The tamarillo: chemical composition during growth and maturation

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Abstract Tamarillo (*Cyphomandra betacea*, red strain) fruits of known age were sampled for analysis of their chemical composition at all stages from newly set to fully mature. Concentrations of total nitrogen, starch, pectins, anthocyanin pigments, and individual sugars and acids were measured. Changes throughout the process of maturation are discussed in relation to the physiology of the fruit. Fruits grew rapidly and reached full size about 16 weeks after anthesis; maturity was attained 11 weeks later, at about 27 weeks. Marked changes in skin and pulp colour occurred during development. Total nitrogen varied little. Starch content, which during development reached 14% of fresh weight, fell to less than 1% at maturity. At their maximum, total sugars (mainly sucrose, glucose, and fructose) attained 5% of fresh weight. As fruits matured to eating ripeness, the initially high concentrations of both anthocyanins and acids in the flesh decreased substantially; proportions of the different pectic compounds also altered.

Keywords Tamarillos; *Cyphomandra betacea*; fruit analysis; fruit physiology; fruit maturation; chemical analysis; nitrogen; starch; pectins; anthocyanins; sugars; organic acids.

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INTRODUCTION

The tamarillo or tree tomato (*Cyphomandra betacea* Sendtn.), a native of Peru and Brazil, is cultivated in many regions of the world (Heatherbell et al. 1975). The fruit has achieved considerable commercial importance in New Zealand; the 1981 crop forecast was 2530 tonnes. The tamarillo is not only an appealing fresh-market commodity but is also commercially processed into a range of products (Strachan 1970). Aspects of the chemical composition of the mature fruit have already been reported (Munsell et al. 1953; Munsell et al. 1950; Dawes & Callaghan 1970), and we have reported a detailed examination of pigments (Wrolstad & Heatherbell 1974) and of individual sugars and non-volatile acids (Heatherbell et al. 1975) in mature fruit. Pratt & Reid (1976) studied changes in physiological parameters during the maturation of tamarillos.

We report here a study of the chemical composition of the fruit during maturation, using samples similar to those of Pratt & Reid (1976).

MATERIALS AND METHODS

Sampling and preparation

Tamarillo fruits were obtained from a block of trees of the red strain in a commercial orchard near Auckland. In order to obtain fruits of known maturity, newly set fruitlets, selected at a development stage about 1 week after anthesis, were tagged at weekly intervals as described previously (Pratt & Reid 1976). When the first-tagged fruits had fully matured (26 weeks from tagging), fruits of all ages were harvested for analysis.

Fruits to be used for anthocyanin estimation were peeled immediately after harvest, and the peel and pulp fractions were frozen separately; all other samples were frozen whole at −40°C and stored at −18°C. The frozen samples were powdered in a mortar and pestle cooled with liquid nitrogen. Some analyses utilised the frozen powder; for others, the powder was freeze-dried before analysis.

Analyses

Total nitrogen: Nitrogen content of the freeze-dried fruit was estimated by the standard Kjeldahl method (Association of Official Analytical Chemists 1965).

Anthocyanins: The anthocyanin content of liquid-nitrogen-powdered, freeze-dried peel and pulp fractions was determined as described previously (Wrolstad & Heatherbell 1974).

Starch: The starch content of the fruit was determined on the freeze-dried powders using a standard colorimetric procedure (Snell & Snell 1953).

Sugars and acids: The concentration of individual sugars and acids in frozen powdered fruit samples was determined by gas–liquid chromatography (Heatherbell 1974).

Pectin: The pectins in the freeze-dried tissue were separated and determined by the methods described by Rouse & Atkins (1955).

RESULTS

Changes in the appearance of maturing tamarillos

Representative fruits from the samples harvested for analysis are shown in Fig. 1, both in side view and cut across the equator. At 15 weeks the first purple coloration of the skin appeared, and thereafter increased in density. The green chlorophyll underlay disappeared from the fruits between 18 and 22 weeks after tagging. The purple coloration in the locules was first evident about 11 weeks after tagging, rapidly intensified, but then lessened markedly during the last 6 weeks of fruit maturation.

Growth

The fruits grew rapidly until about 15 weeks after tagging, by which time they had reached full size. Growth of maturing tamarillos, as measured by fruit length, is shown in Fig. 2A, replotted from the data of Pratt & Reid (1976). Growth was essentially linear.

Total nitrogen content

The nitrogen content (on a dry-weight basis) of maturing tamarillos is also shown in Fig. 2A. Despite the large increase in fruit size during the early part of maturation, there was little change in the concentration of total nitrogen throughout development.

Starch content

The starch content of immature tamarillos 10 weeks after tagging (Fig. 2B) was high (14% of the fresh weight). After the fruit reached full size, starch content fell rapidly, until at maturity (26 weeks) it was less than 1% of the fresh weight.

Individual sugars

About 2 weeks after the fruit had reached full size, the total sugar content increased rapidly (Fig. 2C), reaching a peak, 18 weeks after tagging, of more than 5% of the fresh weight. The levels of the important individual sugars (sucrose, glucose, and fructose) reflected the changes seen in the total sugar content during maturation.

Individual acids

Citric and malic acids were the predominant acids present throughout fruit maturation (Fig. 2D). The concentration of malic acid was low throughout, and declined slowly after the fruit had reached full size (15 weeks). The citric acid concentration rose rapidly during the early part of fruit maturation, reaching more than 2% of the fresh weight of the fruit 19 weeks after tagging, and declining steadily thereafter to 1.4% at full maturity. The total acid content followed closely that of citric acid, which comprised over 80% of total acids during most of the maturation period.

Pectins

During fruit maturation the pectin content of the fruit fell gradually from about 1% to 0.75% of the fresh weight (Fig. 2E). Water-soluble pectins, the smallest of the pectin fractions in immature fruit, rose steadily in concentration throughout maturation, and were the major component in mature fruit (0.4% f.wt). In contrast, the concentration of alkali-soluble protopectin decreased during maturation, and in mature fruit was only 0.1% of the fresh weight. Pectic acids (soluble in oxalate), which were relatively high in concentration in immature fruit, also decreased.

Anthocyanins

Anthocyanin pigments were undetectable until 10 weeks after tagging (Fig. 2F). At this time the concentration of anthocyanin in the flesh rose rapidly, reaching a peak of 1.4 mg/g f.wt at about 16 weeks after tagging. The concentration of pigment fell rapidly thereafter, so that at maturity the fruit contained less than one-fifth of this peak concentration of anthocyanin pigment in the flesh. As can be seen in Fig. 1, the peel contained little anthocyanin pigment until about 15 weeks after tagging (when

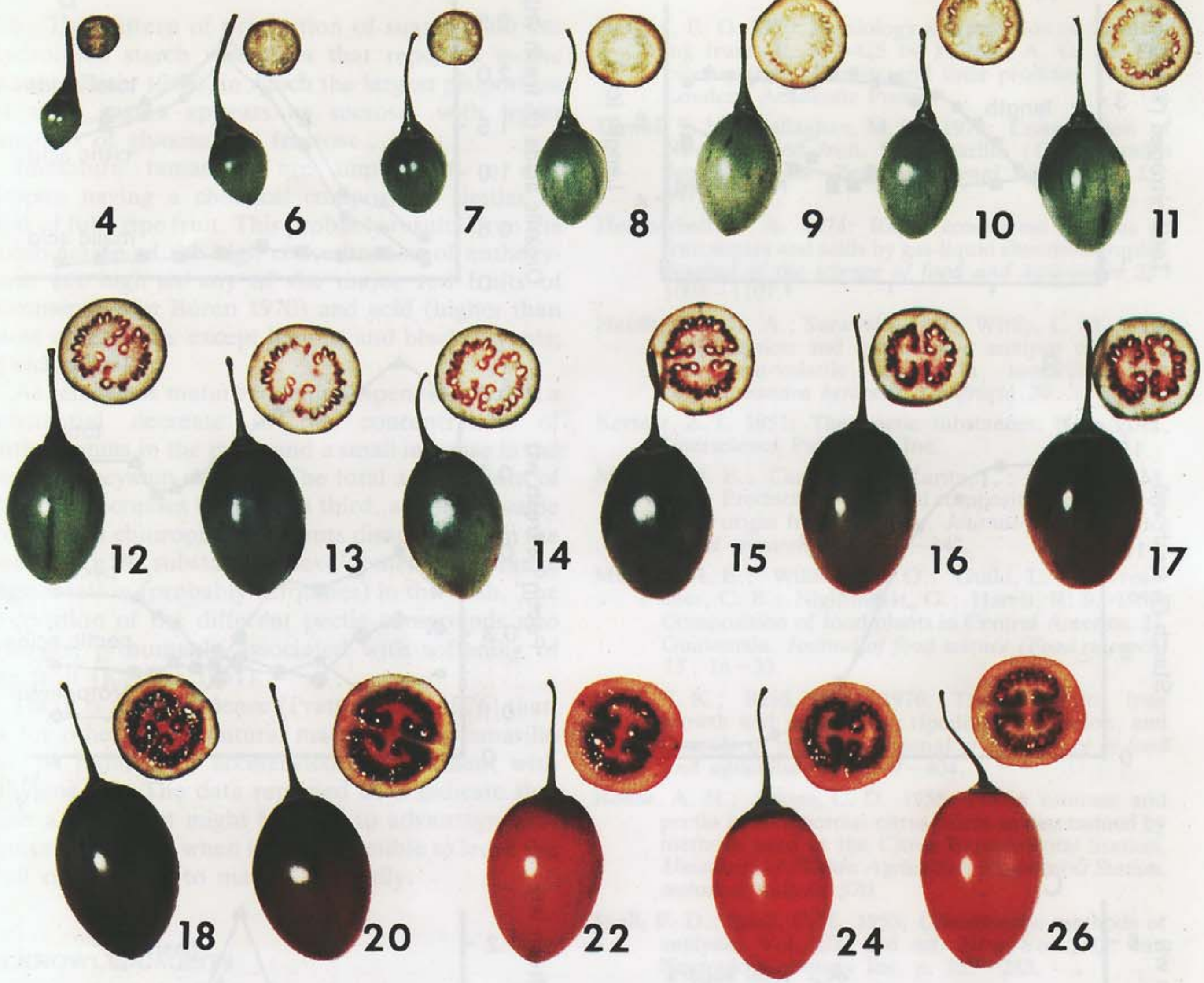

Fig. 1 Maturation of tamarillos. Tamarillo fruits tagged at intervals through the growing season were harvested when the oldest fruits had matured for 26 weeks from the date of tagging. (Numerals indicate age, in weeks, from tagging.)

flesh anthocyanin content was at its peak). Thereafter, the anthocyanin content of the skin increased until the fruit was fully mature.

DISCUSSION

In most fruits, development is divided broadly into periods of cell division, cell enlargement, and maturation (Bollard 1970). The rate of growth may change during these different phases, often being slower during maturation, but the tamarillo appears quite unusual in that growth ceases 10 weeks before the fruit is fully mature. In most other fruits, too, the changes in sugars, acids, and other components of flavour and colour which give the fruit its eating quality are normally associated with the latter part of the maturation phase. In the tamarillo, by contrast, many of these events are completed well before the fruit is considered ready for harvest.

For example, the decrease in the concentration of starch, which accompanies ripening (the last part of the maturation phase) in such fruits as the apple, kiwifruit, and banana, occurs in the tamarillo as the fruit attains full size. Developing tamarillos are rich in starch, and the sugars present in the fruit probably derive from hydrolysis of this stored material. Between 15 and 18 weeks after tagging, the concentration of total sugars rose from a negligible concentration to just under 6%. This increase almost exactly matched the decrease in starch content over the same period, from 9% to

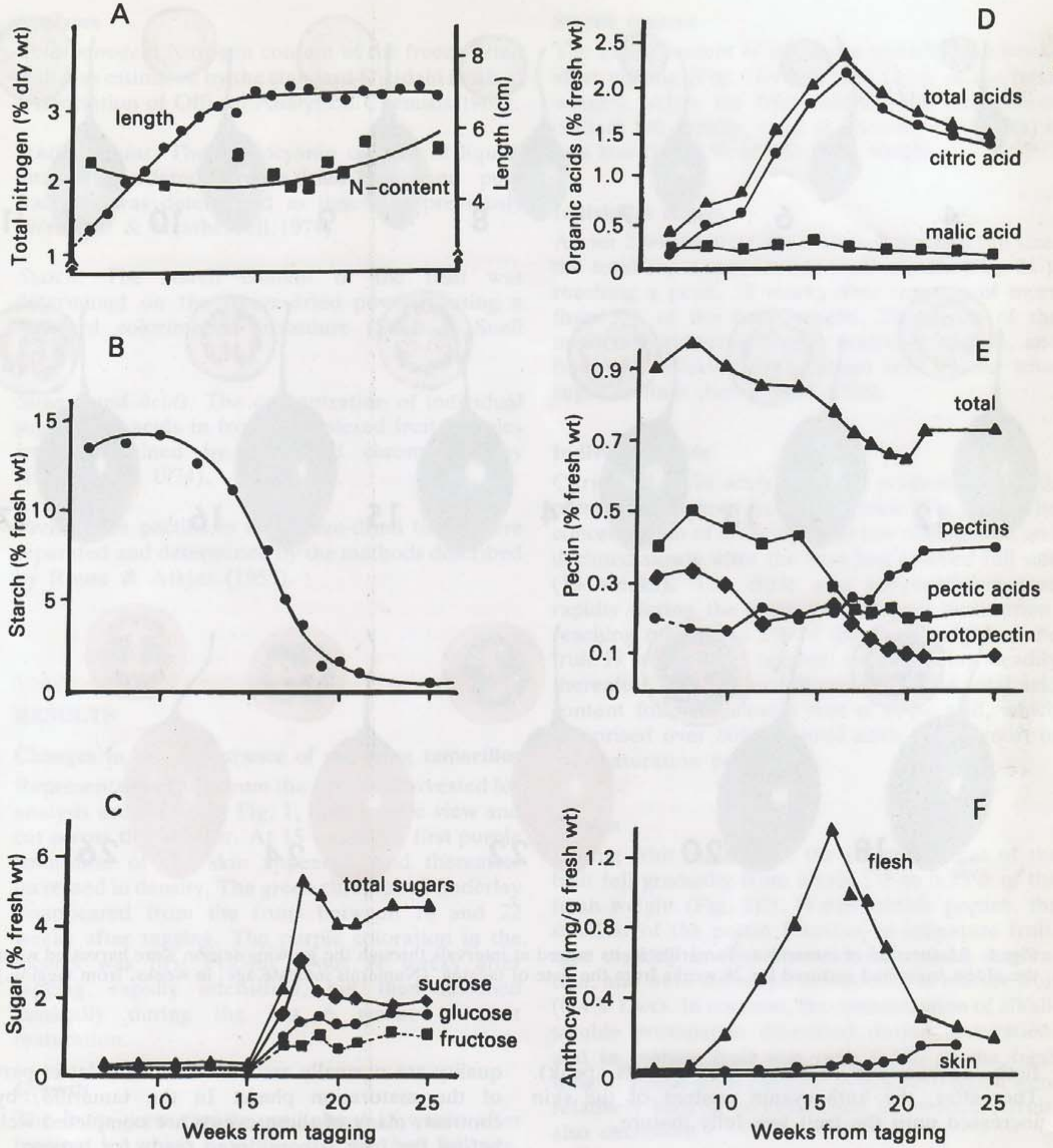

Fig. 2 Growth and chemical changes in the maturing tamarillo. A-C, E, F: Data obtained from tamarillo fruits tagged at intervals throughout the growing season, then harvested 26 weeks from the start of tagging.

A: Growth in length, and total nitrogen content. **B**: Starch content. **C**: Concentrations of sucrose, glucose, fructose, and total sugars. **D**: Concentrations of organic acids (citric, malic, total acids) in a sample of tagged tamarillo fruits of different maturities. **E**: Pectin fractions (protopectin, pectic acids, pectins) and total pectic substances. **F**: Anthocyanin content of flesh and skin.

3%. The pattern of production of sugars from the hydrolysed starch resembles that reported in the mango (Biale 1960), in which the largest proportion of total sugars appears as sucrose, with lesser amounts of glucose and fructose.

Immature tamarillos are unpleasant to eat, despite having a chemical composition similar to that of fully ripe fruit. This probably results from the combination of the high concentration of anthocyanin (as high as any of the major red fruits of commerce; van Buren 1970) and acid (higher than most other fruits except lemons and blackcurrants; Ulrich 1970).

As tamarillos mature to eating ripeness, there is a substantial decrease in the concentration of anthocyanins in the pulp, and a small increase in the peel anthocyanin content. The total acid content of the fruit decreases by about a third, and at the same time as the chlorophyll pigments disappear from the peel there is substantial development of orange pigmentation (probably carotenes) in the flesh. The proportion of the different pectic compounds also changes, presumably associated with softening of the fruit (Kertesz 1951).

There is some evidence (Pratt & Reid 1976) that, as for other fruits, natural maturation in tamarillo can be induced or accelerated by treatment with ethylene gas. The data reported here indicate that such a treatment might be used to advantage with this crop at times when it is not possible to leave the fruit on the tree to mature naturally.

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