Maturity indexing and storage protocols for 'Lamb Hass' and 'Reed' avocado cultivars

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ABSTRACT

The aim of this study was to develop science-based maturity indexing and ripening protocols for 'Lamb Hass' and 'Reed' avocado fruit. The study also evaluated the effect of orchard location on the maturity of these cultivars. Fruit were sampled bi-weekly from two commercial orchards, located at Wartburg, KwaZulu-Natal Province and Mooketsi in Limpopo Province. Mesocarp dry matter content (DM) was assessed during growth, from the golf-ball stage until fruit reached minimum maturity (determined by the fruit's ability to ripen without shrivelling). Results showed that in both cultivars, mesocarp DM increased with time. In August 2019, 'Lamb Hass' from Wartburg and Mooketsi had respective DM of 26.55 and 27.41%, and 'Lamb Hass' ripened completely, signifying minimum maturity. For the cultivar 'Reed', fruit harvested from Mooketsi reached minimum maturity in October 2019, with DM content of 29.4%, while fruit from Wartburg reached minimum maturity and 29.7% DM two weeks later (end October 2019). The earlier maturity in fruit from Mooketsi could be attributed to higher annual temperatures of 30°C compared to 24°C average temperature in Wartburg. Upon reaching minimum maturity, postharvest experiments were conducted to develop storage protocols for both cultivars. In these experiments, fruit harvested at minimum maturity (early season), mid-season and late season were stored for 28 days, at three different temperatures, namely 4.0, 5.5 and 8.0°C. Postharvest results showed that early-season fruit ripened after 9, 8 and 6 days when stored at 4.0, 5.5 and 8.0°C respectively, while late-season fruit ripened 2 days faster when compared to early season fruit. 'Reed' fruit stored at 4.0 and 5.5°C had higher incidence of chilling injury of 28% and 24% respectively than fruit stored at 8.0°C (8%). Chilling injury was reduced on mid- and late-season fruit. Based on the results obtained in this study, the minimum maturity for 'Lamb Hass' is 27% DM while that of 'Reed' is 29.5% DM. Fruit of these cultivars harvested at minimum maturity should be stored at 8.0°C, while those harvested mid- and late season could be stored at 5.5°C.

Keywords: 'Lamb Hass', 'Reed', dry matter, maturity, ripening protocol

INTRODUCTION

Avocado fruit contributed 32% (R1.1 billion) to the total gross value of South African subtropical fruit (R3.4 billion) during the 2014/15 season (DAFF, 2016). The avocado industry is continually expanding and planting continues to grow at a pace, with at least additional 1 000 ha being developed per annum to bring total production in South Africa to 17 500 ha (SAAGA, 2018). 'Hass' dominates the majority of the new plantings but other cultivars, including 'Lamb Hass' and 'Reed', are being introduced to lengthen the export season. The additional cultivars are contributing to the industry being able to provide a local year-round avocado supply.

As an export oriented industry, the success of the South African avocado industry depends on the assurance of quality fruit to consumers. However, postharvest problems of uneven ripening and variable quality are major challenges in the competitive international market and should be addressed in earnest. The problem is especially serious with regard to newly introduced cultivars, since there are no maturity indices currently, neither is there a general consensus on the optimal postharvest handling and ripening protocols for these cultivars. This information is important to ensure the delivery of good quality fruit to consumers, particularly for long supply chains in the international market.

Few of the quality sub-standards that are usually acquired by the South African avocado industry during export are lengthy ripening times and uneven ripening for both 'Hass' and 'Fuerte', as well as the poor ripe colour of 'Hass' fruit peels (Nelson, 2010). According to Ernst *et al*. (2015), 'Lamb Hass' shows a more even ripening pattern than 'Hass', while 'Lamb Hass' has also proven to suit the ripe-and-ready market,

outperforming 'Hass' on ease and evenness of ripening, waste levels, as well as shelf life.

One of the characteristics of avocado fruit is that it does not ripen while attached to the tree and does not show any visual traits of maturity (Magwaza and Tesfay, 2015). Thus, proper maturity evaluations are essential to assure high quality during postharvest handling, as well as to determine appropriate storage and transportation conditions (Crane *et al*., 2013; Magwaza and Tesfay, 2015).

Fruit quality is the result of the contribution of several factors but maturity is the most important factor affecting ripening and postharvest quality. Currently, avocado maturity is mostly determined using indices such as mesocarp oil, dry matter, or moisture content, all quantified destructively using representative samples of a batch in a consignment.

Considering that postharvest performance of the fruit is highly influenced by genotype, there have been specific problems reported by the avocado industry with regards to the cultivars ('Lamb Hass' and 'Reed'). One of the biggest problems is uneven ripening upon arrival in the export market (Kruger *et al*., 2017). According to Nelson (2010), variability in fruit maturity within the same consignment is largely responsible for this phenomenon. The objectives of this study were to develop reliable science-based maturity indices and storage protocols for 'Lamb Hass' and 'Reed' avocado fruit cultivars.

MATERIALS AND METHODS

Maturity indexing

Fruit sampling initiated on the 15th of May 2019. The first orchard for collection of fruit material was Conlink Trust farm in Wartburg, KwaZulu-Natal midlands (29°27'22.1"S 30°40'41.2"E). This area is characterized by a subtropical highland oceanic climate, receiving about 905 mm average annual rainfall and the average maximum annual temperature is 23.0°C (Fig. 1). The second orchard was the ZZ2 farm in Mooketsi, Limpopo (23°34'46.3"S 30°08'36.7"E), a cool semi-arid area which receives about 598 mm average annual rainfall and average annual maximum temperature of 23.8°C (Fig. 1). Ten trees per cultivar per study site were randomly selected and 20 fruit per tree were harvested bi-weekly from week 22 after fruit set (golf-ball size) until fruit reached minimum maturity (determined by the fruit's ability to ripen without shrivelling). During each sampling date, fruit were packed in open boxes and transported to the postharvest laboratory at the University of KwaZulu-Natal. Fruit from Wartburg were transported within two hours after picking while fruit from Mooketsi reached the laboratory in one to two days, due to logistical reasons.

Dry matter content

During each sampling date, fruit were assigned to ten replicates, peeled with a knife, sliced and put in brown paper bags and weighed for mesocarp wet weight. Fresh mesocarp weighted samples were then oven dried at 70ºC for 24 hours and weighed again for dry weight. Percentage dry matter content was calculated using Equation 1 (below):

Equation 1: Dry matter = (dry weight ÷ wet weight) × 100

Storage protocol

Early harvesting started immediately after fruit had reached minimum maturity. This was August for 'Lamb Hass' and October for 'Reed'. Three different cold storage rooms were used (4.0, 5.5 and 8.0°C). A total of 30 fruit were sampled per cultivar. Ten fruit were assigned to each cold storage temperature, with three fruit marked as replicates one to three, while the remaining fruit were left unmarked for weekly sampling.

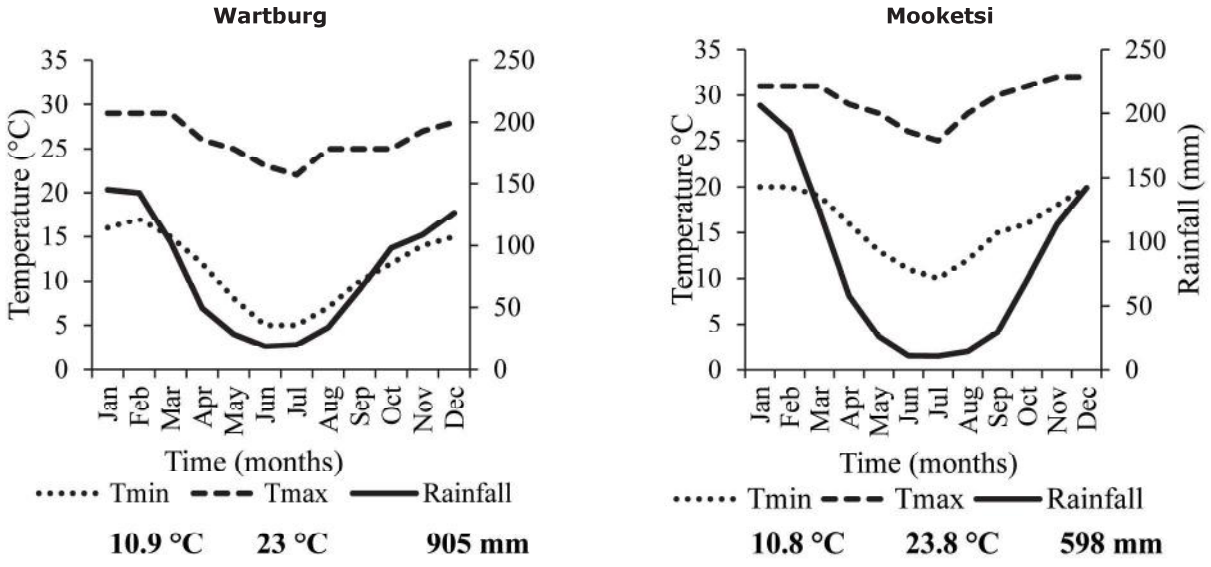

Figure 1: The minimum temperature (°C), maximum temperature (°C) and total rainfall (mm) recorded during January-December 1982-2012 (Climate-data.org)

Fruit were stored for 28 days, with fruit removed from cold storage after 21 days and ripened at room temperature to evaluate shelf life. This was done for every cultivar and location. Data for fruit quality parameters such firmness, mass loss, chilling injury and days to edible ripeness were recorded. This was also done for mid- and late season harvested fruit.

Fruit firmness

Fruit firmness was determined weekly during cold storage as well as during the ripening period, using a hand-held firmness tester (Bareiss, Germany). Two readings, on a scale of 100 (hard, unripe) to <60 (ready to eat), were taken at the equatorial region of the fruit on opposite sides and averaged.

Statistical analyses

The collected data was subjected to the analyses of variance (ANOVA) using GenStat statistical software (GenStat®, 18th edition, VSN International, UK) 18. Mean separation was performed using Fischer's least significant difference (LSD) with a significance level of 0.05.

RESULTS AND DISCUSSION

Maturity indexing

There were no significant differences ($p > 0.05$) in DM between fruit from the two locations (Fig. 2). These results confirm the findings of Kremer-Köhne (2000), who found no significance differences in DM between fruit from Westfalia Estate (KwaZulu-Natal midlands) and Goedgelegen Estate (Mooketsi, Limpopo). In the present study, DM content increased from the first sampling date until July when the rate of DM accumulation decreased slightly. During this period, mesocarp texture gradually changed from completely mealy to partly buttery upon ripening. The slight decrease in the rate of DM accumulation could be attributed to the decline in temperatures during that period, a factor also observed by Lahav and Trochoulias (1982), who showed that temperatures below 22°C decrease the rate of DM accumulation in 'Hass'.

In both locations, minimum maturity was observed end August when DM content was 26.5% and 27.4% in fruit from Wartburg and Mooketsi, respectively. This was when fruit started to display no signs of shrivelling and had a more buttery flavour. The seed coat was dry, dark and somewhat shrivelled, instead of whitish when fruit were still premature. Dixon *et al*. (2008) reported a minimum maturity DM of 27% in 'Lamb Hass' fruit grown in the far north of New Zealand, where the climate is almost tropical and with a higher relative humidity (RH), compared to Wartburg and Limpopo conditions. Fruit were declared mature in October with 34% DM content recorded. Some fruit had started to exhibit a purplish exocarp upon ripening, indicative of over-mature fruit (Perkins *et al*., 2017).

In the cultivar 'Reed', no significant differences ($p > 0.05$) in DM accumulation were observed between the fruit from Wartburg and Mooketsi (Fig. 3). DM accumulation increased linearly from the first sampling date until August. Fruit from Mooketsi reached minimum maturity in mid-October (Fig. 3), two weeks earlier than those from Wartburg which reached minimum maturity in end October (Fig. 3). The minimum maturity dry matter content was 29.4% and 29.7% in fruit from Mooketsi and Wartburg, respectively.

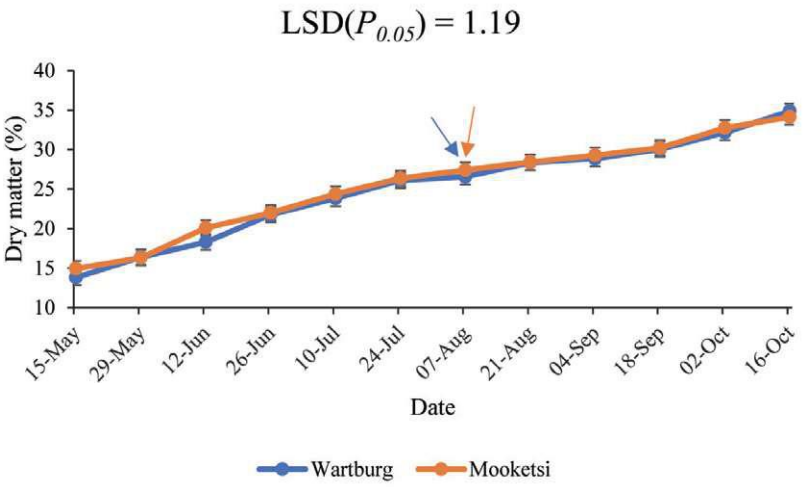

Figure 2: Dry matter accumulation comparison in 'Lamb Hass' avocado fruit cultivar between the two locations, Wartburg and Mooketsi. The arrows indicate minimum maturity for both cultivars

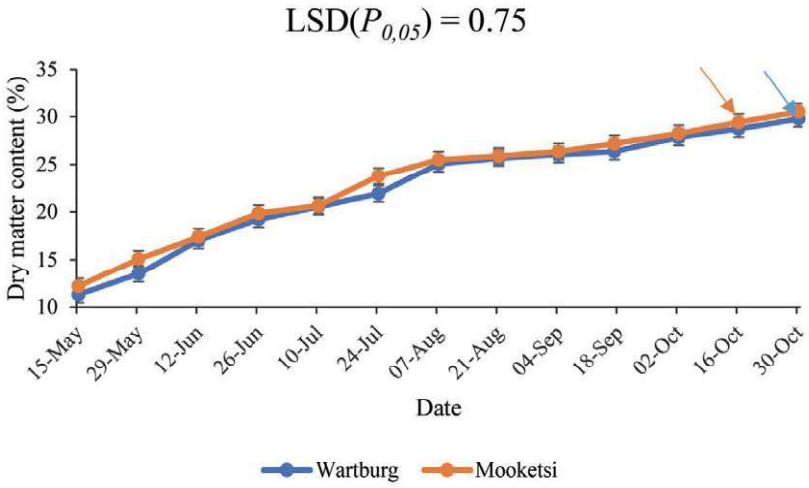

Figure 3: Comparison of DM accumulation between fruit from 'Reed' avocados in Wartburg and Mooketsi. The arrows indicate the minimum maturity for each location

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Magwaza and Tesfay (2015) stated that fruit with a DM content above 20% are considered minimally mature while those with a DM around 40% are over-mature. The results obtained in this study fall within this range. The harvest season of avocado fruit widely varies depending on numerous factors, including maturity, climate, water regime and sunlight, among others; although the most important is cultivar (Moretti *et al*., 2010). In this study, the differences in the average annual rainfall and temperature between the two regions (Mooketsi: rainfall = 992 mm, temperature = 30ºC; Wartburg: rainfall = 789 mm; temperature = 24ºC) had no significant influence on fruit DM accumulation.

Storage protocol

Mass loss

Fruit mass loss declined with storage time and the greatest mass loss was observed when fruit were removed from cold storage to ripen at room temperature

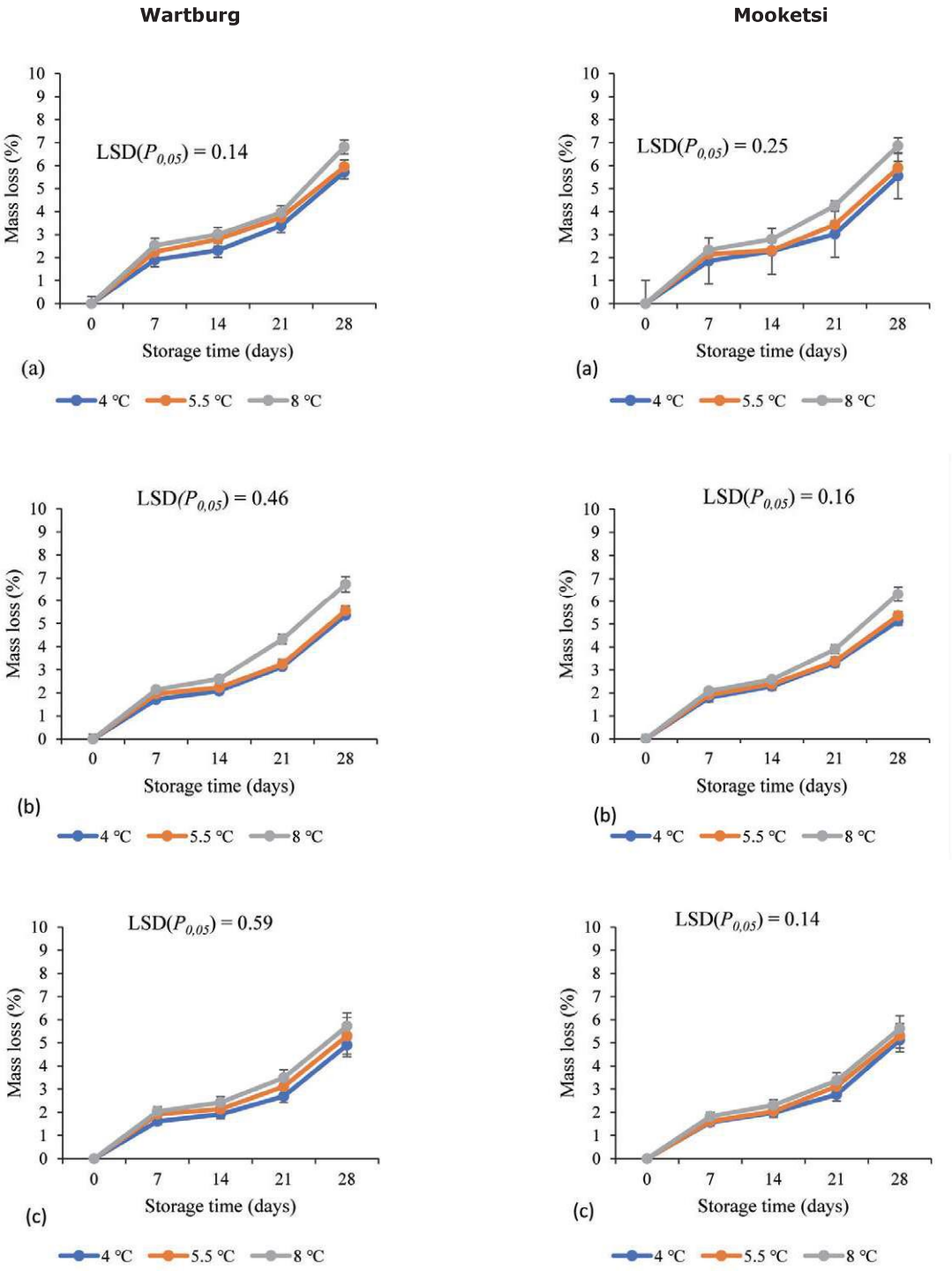

Figure 4: Mass loss in 'Lamb Hass' fruit during storage, a-c indicates early, mid- and late harvest respectively

from day 21 to day 28 (Fig. 4 and 5). In both cultivars, storage temperatures had a significant influence on mass loss over time ($p < 0.001$) (Fig. 4 and 5). Fruit stored at 8.0ºC lost more moisture when compared to fruit stored at 4.0 and 5.5ºC. In both cultivars and at all temperatures, moisture loss decreased with harvest time, so that fruit harvested early lost more moisture than fruit harvested later in the season. Location had no effect on fruit moisture loss ($p > 0.05$). The pattern of mass loss for fruit from both locations was similar (Fig. 4 and 5).

Fruit firmness

Storage temperatures had a significant influence on loss of firmness ($p < 0.001$) (Fig. 6 and 7). The highest rate of firmness loss was observed when fruit were removed from cold storage to room temperature after 21 days. The lowest rate of firmness loss was observed for fruit stored at 4.0ºC while fruit stored at 8.0ºC had the highest firmness loss. Firmness loss increased with harvest time in 'Reed', where fruit harvested later in the season and stored at 8.0ºC had a firmness loss lower than 60 N (Fig. 7 (c)).

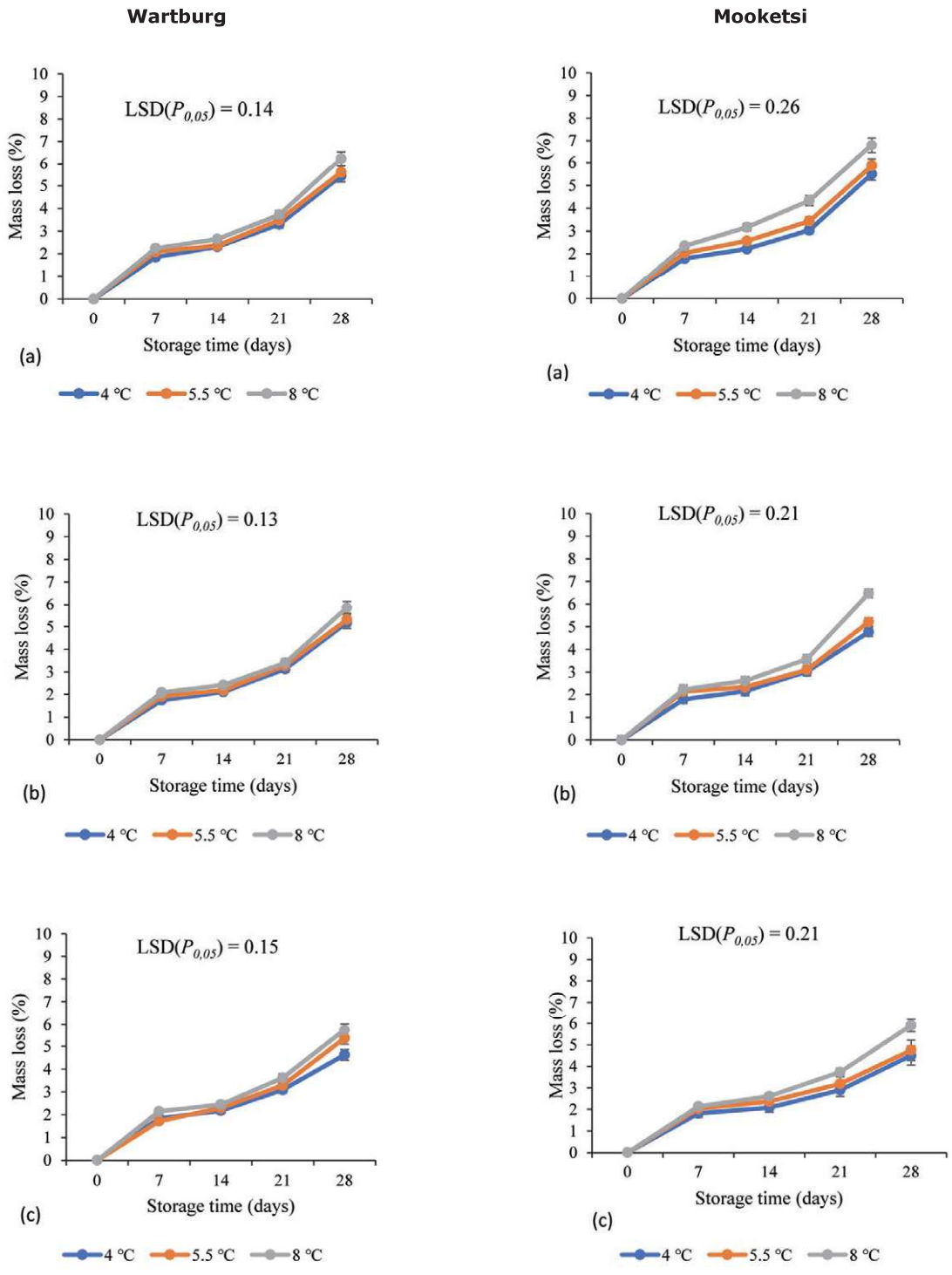

Figure 5: Mass loss in 'Reed' fruit during storage, a-c indicates early, mid- and late harvest respectively

However, this was not the case for 'Lamb Hass' where firmness loss was almost constant, regardless of harvest time (Fig. 6). There were no significant differences ($p > 0.05$) in firmness loss between the two locations for both cultivars (Figs. 6 and 7).

Chilling injury

In both fruit cultivars, the highest incidence of chilling injuries (60-80%) was observed for fruit harvested earlier in the season, and this decreased for fruit harvested later in the season (Figs. 8 and 9). There were significant differences ($p < 0.001$) among storage temperatures for percentage chilling injury (Figs. 8 and 9). Fruit stored at 8.0ºC had smaller incidence of chilling injuries (≤10%) when compared to fruit stored at 4.0 and 5.5ºC (≤30%), for both cultivars. In 'Lamb Hass', the increase in the rate of chilling injury was linear throughout the storage time (Fig. 8). However, in 'Reed' the rate of chilling injury increased exponentially until fruit were removed from

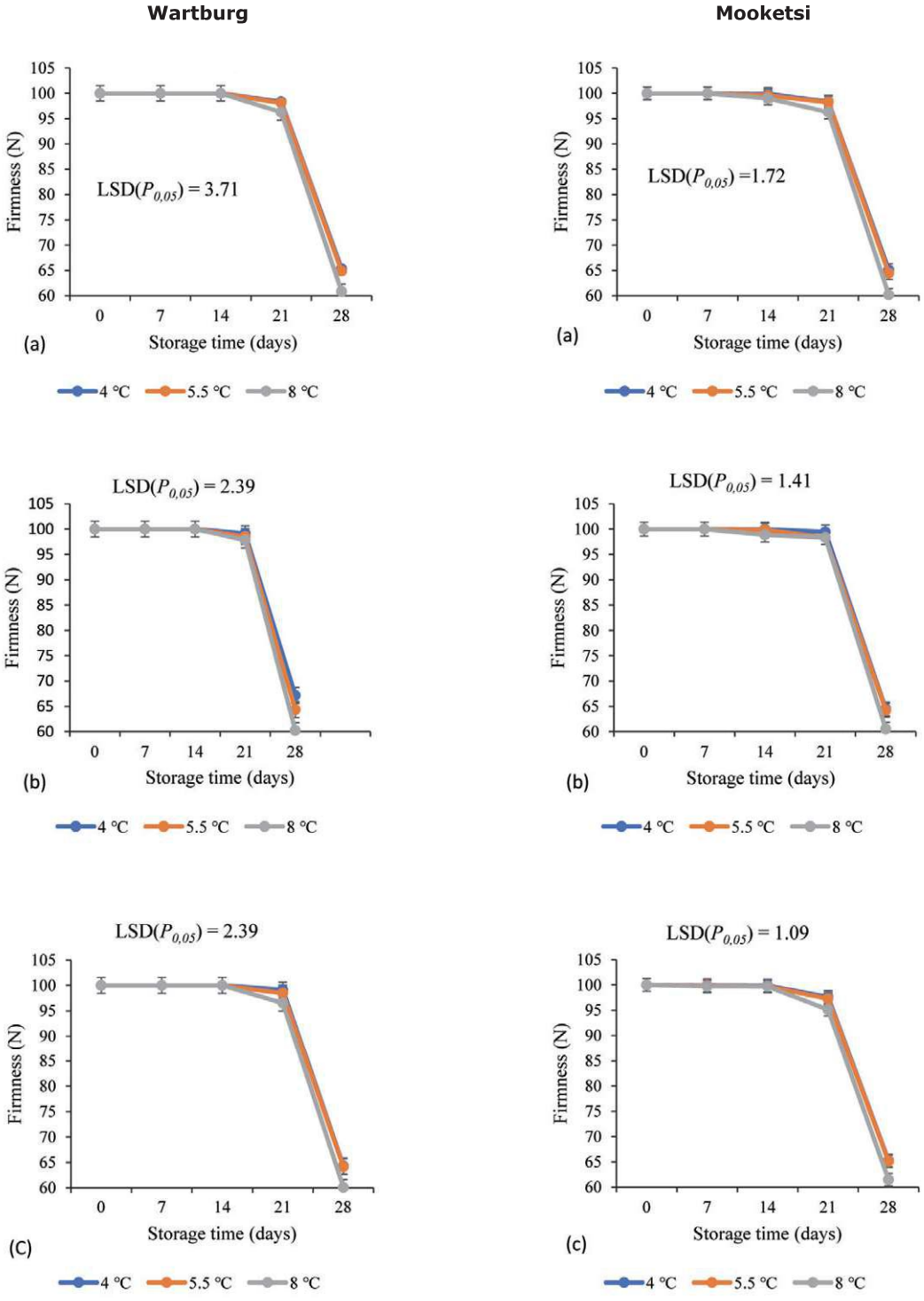

Figure 6: Fruit firmness in 'Lamb Hass' during storage, a-c indicates early, mid- and late harvest respectively

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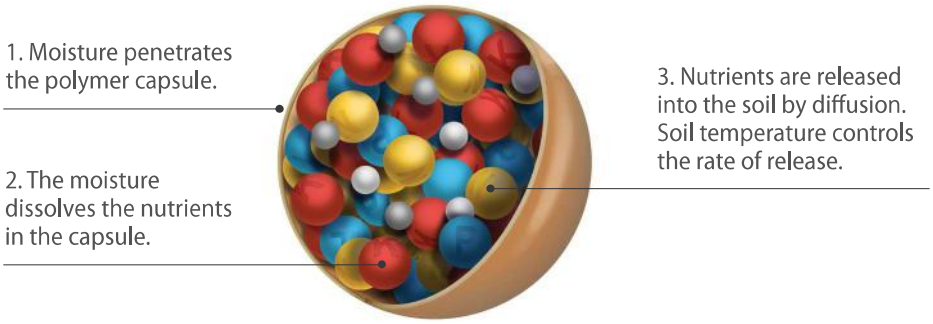

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cold storage, after which it levelled off (Fig. 9). Location had no significant influence on chilling injury in both cultivars ($p > 0.05$).

Time to ripening

Storage temperature significantly influenced ($p < 0.001$) the number of days fruit took to reach edible ripeness (Figs. 10 and 11). Fruit stored at 8.0ºC reached edible ripeness sooner than fruit stored at 4.0 and 5.5ºC, and this decreased with harvest time. For both cultivars, fruit harvested in the early season took 7-12 days to ripen while fruit harvested later in the season took 5-6 days to ripen. Location had no significant influence on the number of days fruit took to reach edible ripeness.

This study demonstrated that storage temperature has a significant effect on all the fruit postharvest parameters investigated. The difference observed was influenced by harvest time (early, mid-, late harvest). These results agree with Dixon *et al*. (2004)

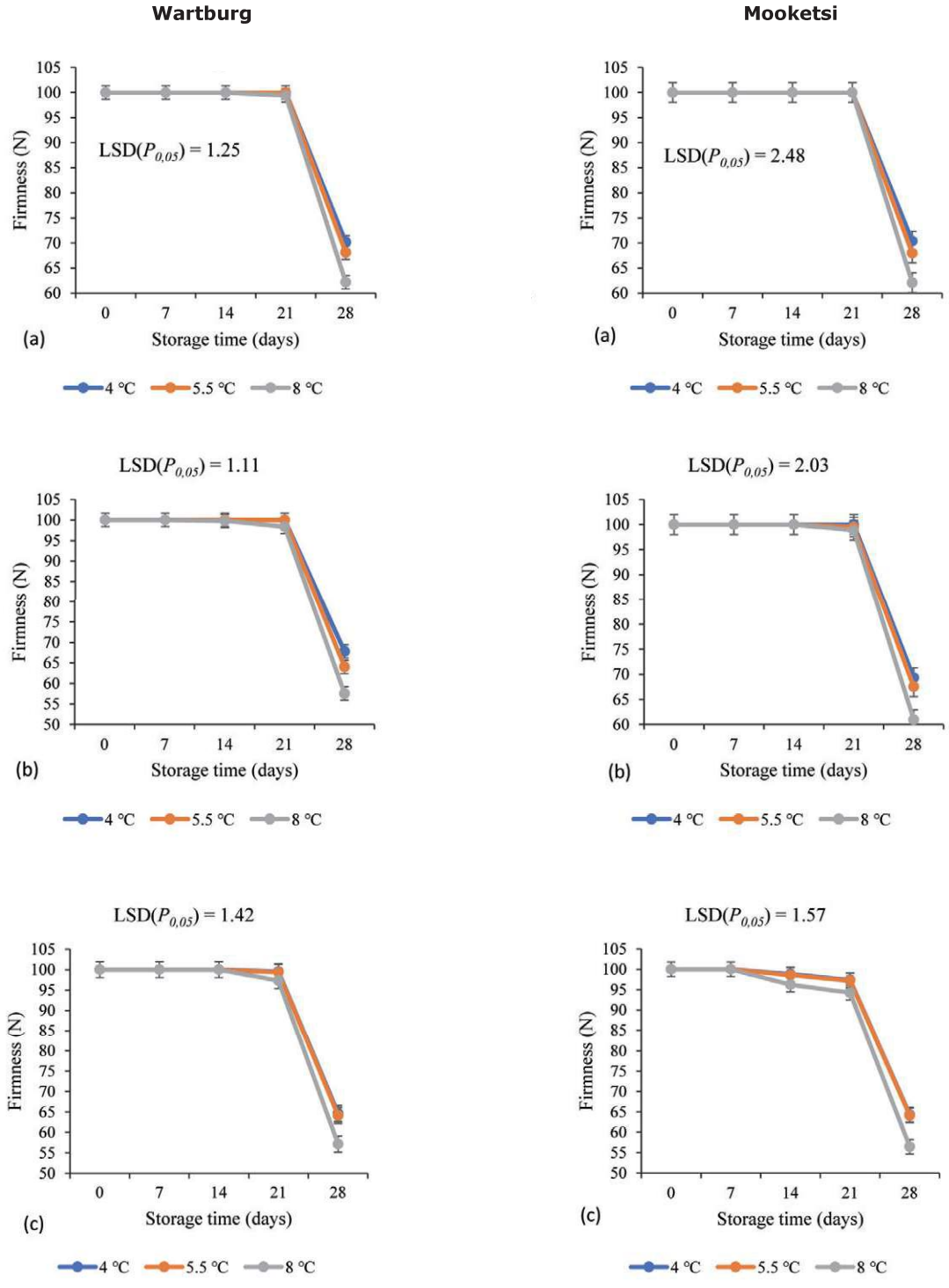

Figure 7: Fruit firmness in 'Reed' fruit during storage, a-c indicates early, mid- and late harvest respectively

who showed that fruit age, storage temperature and maturity affect 'Hass' avocado fruit quality and ripening. Blakey *et al*. (2009) found storage at 5.5ºC effective in minimizing incidence of chilling injury and mass loss while maintaining fruit quality. Meyer and Terry (2010) showed that, as the harvest season progresses, storage temperatures should be modified since fruit with different maturity levels respond differently to storage temperature.

CONCLUSION

DM content is a reliable maturity marker for 'Lamb Hass' and 'Reed'. The minimum maturity DM for 'Lamb Hass' is 26.5% and 27.4% for fruit grown in Wartburg and Mooketsi, respectively. In 'Reed' the minimum maturity DM content is 29.7% and 29.4% for fruit grown in Wartburg and Mooketsi, respectively. This study demonstrated that 'Lamb Hass' grown in Wartburg and Mooketsi show no noticeable

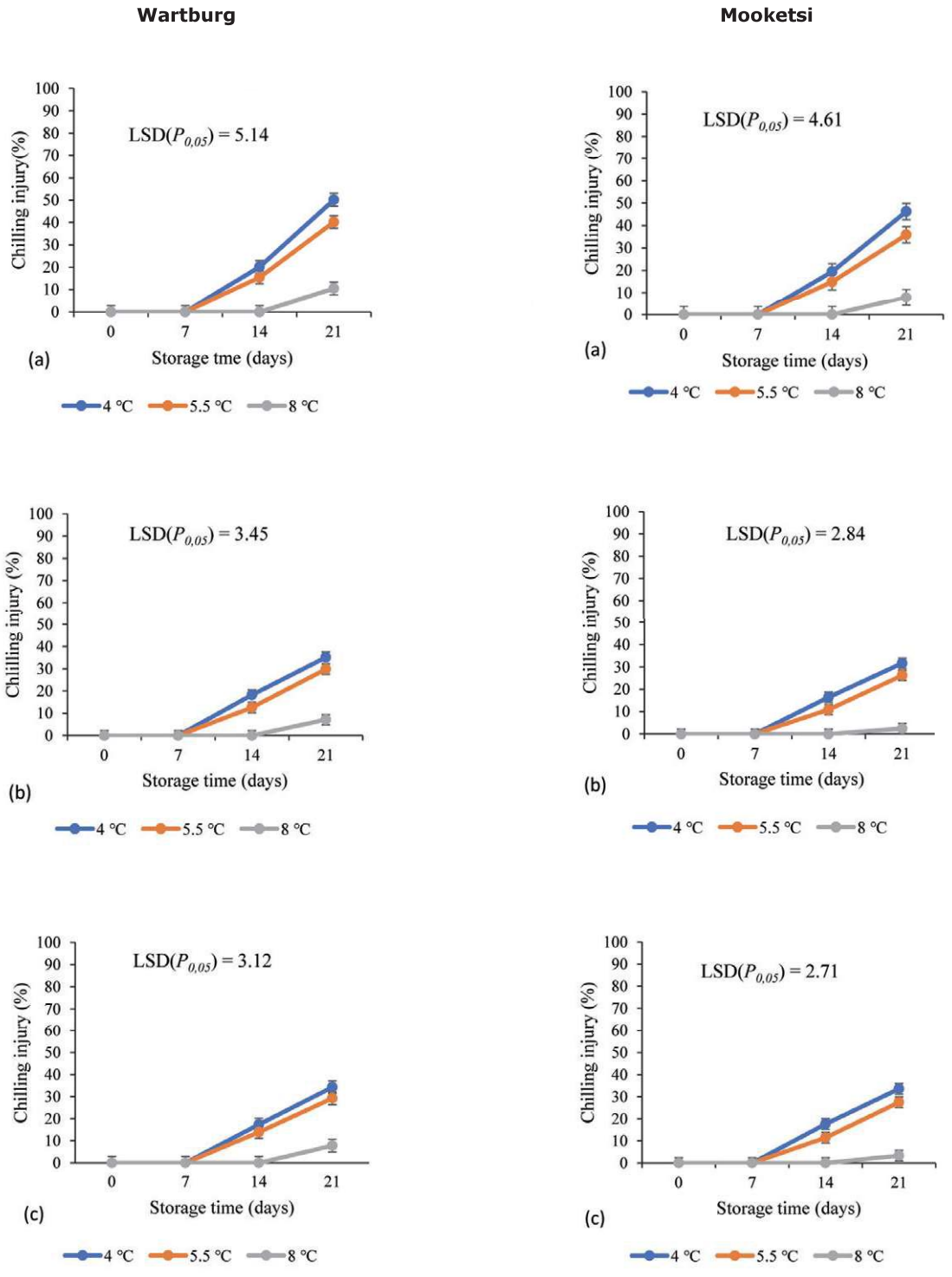

Figure 8: Chilling injury in 'Lamb Hass' during storage, a-c indicates early, mid- and late harvest respectively

difference in DM accumulation, however DM accumulates faster in 'Reed' planted in Wartburg. Timing of harvest influences fruit mass loss and firmness loss in both 'Lamb Hass' and 'Reed' fruit during storage. This study showed that fruit harvested earlier in the season are more susceptible to chilling injury than fruit harvested later in the season. For both cultivars, fruit harvested earlier in the season and mid-season should be stored at 8.0°C to reduce chilling injury. Late-season fruit should be stored at 5.5°C. Further investigation on the biochemical behaviour and the enzymes involved in reducing quality of these avocado fruit cultivars is recommended.

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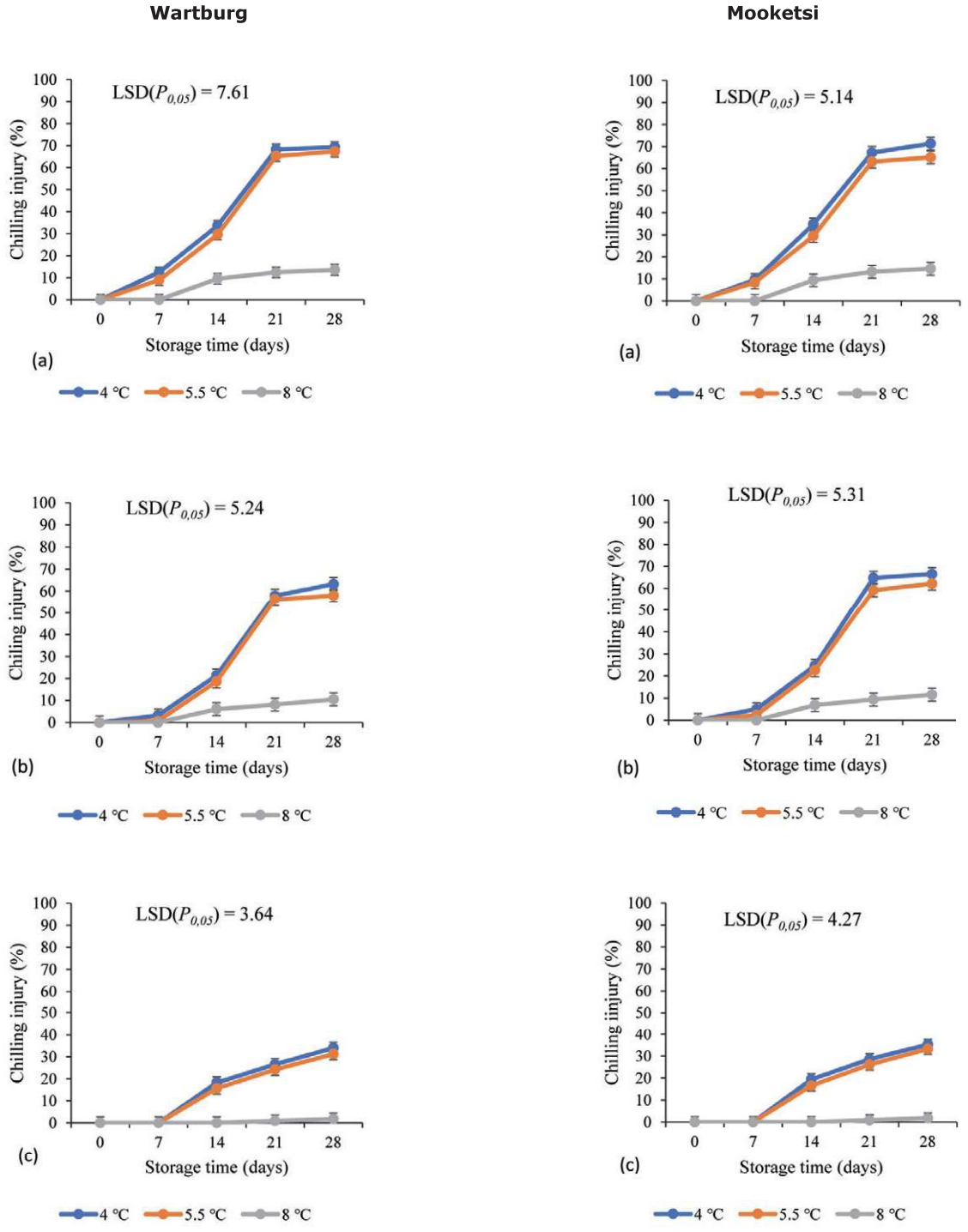

Figure 9: Chilling injury in 'Reed', a-c indicates early, mid- and late harvest respectively

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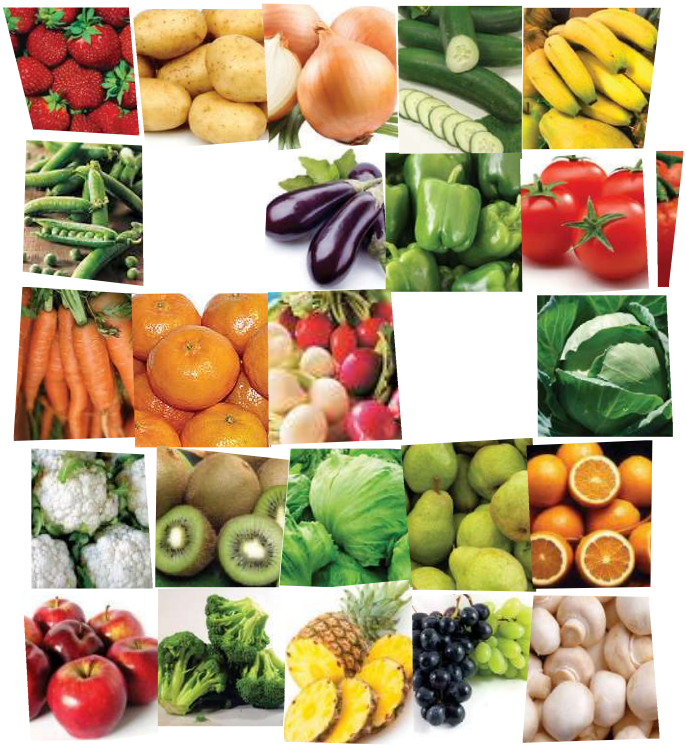

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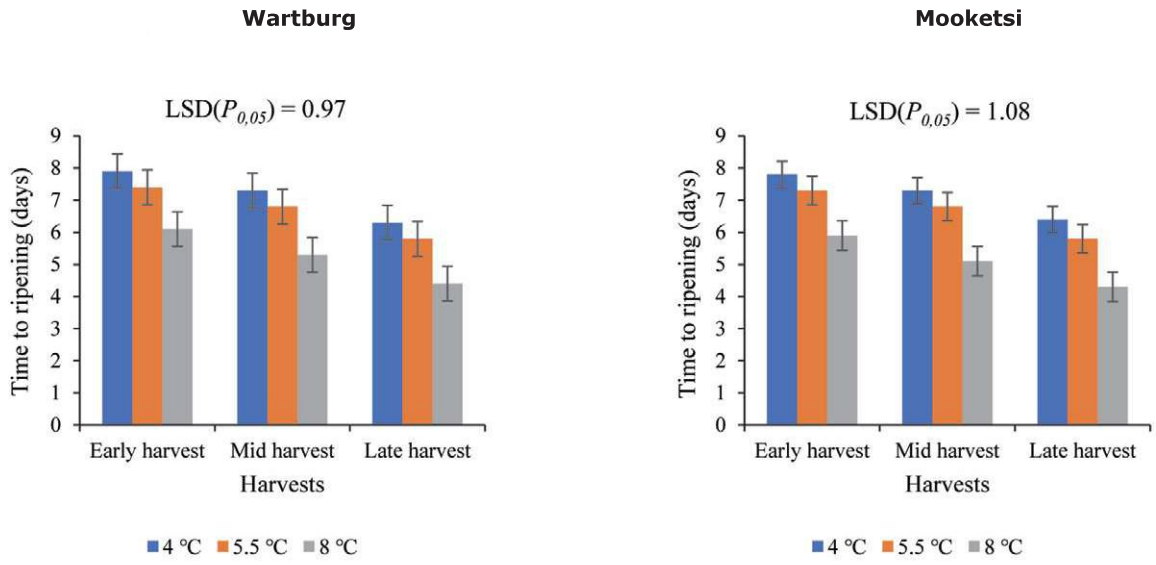

Figure 10: Time to ripening for 'Lamb Hass' fruit after storage

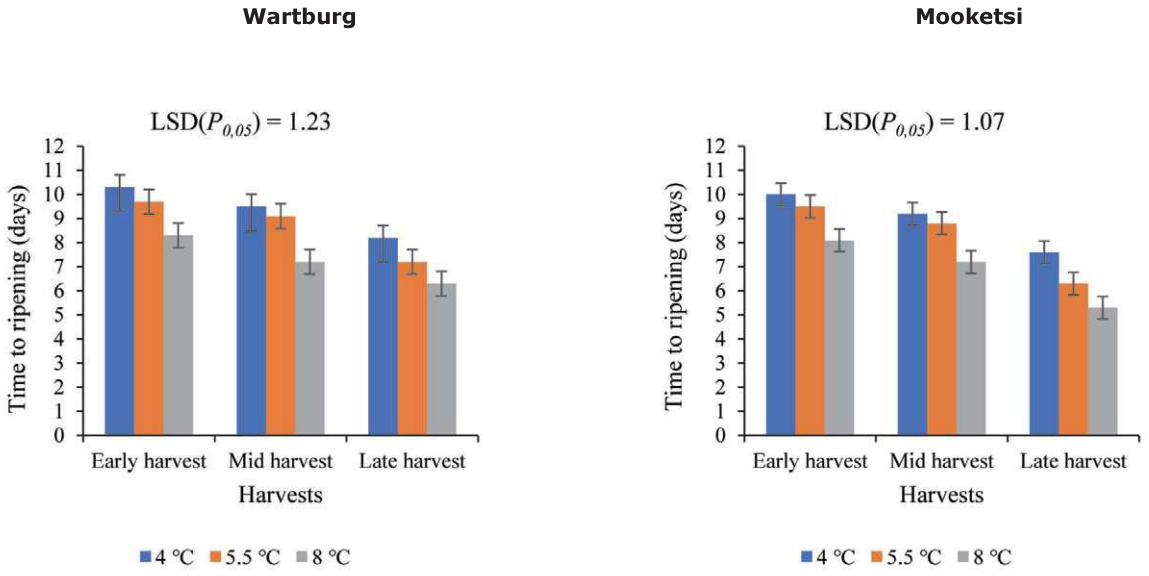

Figure 11: Time to ripening for 'Reed' fruit after storage

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