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Effects of maturity at harvest and ripening on the eating quality of papaw fruit

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Abstract

Papaw fruit (*Carica papaya* L.), derived from an experimental breeding programme, were harvested from two locations at eight maturities ranging from small dark green fruit to fully coloured tree-ripened fruit.

Dark green fruit developed yellow skin colour during ripening at the same rate as pale green 'breaker' fruit, but they did not have the same extent of skin-colour development at eating ripe as the more mature fruit. Overall, unripe fruit which had reached or closely approached full maturity on the tree, had better eating quality when ripened than immature fruit. Therefore papaw fruit should not be harvested before reaching full maturity (pale green to tinge of colour).

Low correlation coefficients were found for all maturities (even mature fruit) between 'greenlife' and skin colour, flesh colour, aroma, flavour and texture of ripened fruit. This indicated that, even with fruit selected from a post-harvest plant improvement programme, poor relationships were found between maturity at harvest and ripe fruit quality.

INTRODUCTION

The papaw (*Carica papaya* L.) is a soft tropical fruit susceptible to post-harvest injury during handling, transport and marketing. Lee *et al.* (1973) carried out transport trials on papaw fruit (cv. Solo) and found that careful control of maturity at harvest is necessary, since green immature fruit will not ripen to give normal ripe fruit quality. Marriot and Proctor (1979) make a similar observation.

Akamine and Goo (1977) carried out simulated shipping trials with Solo fruit at three stages of ripeness and concluded that fruit should be harvested at 20 to 25% yellow skin colour for optimum quality. Hundtoft and Akamine (1973) studied fifteen post-harvest variables which influence market quality of papaya and found that maturity at harvest was one of the most important considerations.

In Queensland seed propagation of dioecious lines has led to wide variability in the physical, chemical and sensory properties of commercial fruit (Aquilizan and Deuter 1981). Plant breeding programmes by the Queensland Department of Primary Industries (QDPI) have aimed to develop superior dioecious lines and to maintain these in the industry through controlled cross pollination. These dioecious lines are the only types having sufficient cold tolerance for the growing conditions in southern Queensland.

Growers harvest mature, green skin or slightly yellow-coloured fruit to obtain maximum post-harvest shelflife with least injury, commensurate with overall ripe fruit quality. Desirable characteristics found in the Queensland selected lines are improved crop yield, with uniform, medium-sized, firm fruit having a golden yellow skin colour when ripe. Thick flesh with a small ovarian cavity and resistance to ripe fruit rots are also desirable fruit characteristics. However, Chan and Tee (1979) reported poor musky flavour and soft

texture in two yellow-fleshed Queensland papaw strains which they compared unfavourably with Sunrise Solo, the fragrant, sweet, orange-red fleshed Hawaiian cultivar.

The commercial quality of Queensland grown papaw fruit is important in the continued viability of the industry. This paper reports on relationships studied between indices of stage of development (designated maturity) and post-harvest quality of Queensland grown papaw fruit derived from the Departmental breeding programme.

MATERIALS AND METHODS

To obtain uniform fruit for these experiments, progeny derived from the QDPI plant breeding programme was used. Trees were available at two locations, namely a commercial grower (Grower 1) and the Maroochy Horticultural Research Station (Grower 2), both of which are at Nambour in southern Queensland. Fruit were harvested on one occasion from sets of ten selected trees at each location, eight categories of maturity and ripeness being selected from each tree:

Maturity 1—small size, dark green skin;
Maturity 2—medium size, dark green skin;
Maturity 3—mature, pale green, no yellow colour;
Maturity 4—tinge of yellow colour;
Maturity 5—quarter yellow colour;
Maturity 6—half yellow colour;
Maturity 7—three-quarter yellow colour; and
Maturity 8—full yellow colour.

Respiration measurements were made at 20°C on fruit at Maturities 1 to 4 in a flowing saturated air-stream by gas chromatography by the method of McGlasson (1969). Carbon dioxide production rates of individual fruits were then plotted to produce respiratory curves. From these curves, the onset and midpoint of the climacteric rise, the climacteric peak and 2 days post-climacteric were determined for each fruit.

As respiration rates were recorded, skin colour ratings were made on each fruit so that these could be related to the onset, midpoint and peak of the climacteric and two days post-climacteric.

In a second experiment, fruit from each location at Maturities 1 to 4 were ripened in air at 20°C, or were controlled ripened using ethylene gas (100 ppm) at 20°C for 24 hours followed by ripening in air at 20°C. Ripening fruit at Maturities 5 to 8 were also treated similarly for comparison.

Fruit firmness measurements were made daily on individual fruits using an Instron Model 1122 Universal Testing Instrument fitted with a 12 mm diameter hemispherical probe (crosshead speed 10 mm/min, probe penetration 1 mm, recorder chart speed 200 mm/min). After a forward chart speed of 20 mm, the vertical intersect of the graph produced, measured from the baseline, gave firmness in newtons. Firmness, measured previously by this method on tree-ripened, fully yellow coloured fruit from the selected tree, was used as the objective index to determine optimum ripeness of the experimental fruit. Quality parameters were assessed at this optimum stage.

Skin colour was rated by a 10 member panel on a scale of 0=dark green to 5=full yellow. Flesh colour, aroma, flavour and texture of ripened fruit were rated by a 10 member panel on an hedonic scale of 1 =dislike extremely to 9=like extremely with 5=neither like nor dislike.

RESULTS

The greenlife of individual fruits is defined as the time from harvest to the onset of the respiratory rise. The relationships between greenlife and quality parameters of the ripened fruit of each maturity category were studied using regression analysis.

For fruit harvested at Maturities 1 to 4, the regression lines relating skin colour score (y) to stage of ripening (as judged by fruit respiration) and the time in days after harvest (x) at which skin colour was measured are:

Maturity 1 $y=1.12x-0.56$ ($r=0.927$)

Maturity 2 $y=1.17x-0.30$ ($r=0.897$)

Maturity 3 $y=1.01x-0.57$ ($r=0.869$)

Maturity 4 $y=0.87x+1.17$ ($r=0.876$)

These showed that although Maturity 4 fruit were more coloured at harvest and at the onset of ripening than Maturity 3 ($P=0.05$) and Maturities 1 and 2 ($P=0.01$), all four regression lines had similar slopes. This indicated that skin colour changed at the same rate during ripening for all four maturities, although skin colour development of ripe fruit was greater for Maturities 3 and 4.

The greenlife of fruit ranged from 10 days for Maturity 1 to 2 days for Maturity 4. Skin colour at the onset of the respiratory rise (y) was related to greenlife (x) according to the quadratic regression formula:

$$y=2.40-0.38\ x+0.02\ x^2\ (r=0.700)$$

This shows that the more mature the fruit were at harvest then the more advanced was the skin colour at the onset of the respiratory rise.

Skin colour, flesh colour, flesh aroma and flesh flavour all increased as greenlife at harvest decreased.

Skin colour

$$y=4.36-0.11x\ (r=0.433)$$

Overall mean Grower 2 ($Y=4.2$)>Grower 1 ($y=3.7$),

LSD ($P<0.05$)=0.4.

Flesh colour

$$y=6.56-0.27x\ (r=0.458)$$

Overall grower means were not significantly different at $P=0.05$.

Flesh aroma

$$y=5.42-0.21x\ (r=0.454)$$

Overall grower means were not significantly different at $P=0.05$.

Flesh flavour

$$y=6.90-0.93x+0.06x^2 \ (r=0.611)$$

Overall mean Grower 1 ($y=5.3$)>Grower 2 ($y=4.3$),

LSD ($P<0.05$)=0.9

Flesh texture

Linear and quadratic regressions were not significant at $P=0.05$.

The fruit harvested from the two locations showed significant differences ($P=0.05$) in both skin colour and flesh flavour. No correlation was found between flesh texture of fully ripe fruit and maturity at harvest ($P=0.05$). All regression coefficients were low indicating that factors other than greenlife at harvest have important effects on these quality parameters.

Ripening with ethylene did not change skin colour at optimum eating quality (Table 1). In both treatments skin colour of fully ripe fruit increased with increasing maturity at harvest.

Table 1. Effect of controlled ripening with ethylene gas on the skin and flesh colour, aroma, flavour, texture and ripening time of papaw fruit. Firmness, measured by Instron on tree-ripened, fully yellow-coloured fruit, was used as an objective index to determine optimum ripeness of individual experimental fruit. Mean values are on 20 fruit

Parameter	Treatment	Maturity category at harvest							
(ripe fruit)		M1	M2	M3	M4	M5	M6	M7	M8
Skin colour	Untreated	3.3	3.7	3.9	3.9	4.2	4.2	4.4	4.7
	Ethylene gas	3.7	4.0	4.3	4.4	4.3	4.6	4.7	4.8
		LSD (P=0.05)=0.5 (treatment); 0.4 (maturity)							
Flesh colour	Untreated	4.0	5.0	6.7	6.0	5.8	6.5	6.3	6.7
	Ethylene gas	4.7	5.1	6.6	6.7	6.5	6.6	6.2	6.5
		LSD (P=0.05)=1.2 (treatment); 0.9 (maturity)							
Aroma	Untreated	3.7	3.7	4.8	5.1	5.4	5.5	5.5	5.0
	Ethylene gas	4.3	4.6	5.7	5.8	5.2	5.2	5.4	5.4
		LSD (P=0.05)=1.0 (treatment); 0.7 (maturity)							
Flavour	Untreated	3.7	4.5	5.9	5.4	5.7	6.1	5.7	5.4
	Ethylene gas	4.2	4.4	5.4	6.0	5.9	5.9	6.0	5.2
Texture	Untreated	5.4	5.3	6.1	5.9	5.4	5.7	5.4	5.5
	Ethylene gas	4.8	5.0	5.2	5.7	5.9	6.3	6.3	6.2
		LSD (P=0.05)=1.0 (treatment); 0.7 (maturity)							
Days from harvest to eating ripe	Untreated	15.7	13.8	9.6	7.7	5.8	4.7	3.2	0.8
	Ethylene gas	11.2	10.3	6.2	5.1	3.8	4.1	2.0	1.0
		LSD (P=0.05)=2.4 (treatment); 1.7 (maturity)							

Ethylene treatment did not significantly improve flesh colour, aroma, or flavour of fruit at the fully ripe stage compared with fruit ripened in air. Again these parameters increased with increasing maturity at harvest. However, aroma and flavour scores for all fruit were low.

The texture of ethylene treated fruit became more acceptable as the maturity at harvest increased. This was not the case with fruit ripened in air. However, overall the texture of ethylene treated fruit was not significantly better than air ripened fruit.

As would be expected ethylene-treated fruit of Maturities 1 to 4 ripened much earlier than untreated fruit, but ethylene did not significantly reduce the ripening time of coloured or ripening fruit (Maturities 5 to 8). Even with ethylene treatment, fruit with Maturities 1 to 2 took much longer to ripen than maturities 3 to 8 (Table 1).

DISCUSSION

Results show that green-skinned fruit which is ripening, develops yellow skin colour at the same rate as more mature fruit, but that mature fruit will have significantly more yellow skin colour when ripe than the less mature fruit.

Since the regression coefficients relating greenlife to colour, aroma, flavour and texture of the ripened fruit were all low, it follows that other influences, for example, environmental conditions, genotype, must have a large effect on these factors. Significant differences were found between the two sites for skin colour and flesh flavour, which again shows the importance of other influences on these quality parameters. None of the parameters measured varied sufficiently to be useful as maturity indices.

The main effect of applying ethylene gas was to reduce the time for fruit to ripen. The panel detected that ethylene ripened fruit had different texture scores with different maturities, but the Instron readings of fruit firmness did not show differences. Therefore, on these fruit, the Instron firmness ratings were poorly related to flesh texture. Texture in individual ripe fruit varied considerably from tough and rubbery to soft and mushy, although as previously stated, texture improved with maturity in all ethylene-treated fruit.

Taste panel scores, particularly those for aroma and flavour, were relatively low for all fruit, even those which had ripened on the tree. This may indicate insufficient emphasis on ripe fruit quality in the breeding programme or these factors may be related to environmental conditions.

The results show that poor ripe fruit quality will be obtained by harvesting immature papaw fruit of dark green colour. Such fruit are not normally harvested commercially. Mature pale green fruit at harvest developed ripe fruit eating quality equal to that of fruit which had commenced to ripen on the tree, and had sufficient postharvest shelf-life (in excess of 1 week) for transportation and marketing. However, even with selection of experimental fruit derived from a plant improvement programme, the overall eating quality of these dioecious lines of papaw fruit examined was generally poor.

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