Investigating the pre-harvest factors associated with the postharvest quality of 'Hass' avocados exported to the UK

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ABSTRACT

Over the years, a number of researchers have suggested that changes in the quality of avocado fruit are related to the differences in biochemical composition of the fruit as the season progresses. However, a recent thorough study, including biochemical analysis of fruit from different locations and of various maturities (early, mid- and late season fruit) has not been conducted. This project aimed to investigate the differences in the fruit biochemical composition to enable differentiation between 'good' and 'poor' quality avocado fruit destined for export. This implies the development of a model that would include concentration thresholds for various biochemical compounds in the skin and pulp to be used as a tool to predict the quality of the fruit. It has been agreed with SAAGA that this investigation would take place across the ten orchards/four growers identified with the help from SAAGA's overseas technical officer. The level of nitrogen being used in the orchard was previously identified among the factors that could affect the quality of the fruit, thus orchards selected for our trials included those with high, low and what is considered to be an 'optimum' nitrogen level. Fruit assessment and subsequent biochemical analysis were conducted at four different stages of ripeness, to see if any of the compounds (either its concentration at harvest or changes in its concentration within the supply chain to the 'ripe and ready to eat' stage) could be used as a tool to predict the quality of avocado fruit reaching the consumer. In the early and mid-season fruit, the level of nitrogen had no negative effect, however in the late season fruit higher level of nitrogen led to high incidence of grey pulp (36-62%). At the same time this mesocarp disorder was not observed in the orchards with lower nitrogen level. D-Mannoheptulose content showed decreasing trend from early to late season, and was found to correlate with a number of days to ripen. The main fatty acid identified in avocado fruit was oleic acid (18:1). Its content increased as the season progressed in fruit from all the orchards, however, we have noticed that oleic acid content was higher when high level of nitrogen was used.

INTRODUCTION

The majority of South African avocados are exported to the European Union – the biggest export market for the South African fruit (www.foodtradesa.co.za, 2018). However, due to long distance shipping and time required to reach the destination, avocado fruit are prone to developing various disorders, especially in the mesocarp, e.g. grey pulp, vascular browning, etc. (Nelson, 2010). Furthermore, considerable variation in the ripening patterns has been reported, while the use of 1-MCP delays the ripening even further, an unwanted trait for the retailers in the UK who market the product as 'ripe and ready to eat'.

In recent years, the European market has become extremely competitive and other countries (Chile, Peru) are now supplying large volumes of avocados, taking a big share of the market (Nelson, 2010, 2012). The quality of avocado fruit is determined by a number of factors, including irrigation (Kruger *et al.*, 2015), nutrition (Kruger *et al.*, 2016) and fungicide spray programme in the orchards, growing location (Mathaba *et al.*, 2016) due to climate conditions, season (early, mid- and late), and subsequent storage conditions (Kruger & Lemmer, 2016). Quality of the fruit is also affected by physiological changes during the ripening process.

In South Africa, avocados are grown in different areas under different climatic conditions, e.g. in the warm subtropical north-eastern Tzaneen, and the cool subtropical midlands of KwaZulu-Natal. Orchards' temperature and rainfall have previously been identified among the factors that may affect the fruit quality (Kruger *et al.*, 2004). It has also been suggested that fruit grown on the high potential soils have lower storage potential, e.g. in Kiepersol orchards located at low altitudes on old banana plantations. On the other hand, better storability of the fruit would be expected in KwaZulu-Natal orchards and areas of White River, Nelspruit and Barberton, where avocado trees are grown on the sandy soils. The quality of the fruit may also be affected in the orchards where nitrogen has been supplied in excess. According to Nelson (2010) the quality of avocado fruit is not only affected by the differences in the climatic conditions, but is also associated with the orchard nutrition management.

It has been reported that fruit grown in the cooler regions are expected to have higher ratio of monounsaturated oleic acid than fruit in the warmer areas. The percentage of oleic acid in the avocado fruit was indeed found to be higher in KwaZulu-Natal than Tzaneen (Kaiser & Wostenholme, 1993). Similar observation has been reported by Requejo-Tapia *et al.* (1999) who compared avocado growing areas in New Zealand. However, as Requejo-Tapia *et al.* (1999) suggested, temperature cannot be considered as the only factor affecting the fatty acids composition. This has been recently confirmed in Chile, where Ferreyra *et al.* (2016) found that fatty acids composition may be affected due to the factors related to the climate (temperature, altitude, etc.) and those related to plant nutrition and soil properties. Nonetheless, the temperature was still identified as the most important factor. In the recent study, in Colombia, the highest percentage of oleic acid has been observed in 'Hass' avocados grown at higher altitudes (Carvalho & Velasquez, 2015), whereas at lower altitudes oleic acid content was lower, with palmitoleic and linoleic acids content being increased. Thus, it is clear that the fatty acids composition is affected by the orchard's location.

The changes in the fruit quality as the season progresses have been suggested by a number of researchers to be related to the changes in the biochemical composition. However, a thorough study, as this one, including different locations and fruit maturities (early, mid- and late season), has not recently been conducted. At the same time, similar type of study has recently been conducted in Chile (Ferreyra *et al.*, 2016) and Colombia (Carvalho & Velasquez, 2015), i.e. direct competitors. Thus, it is necessary that South Africa does not stay behind and moves down in the pecking order of preferred avocado suppliers for the European market. The overall objectives of this project are: i) to determine the incidence of diseases (anthracnose, stem-end rot) in ripe early, mid- and late season 'Hass' avocado fruit from different regions (Tzaneen, Mpumalanga and KwaZulu-Natal); ii) to determine the incidence of mesocarp disorders in ripe early, mid- and late season 'Hass' avocado fruit from different regions; iii) to conduct biochemical analyses (C7 sugar, fatty acids and phenolic compounds) in early, mid- and late season 'Hass' avocado fruit from several regions in South Africa just after harvest, after cold storage at commercially used temperatures for export, in triggered and at the 'ripe and ready to eat' stage; and iv) to see if the incidence of diseases and mesocarp disorders can be directly linked with biochemical composition of the fruit.

MATERIALS AND METHODS

Ten orchards were identified with the help from SAAGA's overseas technical officer, and the producers were visited in early April 2017. We used the leaf nutritional data to identify the level of nitrogen being used in the specific orchards. In each of the orchards, 6-7 trees were marked to be subsequently sampled over the season. Fruit were sampled three times, i.e. early, mid- and late season with the moisture content of around 75%, 70% and 65%, respectively. Ten 'count 16' boxes (160 fruit) were harvested on each occasion. Pulp moisture content and initial biochemical composition analysis were conducted at harvest (10 fruit per orchard). A remaining 150 fruit were stored at the recommended export temperature for 28 days, and the biochemical analysis was conducted afterwards. After cold storage, 140 fruit were ripened at the room temperature of around 18±1 °C. Once the fruit reached the stage where it was noticed that ripening has been triggered, a set of fruit was processed for biochemical analysis. Finally, when the fruit reached 'ripe and ready to eat' stage – as indicated by fruit softening, the note was taken on the number of days to ripen and the skin colouration was recorded – the fruit were assessed, i.e. cut in halves and visually inspected for presence of fungal decay (anthracnose, stem-end rot) or physiological mesocarp disorders, such as vascular browning, grey pulp, black cold damage, etc. At all ripening stages, sets of samples were frozen in liquid nitrogen and kept in a -85 °C freezer until preparation for biochemical analysis.

RESULTS AND DISCUSSION

Figure 1 depicts the number of days to ripen for early, mid- and late season 'Hass' avocado fruit originating from high and low nitrogen level orchards from different producers in the Tzaneen region. The early season fruit from high nitrogen level orchards seemed to ripen a bit slower when compared to the low nitrogen level orchards. However, this trend was not observed for mid- and late season fruit.

Figure 2 illustrates the percentage of grey pulp in early, mid- and late season 'Hass' avocado fruit from high and low nitrogen level orchards, from different producers in the Tzaneen production area. No grey pulp was observed in early season fruit regardless of the level of nitrogen being used in the orchard. Only in the case of one high nitrogen level orchard, mid-season fruit had relatively high incidence of grey pulp (19%), suggesting that the issue was not solely due to the dose of nitrogen. The issue of grey pulp due to excess nitrogen supply was only evident in the late season fruit. At the same time, at the low nitrogen level no grey pulp was reported throughout the season.

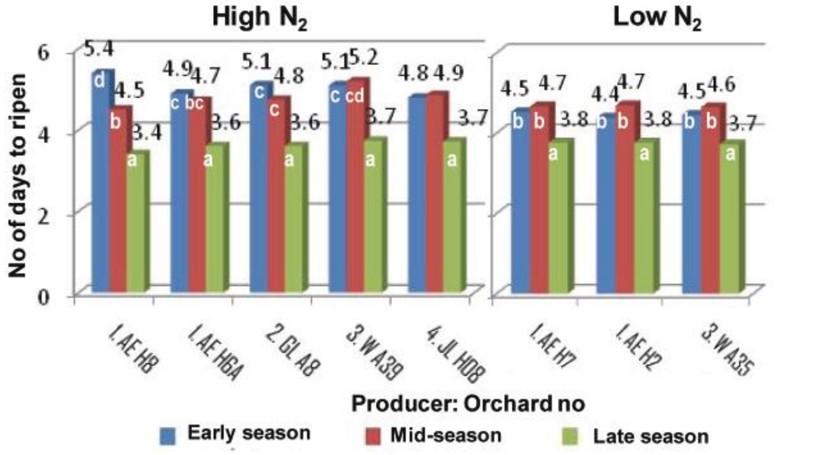

Figure 1: The number of days to ripen 'Hass' fruit originating from high and low nitrogen level orchards, from different producers in the Tzaneen production area during the early, mid- and late season.

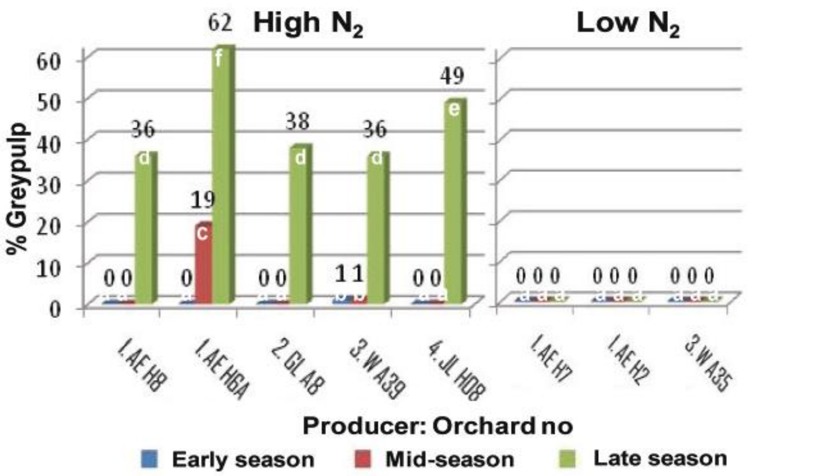

Figure 2: The percentage grey pulp in 'Hass' fruit from high and low nitrogen level orchards, from different producers in the Tzaneen production area during the early, mid- and late season.

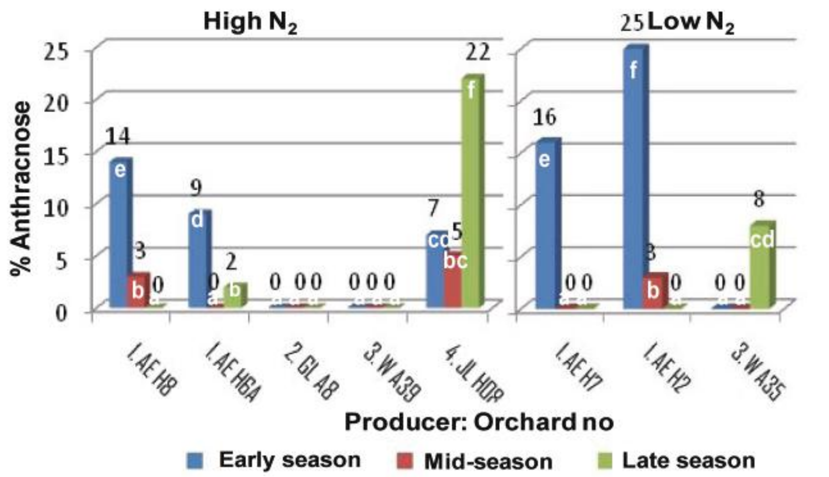

Figure 3: The percentage anthracnose of 'Hass' fruit originating from high and low nitrogen level orchards, from different producers in the Tzaneen production area during the early, mid- and late season.

Figure 3 presents the percentage of 'Hass' avocado fruit with anthracnose in the fruit originating from high and low nitrogen level orchards from different producers in the Tzaneen production area. One of the producers obtained fruit with significantly higher incidence of anthracnose (early season fruit) regardless of the nitrogen level being used in the orchards. This suggests that the fungicide sprays were not effective enough compared to the other growers.

Figure 4 illustrates the percentage of vascular staining of early, mid- and late season 'Hass' avocado fruit originating from high and low nitrogen level orchards from different producers in the Tzaneen production area. High nitrogen level orchards consistently obtained higher proportion of fruit with vascular staining compared to the low nitrogen level orchards. This will need to be correlated with specific phenolic compounds once the data become available.

D-Mannoheptulose (C7 sugar) is known to be the main sugar in avocado fruit (Liu *et al.*, 2002; Meyer & Terry, 2008), whereas fructose and glucose that are often found in the majority of fruit, have been reported to be only present at very low concentrations in avocados. The content of D-Mannoheptulose in early, mid- and late season 'Hass' fruit pulp of fruit originating from high, optimum and low nitrogen level orchards from different producers in the Tzaneen production area, is portrayed in Figure 5. The D-Mannoheptulose content showed a decreasing trend from early to late season, which correlates well with a decrease in the number of days to ripen as the season progressed (Fig. 1). This would fit with the idea (Liu *et al.*, 2002) that higher content of D-Mannoheptulose is responsible for delayed ripening.

Furthermore, during ripening the content of C7 sugar decreased. Higher content of this sugar has previously been observed in unripe and ripening fruit when compared to 'ripe and ready to eat' fruit (Landahl *et al.*, 2009; Blakey *et al.*, 2012; Obenland *et al.*, 2012). This finding was further confirmed in fruit exposed to 1-MCP, where ripening was inhibited/delayed and D-Mannoheptulose was maintained at higher level (Meyer & Terry, 2008).

D-Mannoheptulose has been reported to be the main antioxidant and energy source (Bertling & Bower, 2005) in the mesocarp of avocado fruit. As the level of C7 sugar declines with fruit maturity, the fruit's ability to withstand oxidative stress is reduced in the late season fruit. Thus, Bertling *et al.* (2007) suggested orchard management practices increase D-Mannoheptulose content in the fruit prior to harvesting. This agrees with the data reported by Lallu *et al.* (2005) where higher proportion of sound fruit was associated with higher content of D-Mannoheptulose.

The oleic acid content of early, mid- and late season 'Hass' avocado fruit pulp in fruit originating from high, optimum and low nitrogen level orchards from different producers in the Tzaneen production area, is presented in Figure 6. The oleic acid values obtained, showed an increasing trend as the season progressed. The moisture content of avocado fruit declines as the season progresses, with simultaneous increase in the oil content and oleic acid being the main fatty acid in avocado fruit (Gamble *et al.*, 2010). The fruit from the high nitrogen level orchards had higher values for this fatty acid when compared to low nitrogen level orchards.

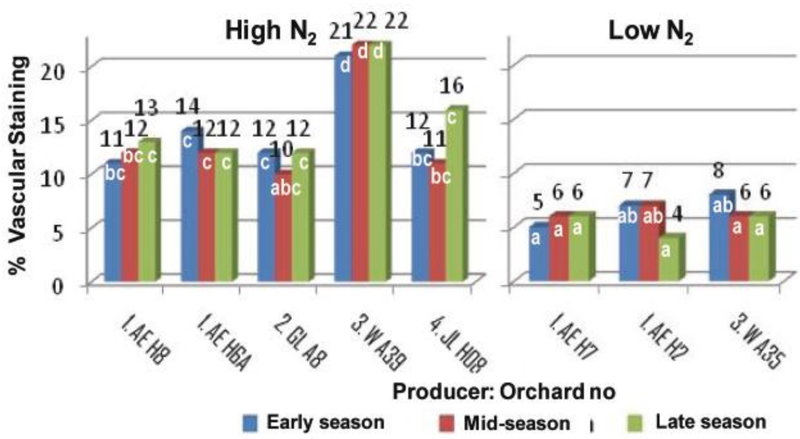

Figure 4: The percentage vascular staining of 'Hass' fruit originating from high and low nitrogen orchards, from different producers in the Tzaneen production area during the early, mid- and late season.

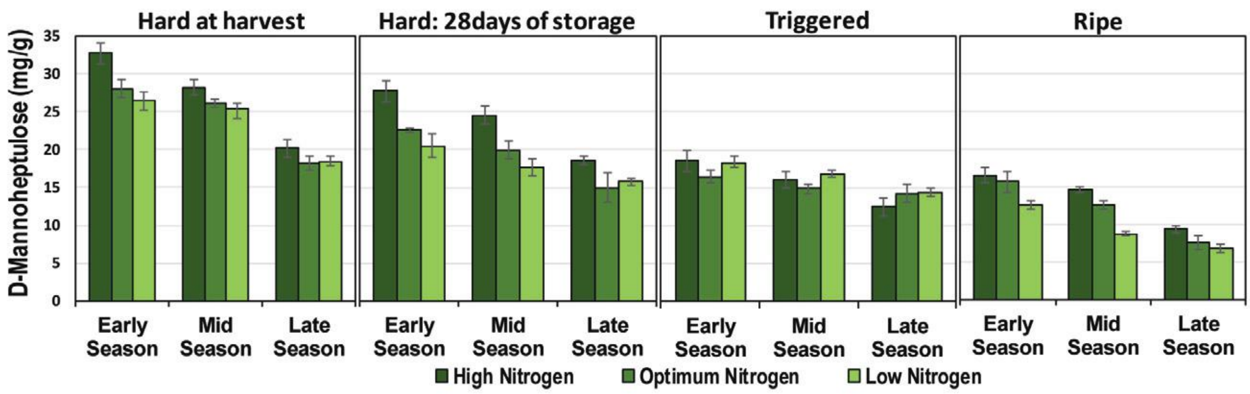

Figure 5: The D-Mannoheptulose content of 'Hass' fruit pulp of fruit originating from high, optimum and low nitrogen level orchards, from different producers in the Tzaneen production area during the early, mid- and late season.

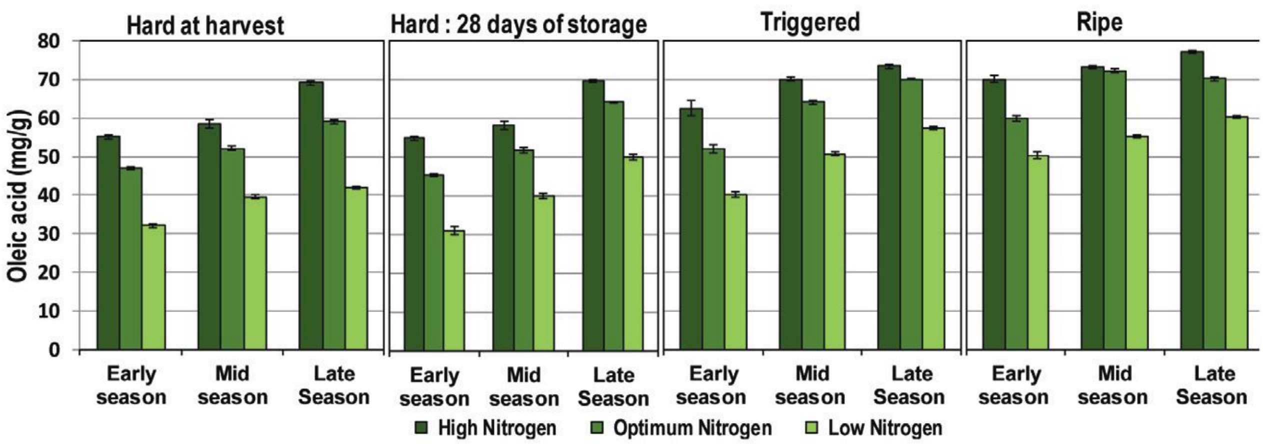

Figure 6: The oleic acid content of 'Hass' fruit pulp of fruit originating from high, optimum and low nitrogen level orchards, from different producers in the Tzaneen production area during the early, mid- and late season.

The content of oleic acid did not change significantly over the 28 days cold storage period. However, as the ripening progressed, the values for this fatty acid increased.

The phenolic acid analysis was not completed at the time of writing this article. It is well known that phenolic compounds are often associated with tissue browning/discolouration, thus the aim is to see whether the composition of phenolic compounds could be associated with specific disorders, for example grey pulp, especially in the late season fruit from high nitrogen level orchards.

CONCLUSION

D-Mannoheptulose content showed a decreasing trend from early to late season that correlates well with a decrease in number of days to ripen as the season progresses. High nitrogen level orchards gave fruit with higher values of this C7 sugar when compared to low nitrogen level orchards. During ripening, C7 sugar declined regardless of the level of nitrogen in the orchard.

The content of oleic acid increased as the season progressed in fruit from both high and low nitrogen level orchards. However, fruit from high nitrogen level orchards had higher values for this fatty acid when compared to low nitrogen level orchards. During ripening the content of this fatty acid increased significantly in all fruit. The full data analysis has not been completed.

FUTURE WORK

The low incidence of anthracnose during the 2017 season could be attributed to the dry season of the preceding year. It is proposed that the trials will be repeated in 2018 for the Tzaneen production area to monitor the incidence of mesocarp disorders over two consecutive years. This also implies that the trials using fruit from the Nelspruit region will be conducted in the third year of the project, i.e. during the 2019 season. This will allow the comparison of the pre-harvest factors associated with the postharvest quality of 'Hass' avocado fruit from different regions.

Acknowledgements

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