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Comparative effects of canopy position on physicochemical properties of 'Marsh' grapefruit during non-chilling postharvest cold storage

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ABSTRACT

The physicochemical properties of citrus fruit play critical roles in its maturity and quality determination. Hence, this study investigated the effect of canopy position on physicochemical properties of 'Marsh' grapefruit across different production regions at harvest and after storage at 7.5 °C for 3, 6, and 9 weeks. The study also evaluated the use of BrimA as an adoptable internal quality and maturity parameter for 'Marsh' grapefruit. Fruit from inside canopy (IC) and outside canopy (OC) were harvested from KwaZulu-Natal (KZN) and Mpumalanga (MP) provinces in South Africa. Titratable acidity was determined by titration and calculation of the sugar/acid ratio (TSS/TA) was established while BrimA was derived from sugar and acid with tongue sensitivity index. Colour indices were measured using calibrated colorimeter while sugars were measured using high performance liquid chromatography (HPLC). At harvest, IC fruit from MP province were more luminous than the OC fruit while inverse results were recorded for fruit from KZN. At harvest, IC fruit had higher percentage of titratable acidity (TA) (2.73%) than OC fruit (2.40%) from MP, with opposite results from KZN. The BrimA showed a strong and positive correlation with TSS/TA (r = 0.9364). Overall, our result suggested that canopy position affect some physicochemical properties of 'Marsh' grapefruit. However, harvested fruit displayed a high level of maturity and quality over the period of cold storage. BrimA could potentially be used as an index of internal quality of grapefruit but further studies into the subject is required.

1. Introduction

'Marsh' grapefruit (*Citrus paradisi* Macfadyen) is an economically important citrus cultivar hybridized from an orange and a shaddock during the early 1700s in the West Indies (Kiani and Imam, 2007; Agustí et al., 2014). The fruit is widely cultivated in many parts of the world, including South Africa, United States of America, and Israel (Vacante, 2010) for its highly nutritional and medicinal properties (Kiani and Imam, 2007).

In the fresh produce market, physicochemical properties such as colour, shape and size constitute initial factors influencing consumers' decision to purchase (Opara and Pathare, 2014; Magwaza and Opara, 2015). Rind colour is perceived to be a major external quality factor as consumer preference is largely determined by fruit appearance in both local and international markets before any purchase is done (Singh and Reddy, 2006). Furthermore, previous studies have shown that colour and overall appearance are important quality attributes affecting acceptability of citrus and other kinds of fruit (Pathare et al., 2013). From consumer purchase perspective, this suggests that good looking citrus fruit will most likely exhibit quality taste experience which ultimately translate to financial gains for citrus fruit growers. However, consumer choice of subsequent procurements is dependent on fruit internal chemical properties such as total soluble solids (TSS), titratable acidity (TA) as well as the ratio of total soluble solids to titratable acidity (TSS/TA) (Opara and Pathare, 2014; Magwaza and Opara, 2015). Further indices of quality include sweetness index (SI), determined by the quantity of individual non-saturated sugar components (Beckles, 2012; Magwaza and Opara, 2015), and total sweetness index (TSI), which is determined based on the contribution of main sugar components in relation to sucrose (Baldwin et al., 1998; Magwaza and Opara, 2015). Being a non-climacteric fruit, quality of citrus fruit generally decreases after harvest (Baldwin, 2009). However, knowledge of the level of sweetness (fructose, sucrose, and glucose) or sourness (citric acid and malic acid) of grapefruit will be beneficial to citrus

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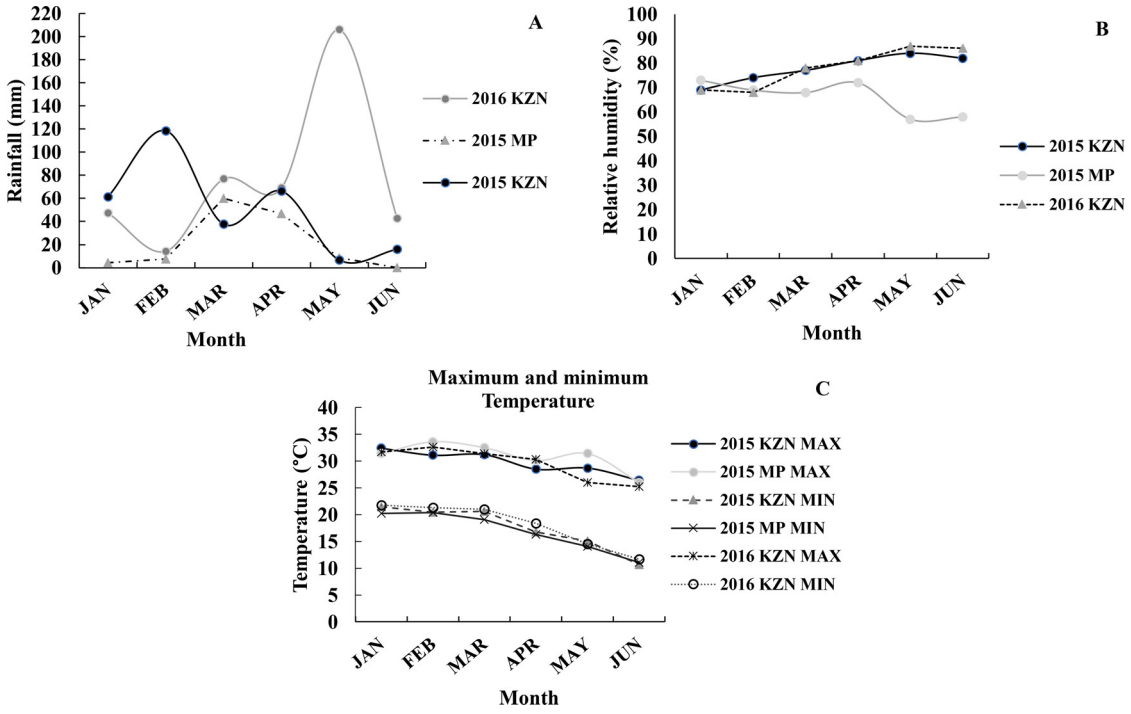

Fig. 1. Rainfall (mm, A), relative humidity (%, B), maximum temperature and minimum temperature (°C, C) registered during 2015 and 2016 seasons in KwaZulu-Natal (KZN) and Mpumalanga (MP) provinces.
(Source: South African weather services)

industry. This is because high quality flavoured grapefruit have more commercial value at both local and international markets than fruit of lower quality (Kader, 2008).

Although TSS/TA ratio is mostly used as determinant for citrus fruit maturity and internal quality, Jordan et al. (2001) reported that sometimes it does not share any relationship with organoleptic internal quality perception of fruit. As a result, it was suggested that quality measurement parameter that is more associated with citrus fruit internal quality than TSS/TA is BrimA (difference of TSS and TA). BrimA has been reported to be a better internal quality parameter for measuring internal quality or maturity of horticultural products such as grapes (Jordan et al., 2001), pomegranate (Fawole and Opara, 2013) and oranges (Obenland et al., 2009) than other industry standards including TSS, TA and TSS/TA (Magwaza and Opara, 2015). In view of this, California Department of Food and Agriculture set BrimA as industry standard for measuring internal quality of navel oranges (Ross, 2012). BrimA, increasingly becoming an international standard of horticultural fruit maturity and quality, was well introduced, and adequately discussed in a recent review of literature by Magwaza and Opara (2015). Hence, this study investigated the possibility of BrimA as an adoptable internal quality parameter for 'Marsh' grapferuit.

On the other hand, fruit position within tree canopy, based on the level of exposure of fruit to sunlight, is an important pre-harvest factor that has been identified as possible contributor to the postharvest quality of horticultural crops. Canopy positions, exposure to high (outside) or low (inside) sunlight in fruit tree canopy, have long been found to affect vitamin C content of grapefruit (Harding and Thamas, 1942), and physicochemical properties of 'Nules clementine' mandarin fruit thereby influencing its outward appearance (Cronje et al., 2011a, 2013; Magwaza et al., 2013a). However, very limited research has been conducted to study the effect of canopy position on physicochemical properties of 'Marsh' grapefruit. Hence, the aim of this study was to evaluate the effect of canopy position and production region on physicochemical properties of 'Marsh' grapefruit at harvest and after 3, 6, and 9 weeks of cold storage at 7.5 °C.

2. Materials and methods

2.1. Reagent and standards

All chemicals including sodium hydroxide (NaOH), phenolphthalein, folin-ciocalteu reagent, metaphosphoric acid (MPA), sodium carbonate, gallic acid, quercetin, vitamin C, 2, 6 dichloroindophenol dye, 2,2-diphenyl-1-picrylhydrazyl (DPPH), acetone, ethanol (HPLC grade) and sugars standards (sucrose, D-glucose, and D-fructose) were purchased from Sigma-Aldrich Company Ltd. (Dorset, UK). A Phenomenex® column (Rezex RCM - Monosaccharide) was used in the analyses of sugars. Water was purified in a Milli-Q Integral Water Purification System (Merck Millipore corporation, Billerica, MA, USA; $\sigma = 18\ M\ \Omega\ cm^{-1}$).

2.2. Fruit harvesting, sampling, and postharvest handling

Experiments were conducted using 'Marsh' grapefruit budded on 'Troyer' Citrange ([*Poncirus trifoliata* (L.) Raf.] × [*C. sinensis*]) and x639 ([*Poncirus trifoliata* (L.) Raf.] × [*C. reshni*]) rootstocks planted in 1993 on Bolton Citrus Farm, KwaZulu-Natal (KZN) (31° 34′ 44″ S, 28° 44′ 59″ E) and Unifruitti Farm, Mpumalanga (MP) (24° 22′ 24.39″ S, 30° 42′ 17.67″ E) provinces, respectively. Three fruit per canopy position were harvested from a height of 1–2 m from 50 uniform sized trees, from each farm, at commercial maturity during 2015 and 2016 sessions. The canopy positions were inside canopy (IC), i.e. fruit receiving less than 80% of full sunlight, and outside canopy (OC), fruit exposed to 90–100% of full sunlight, of a fruit tree according to Cronje et al., (2011a). The rainfall (mm), relative humidity (%), maximum and minimum temperature (°C) registered during the growing season in KZN and MP provinces are displayed in Fig. 1A–D. After harvesting, fruit were transported within 48 h at ambient temperature in ventilated cartons to the horticultural research laboratory where fruit were washed and sorted for blemishes and fruit damage. Upon arrival at the laboratory, fruit were left for 24 h at room temperature (20 ± 1 °C) to equilibrate after which each fruit was labelled, weighed, and