e.

Table 1. Analyses of untreated wastewaters

No. of samples	BOD_5 mg l^{-1} Range (mean)	COD mg l^{-1} Range (mean)	SS mg l^{-1} Range (mean)	Linear correlation equation	Linear correlation coefficient
53	390–4600 (1602)	691–6215 (2803)	—	$BOD_5 = 0.519xCOD + 150$	0.618
21[A]	475–4600 (2042)	691–6215 (2809)	—	$BOD_5 = 0.688xCOD + 182$	0.920
32[B]	390–2240 (1318)	755–4980 (2799)	—	$BOD_5 = 0.562xCOD + 123$	0.561
28	900–4600 (2090)	—	105–2150 (869)	$BOD_5 = 2.169xSS + 96$	0.722
165	—	399–9394 (3033)	8–3633 (1297)	$COD = 2.193xSS + 140$	0.849

[A] CSIRO Meat Research Laboratory (MRL)
[B] Commercial Laboratory

57% biodegradable) was calculated, considerably higher than the 0.41 recently reported (Aziz and Tebbutt 1980) for untreated domestic sewage. Linear regression analysis of all BOD_5/COD data obtained for untreated wastewaters gave a correlation coefficient of 0.618. Visual inspection of the plot of these results (Fig. 1), however, shows that points representing results from our laboratory (MRL) are consistently higher in BOD_5 than those from the commercial laboratory. This observation is confirmed by comparison of the BOD_5:COD ratio for the results from the two laboratories. For MRL the ratio is 0.73, for the commercial laboratory it is 0.47. Linear regression analysis of the results from each laboratory gave a good correlation for MRL (r = 0.920), with only a poor correlation for the commercial laboratory (r = 0.561). The BOD_5 analyses done at MRL commenced, in all cases, within 30 min of sampling. For the commercial laboratory, the time between sampling and analysis varied between 3 and 48 h. Although the samples were preserved by placing them in ice and/or placing them in a refrigerator at 3 °C, it would have taken many hours to reduce the temperature of the samples to a value where bacterial action was negligible. Furthermore, because approximately 50% of the total BOD_5 of untreated abattoir effluent was used in the first 24 h at 20 °C, the BOD usage in the time between sampling and analysis would have been significant. The lower biodegradability (BOD_5/COD ratio) and the poorer correlation coefficient of samples analysed at the commercial laboratory may be explained by the effect of this delay on BOD_5. COD values would not be affected by this time delay, as the BOD being exerted at this stage would mainly be for the synthesis of new cells. It would therefore appear that a good correlation does exist between BOD_5 and COD for untreated abattoir wastewater, provided the BOD_5 analysis is commenced within 30 min of sampling.

BOD_5/SS and COD/SS ratios

The organic content of abattoir wastewater appears in both soluble and insoluble components. SS measurements are not normally used, except to monitor bacterial concentration and growth in the aeration ponds, lagoons and clarifiers of treatment plants. Linear regression analysis of the COD, SS (Fig. 2) and BOD_5, SS (Fig. 3) data gave a reasonably linear relationship between COD. and SS (r = 0.849) with a somewhat poorer, but still usable linear correlation between BOD_5 and SS (r = 0.722).

It was found throughout this study that abattoir wastewaters had relatively constant soluble BOD_5 and COD values, and that changes in total BOD_5 or COD were due to changes in SS Consistent relationships should

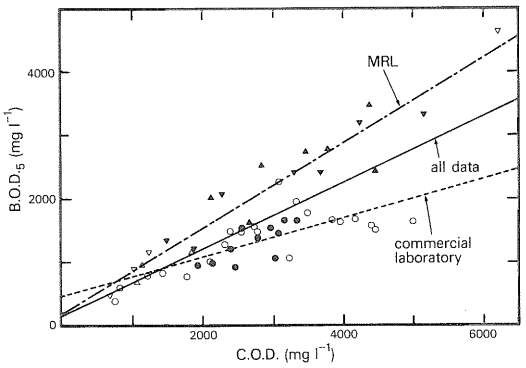

Fig. 1. Variation in BOD_5 with COD for untreated abattoir wastewater. (△, ▲ analysed at MRL; ○, ● analysed at a commercial laboratory; ▲, ● samples from abattoir A; △, ○ samples from other abattoirs.)

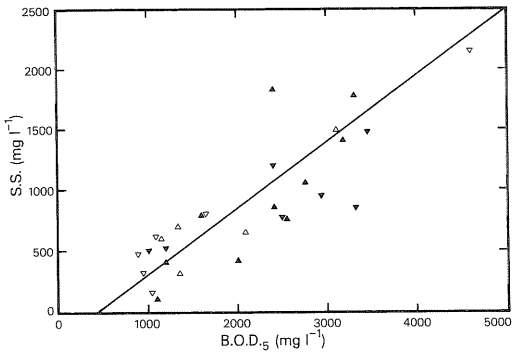

Fig. 2. Variation in SS with BOD_5 for untreated abattoir wastewater. (△, samples from abattoir A; ▲, samples from other abattoirs.)

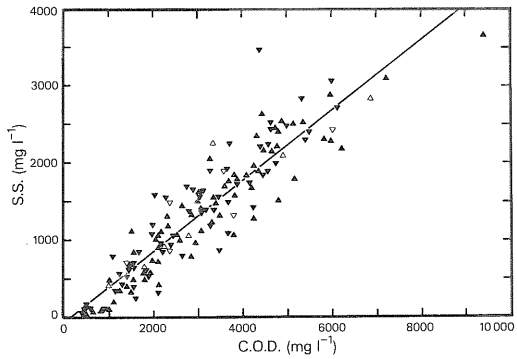

Fig. 3. Variation in SS with COD for untreated abattoir wastewater. (△, samples from abattoir A; ▲, samples from other abattoirs.)

therefore exist between COD, BOD_5 and SS, over a large range of concentrations.

Treated wastewaters

Samples of treated wastewater were taken from a single abattoir which used the activated sludge treatment process. The results obtained from analyses of treated wastewater are summarized in Table 2.

BOD_5/COD ratio

A plot of the BOD_5 *v.* COD data obtained for treated abattoir wastewaters is shown in Fig. 4. Linear regression analysis of this data gave a correlation coefficient of 0.693.

BOD_5/SS and COD/SS ratios

Linear regression analysis of BOD_5 *v.* SS data (Fig. 5) for treated wastewaters gave a satisfactory correlation coefficient of 0.861.

COD and SS data were obtained from samples collected over a full week of operation of the treatment plant, and so covered a large variation of COD and SS concentrations. The data have been divided into two groups, (*a*) SS greater than 200 mg l^{-1}, and (*b*) SS less than 200 mg l^{-1} (Figs 6 and 7 respectively). The correlation coefficient of 0.874 obtained for group (*a*) indicates that at higher SS concentrations, the greater part of the COD content will be due to insoluble material, which is mainly biomass and therefore of constant material. However, analysis of group (*b*) data indicates that at the lower SS concentrations, a very poor correlation exists ($r = 0.260$), reflecting variations in the COD of non-biodegradable, soluble material.

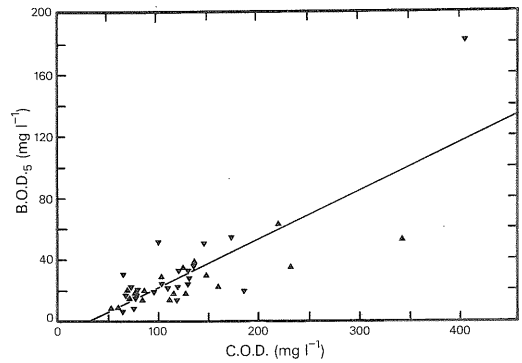

Fig. 4. Variation in BOD_5 with COD for treated abattoir wastewater.

Table 2. Analyses of treated wastewaters

No. of samples	BOD_5 mg l^{-1} Range (mean)	COD mg l^{-1} Range (mean)	SS mg l^{-1} Range (mean)	Linear correlation equation	Linear correlation coefficient
44	6–45 (24.5)	53–342 (113)	—	$BOD_5 = 0.314xCOD-9$	0.693
37	8–322 (135)	—	13–410 (152)	$BOD_5 = 0.816xSS+5$	0.861
153	—	65–5868 (991)	5–6603 (972)	$COD = 0.943xSS+76$	0.963
108 (SS < 120)		65–391 (122)	5–117 (389)	$COD = 3.096xSS$	0.260
43 (SS > 120)		511–5868 (3207)	357–6603 (3355)	$COD = 0.974xSS+64$	0.874

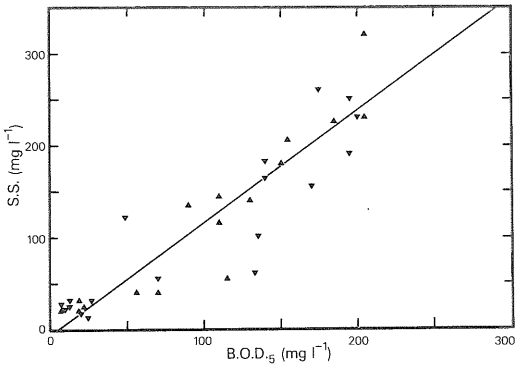

Fig. 5. Variation in SS with BOD_5 for treated abattoir wastewater.

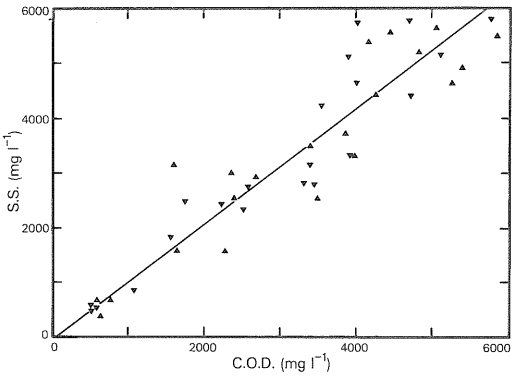

Fig. 6. Variation in SS with COD for treated abattoir wastewater (SS greater than 200 mg l^{-1}).

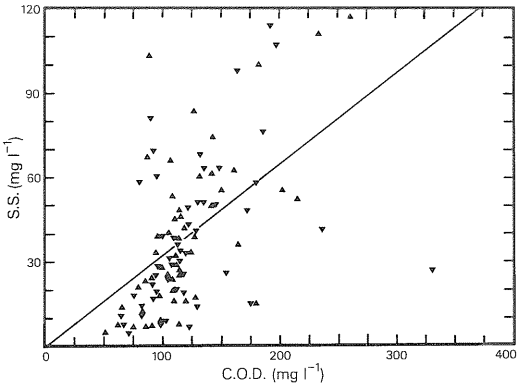

Fig. 7. Variation in SS with COD for treated abattoir wastewater (SS less than 200 mg l^{-1}).

Summary

This study shows that for untreated wastewater, COD gives the best estimate of BOD_5 ($r = 0.920$) and SS gives a reasonable guide ($r = 0.722$). For wastewater that has been treated by the activated sludge process, the reverse is the case, with SS giving a good indication ($r = 0.861$) of BOD_5 and COD giving only a reasonable indication ($r = 0.693$). This result is consistent with the assumption that all of the organic, biodegradable material in the untreated wastewater has been removed, or converted into new biomass, leaving only the non-biodegradable material and the biomass in the treated wastewater. The BOD exerted in the treated wastewater will be for endogenous respiration of the microorganisms present, and will therefore be directly related to its SS content. However, the COD will be affected by variations in concentration of non-biodegradable, soluble material.

Although much of the data for this study was for wastewater taken from a single abattoir, the relationships obtained for untreated wastewater should apply to abattoir wastewater generally, for other food-processing industries that produce wastewater with a high BOD_5 content, linear relationships should also exist between BOD_5, COD and SS. Similarly, for food-processing industries that use wastewater treatment processes other than the activated sludge process (e.g. anaerobic or aerobic lagoons), good correlations should exist between BOD_5, COD, and SS for treated wastewaters. The use of these relationships should lead to better control of such wastewater treatment plants.

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News from the Division

Visit to FRL of CSIRO Advisory Council and N.S.W. State Committee

Members of the CSIRO Advisory Council and of the State Committee for New South Wales spent the morning of 17 June at FRL, as part of a program of meetings and visits in the Sydney area.

The State Committees and Advisory Council are a means of communication between various sections of the Australian community and the Organization and provide the Executive with an important input into the development of CSIRO's research policies.

After a brief introduction by the Chief of the Division, Dr J. H. B. Christian, the visitors were taken on a tour of the laboratories and addressed by research leaders. This was followed by a talk on industry and consumer extension and liaison activities, after which there was a general discussion and a useful exchange of views between members of the group and FRL staff. Topics of particular interest proved to be the planning and funding of research projects brought to CSIRO's notice by the Australian food industry and the ways and means of disseminating research results and Divisional expertise to the Australian community.

Award

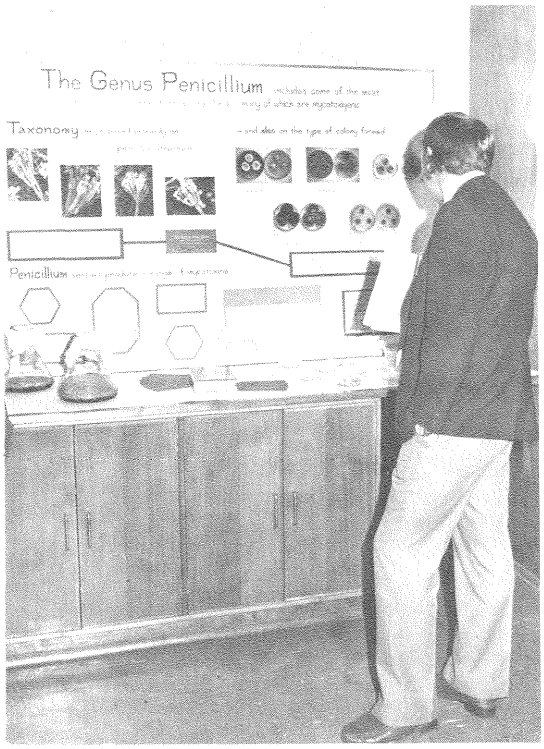
Hicks Prize — 1981

The 'E. W. Hicks Memorial Prize' for 1981 was awarded jointly to Mr Paul Walton (Technical Officer), Food Safety and Nutritional Quality Group, and Mr Brian LeBreton (Apprentice Carpenter) for 'The most meritorious academic record leading to the award of a first post-secondary qualification by part-time study whilst on the staff of the Food Research Laboratory'. Mr LeBreton consistently gained top marks in his apprenticeship courses and Mr Walton further received the 'Leonard J. Lawler Prize' for 1981 for best aggregate mark in Clinical Biochemistry at the New South Wales Institute of Technology. He now intends to pursue a Ph.D. course at the State University of Pennsylvania, U.S.A.

Food Industry Days 1982

On 24 and 25 March 1982, the Division invited senior personnel from the Australian food industry to the Food Research Laboratory at North Ryde, with a view to strengthening the Division's ties with that industry.

The event was opened by Dr K. A. Ferguson, Director of the CSIRO's Institute of Animal and Food Sciences, of which the Division is a part. Then followed brief talks on the aims of the Division by its Chief, Dr J. H. B. Christian, and outlines of the research undertaken by DRL, MRL and FRL by their respective Officers-in-Charge (Mr L. L. Muller, Dr D. J. Walker and Dr A. R. Johnson). FRL's senior liaison officer, Mr K. C. Richardson, spoke about the Division's industry liaison activities. Participants joined in discussions with the speakers and other staff of the Division and this exchange of views formed an essential part of the event.



After lunch, the visitors saw five sets of exhibits in FRL's laboratories, and were shown the scope of the facilities available for use in the general area of food science and technology. Registrants were encouraged to establish or renew contact with individual members of scientific and technical staff.

An open invitation was extended to members of the Australian Institute of Food Science and Technology to tour the laboratories on the afternoon of 25 March and many did so. The Annual General Meeting of the AIFST was also held at FRL that day, followed by an AIFST farewell dinner for Mr J. F. Kefford, recently retired from CSIRO as Assistant Chief (External Relations) (see News from the Division, FRQ 42, 1).

A highlight of the Industry Days was the central display in the foyer of the Hicks Meeting Room at FRL, featuring panels depicting the work of the Division as a whole. Separate panels were devoted to information and extension services, statistics, the Meat Research Laboratory, the Dairy Research Laboratory, FRL's six research groups (Plant Physiology, Food Structure, Food Safety and Nutritional Quality, Chemical Bases of Food Acceptance, Applied Food Science and the Tasmanian Food Research Unit) and the FRL Workshops.

To ensure that the central display would be as informative as possible to non-specialist visitors, the Division secured the services of CSIRO's Chief Graphic Designer to design and assist in mounting the central display. It is intended to update this display from time to time and make it a permanent focal point for visitors to the Laboratory.

The Division has held Industry Days before, but the most recent of these was some 16 years ago. In the period since, a number of specialist courses for the food industry have been held, some of them jointly with educational establishments or government agencies and departments, and of course, contact with the industry has also been maintained by other means. Although it is too early to judge the extent to which the Food Industry Days will enhance the Division's good relations with Australia's food industry, initial reactions have been most gratifying and it is envisaged that similar events will be staged at more frequent intervals in the future.