Sugars as energy sources – is there a link to avocado fruit quality?

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ABSTRACT

The ability of an avocado tree to consistently produce fruit of an acceptable size and quality is dependant upon the production and distribution of carbohydrates. Of particular importance is carbohydrate movement to and within the fruit.

Further, this is important for fruit quality, particularly as related to storage capacity, as total postharvest energy requirements are dependant upon the carbohydrate store within the fruit. Fruit from 'Pinkerton', 'Hass' and 'Fuerte' trees were collected at two dates prior to harvest. Sugar profiles of exocarp, mesocarp and seed were determined by HPLC.

It was found that the seven carbon sugars manno-heptulose and perseitol predominated, while a small amount of sucrose was present. There appeared to be a marked difference in carbohydrate accumulation pattern, with 'Pinkerton' and 'Fuerte' being similar and 'Hass' different.

In the case of manno-heptulose, the highest concentration was found in the mesocarp of 'Hass', but in the exocarp of 'Fuerte' and 'Pinkerton'. A decrease was found in 'Fuerte' between the first and second picking dates.

Perseitol showed a similar pattern to manno-heptulose. It is suggested that these results may explain the inherent quality characteristics of the cultivars tested, and that analysis of these sugars may be used as a predictor of quality. It is further suggested that fruit quality may be improved if the levels of the sugars can be manipulated before harvest.

INTRODUCTION

Avocado cultivars differ in a variety of characteristics, ranging from anatomical features to those related to fruit quality. From a producer's point of view the fruit quality at final fruit maturity / ripeness is one of the most critical components. However, high fruit quality can only be achieved when trees are nurtured properly to produce high-yielding orchards with profitable fruit size and little to no tendency to alternate bearing.

At times of "peak development", such as bud burst and spring flush, the carbohydrates (CHOs) produced in avocado leaves at that time might not be able to supply sufficient energy for the demand by various growing organs of the tree. Therefore, starch reserves have been related to the ability of the avocado tree to produce high yields (Scholefield *et al*., 1985) and low starch reserves have been linked to a reduction in flowering intensity, fruit set and yield (Van der Walt *et al*., 1993).

However, other authors (Kaiser and Wolstenholme, 1994) could not affirm such a relationship. Starch storage in the tree trunk is a typical phenomenon of deciduous trees of the temperate climate zone where it is essential for species survival. In avocado the scenario differs slightly as avocado leaves can supply and manufacture CHOs throughout the seasons. The production and availability of such reserves is essential for high fruit load and larger fruit size.

Previous research by Liu *et al*. (1999) has shown that not starch but C_7 sugars are the predominant non-structural carbohydrates in vegetative avocado tissue. Due to its non-osmotic characteristic as a sugar alcohol, perseitol might also be of major importance as a storage molecule in avocado. The presence of C_7 sugars in the fruit flesh has been confirmed by Liu *et al*. (2002).

In this investigation we tried to establish whether the differences of the three cultivars 'Hass', 'Pinkerton' and 'Fuerte' with respect to fruit size, tendency to alternate bearing and time to harvest are also reflected in the sugar pattern of the fruit preharvest. Furthermore, we wanted to investigate if the size of the pool of C_7 sugars (perseitol and the form it can be converted to, manno-heptulose) can be correlated to the inherent storability characteristics of the cultivars.

MATERIALS AND METHODS

'Fuerte', 'Pinkerton' and 'Hass' fruit were collected on 17 May and 17 June, 2004 from a commercial avocado farm in KwaZulu-Natal. For each cultivar ten fruit were sampled and, in the laboratory under cool conditions, measured, weighed and divided into rind exocarp, mesocarp and seed. The sub-samples were cut into pieces, shock frozen with liquid nitrogen, freeze dried, ground and stored in the freezer.

For sugar analysis a 0.1 g freeze-dried sample was extracted in 10 ml 80% aqueous ethanol, homogenized, incubated at 80°C for 1 h and subsequently stored at 4°C for 24 hrs. Such prepared sample was centrifuged for 15 min, filtered through glass wool, dried and taken up in 2 ml ultra pure water, and filtered through a 0.4 µm filter prior to injection into an HPLC system. The sample was separated using a gel column attached to a Refractive Index detector. Sugar identification was carried out by comparison of retention times of standards.

RESULTS AND DISCUSSION

As expected, peaks of the sugar compounds detected in the three fruit tissues co-chromatographed with standards of sucrose, manno-heptulose and perseitol, confirming reports by Liu *et al*. (2002) of the presence of these sugars in avocado mesocarp. The concentration of the C_6 sugar sucrose was, in all samples, lower than the concentration of either of the C_7 sugars. Further – unidentified – peaks appeared only rarely and did not account for more than 10% of any of the other three sugars. This confirms the important role of C_7 sugars in avocado fruit tissue and indicates that these sugars are also important for fruit growth and development.

In 'Hass' the C_7 sugar manno-heptulose was found to have the highest levels in the mesocarp (M), while in 'Pinkerton' and 'Fuerte' it appeared to have the highest levels in the exocarp (rind) (E) (Fig. 1). In 'Fuerte' the concentration of this sugar decreased from the May to the June sampling, a possible indicator that 'Fuerte' had reached the ripening stage, if, as previously suggested (Cowan, 2004), manno-heptulose is the 'ripening inhibiting factor' proposed by Adato and Gazit (1974). In the other two cultivars manno-heptulose increased in the meso- and exocarp from

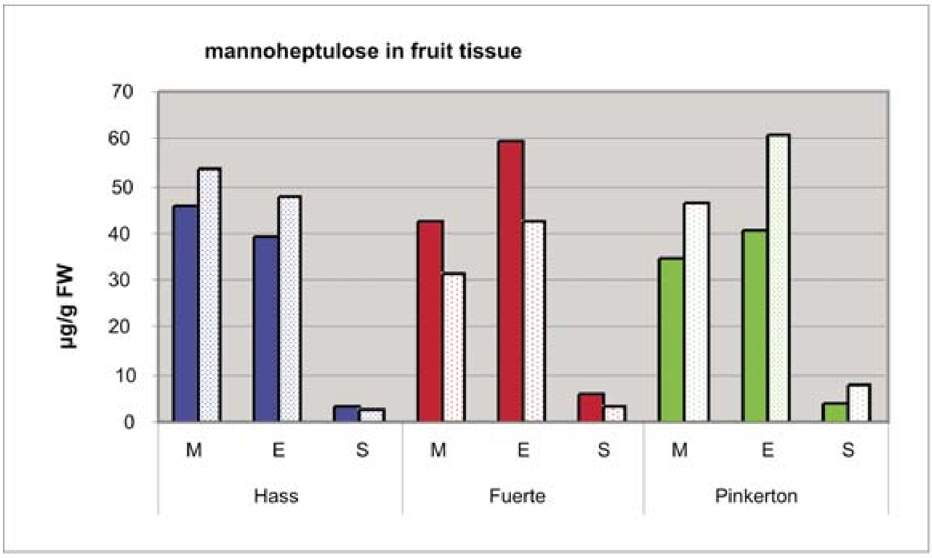

Figure 1. Manno-heptulose concentration in avocado fruit tissue.
Filled bars: May sampling Dotted bars: June sampling

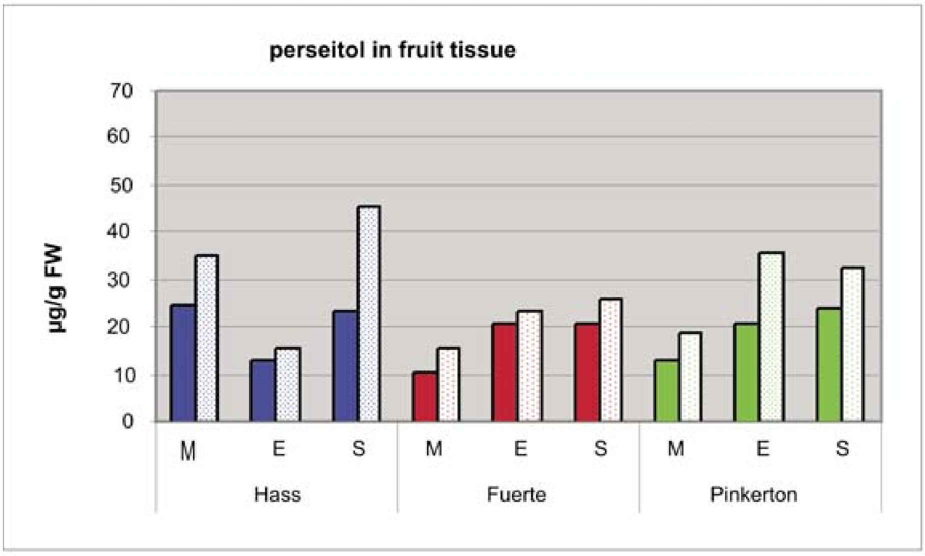

Figure 2. Perseitol concentration in avocado fruit tissue.
Filled bars: May sampling Dotted bars: June sampling

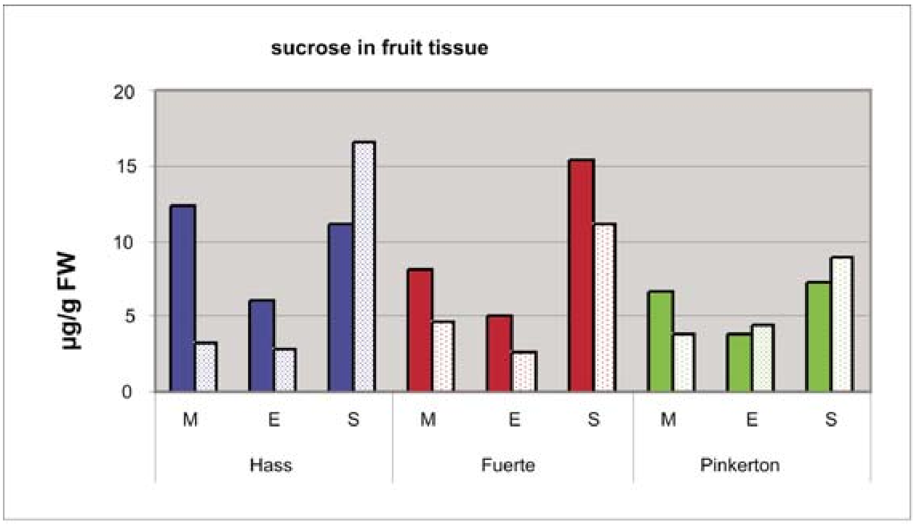

Figure 3. Sucrose concentration in avocado fruit tissue.
Filled bars: May sampling Dotted bars: June sampling

the May to the June sampling, which would mean that these cultivars had not produced an internal signal for ripening. The seed did not seem to be a source of manno-heptulose in any of the three examined cultivars.

The importance of the avocado-characteristic sugar perseitol as previously stated by Liu *et al*. (2002) is confirmed by our results (Fig. 2); levels of this sugar increased as fruit approached picking maturity, indicating that the presence of this sugar alcohol could be related to fruit storability, as levels of this sugar in 'Hass' were higher than in the other two cultivars. Furthermore, different to the distribution pattern for manno-heptulose, the seed seems to be a storage organ for perseitol, as in all three cultivars seed tissue contained equal or higher amounts of this sugar than the mesocarp. 'Hass' mesocarp showed a higher perseitol concentration than the flesh of 'Fuerte' and 'Pinkerton', which could be either a result of a general lower pool of this potential storage sugar, or a sign of depletion of the pool of this carbohydrate.

Sucrose seemed to play a less important role than the C_7 carbon sugars, possibly with a more important energy reserve role for seed development, as the highest levels of this sugar were found in seed tissue, confirming results by Liu *et al*. (1999) that C_7 sugars are more important in the avocado carbon balance than C_6 sugars.

Therefore, it was not surprising to find sucrose levels in fruit tissue of about ⅓ of the C_7 sugar levels (Fig. 3). Although sucrose seems to play a role in processes related to seed development, our data suggest that this form of energy fixation is not important in issues related to fruit maturity or postharvest quality characteristics.

CONCLUSIONS

It is suggested that the levels of C_7 sugars of fruit flesh are important indicators of the "fruit condition", i.e. measurements of C_7 level pools could help in the decision making when storability or potential shipping ability are examined. However, further extensive determination of C_7 sugar pools during fruit growth and development as well as postharvest need to be carried out. If it is revealed that the C_7 sugar pool is related to storability / postharvest quality, measurements of this pool would provide the growers with a tool to determine whether fruit from a particular crop / orchard should be marketed locally or internationally.

Furthermore, we were surprised to find higher levels of C_7 sugar in the 'Fuerte' and 'Pinkerton' exocarp than in the mesocarp. However, such an accumulation and / or active transport into the exocarp might be related to a need for stress resistance of this fruit part, as sugar alcohols like perseitol have been suggested to act as active oxygen scavengers (Dennison *et al*., 1999; Jennings *et al*., 1998). While the relatively thick rind in 'Hass' might act as protective layer for the mesocarp, the lack of such a layer might have to be compensated for by higher C_7 sugar levels in the exocarp of the other cultivars. Furthermore, lack of a physical protective layer in 'Pinkerton' and 'Fuerte' might drain the C_7 sugar pool in the mesocarp and ultimately affect storability negatively. Such a theory must, however, be validated by further experimental evidence of presence and function of the C_7 sugars. Of particular interest will thereby be if and how sugar levels – particular of cultivars known for low postharvest quality – can be increased, and how such alterations of this pool impact on fruit quality.

Further investigations should therefore address the questions of whether excessive vegetative growth will drain CHO reserves and hence result in a lower sugar status of fruit, and, similarly: will treatments reducing vegetative growth increase sugar levels in fruit? It should also be examined if and how the depletion of C_7 sugar levels postharvest can be reduced, and if such a resulting increase in the C_7 sugar pool will improve fruit quality. A further interesting aspect might lie in a closer examination of 'Hass' exocarp, as this tissue did not contain the same level of perseitol as tissue of the other two fruit.

Although 'Hass' exocarp was found not to have the same potential stress protection levels via perseitol, it might make use of other compounds, such as anthocyanins, which act as stress protectants in other crops.

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