

# PROGRESS REPORT: MATURITY INDEXING FOR 'LAMB HASS' AVOCADO, AND RE-EVALUATING THE EFFICACY OF THE CURRENTLY USED MATURITY INDICES FOR 'HASS' AVOCADO CULTIVAR

Asanda Mditshwa<sup>1</sup>, Wendy Mthimkhulu<sup>1</sup>, Samson Tesfay<sup>1</sup>,  
Sabelo Shezi<sup>2</sup> and Lembe Magwaza<sup>3</sup>

<sup>1</sup>Discipline of Horticultural Science, School of Agricultural, Earth and Environmental Sciences,  
University of KwaZulu-Natal, Scottsville 3209, SOUTH AFRICA

<sup>2</sup>School of Agriculture and Life Science, University of South Africa, Pretoria 0002, SOUTH AFRICA

<sup>3</sup>Postharvest Research Group, Cranfield University, Bedfordshire MK43 0AL, UNITED KINGDOM

Corresponding author: mditshwaa@ukzn.ac.za

## ABSTRACT

There is a significant lack of information reporting on the maturity indices of new avocado cultivars. Improper maturity at harvest has been reported to be the main phenomenon resulting in uneven ripening. Although maturity indexing of avocado has been extensively researched, the possibility of using alternative indices such as total soluble solids (TSS), titratable acidity (TA), and pH has not been adequately explored. Therefore, the objective of this study was to test and develop reliable and science-based maturity indices for the 'Lamb Hass' avocado cultivar. The experiments were carried out during the 2024 growing season at Everdon Estates, a commercial orchard of Westfalia, in Howick, KwaZulu-Natal (KZN). After the initial measurements immediately after harvest, the fruit were stored for 28 days at 5.5 °C, followed by 7 days of shelf life. The dry matter content (DM), mesocarp moisture content (MC), and mesocarp oil content (OC), TSS, TA, and pH were evaluated during the season. The findings showed DM content steadily increased with fruit growth. In fact, there was a linear correlation between DM and the different sampling dates. On the other hand, pH gradually declined with advancement in fruit development. Although TSS decreased with sampling time as the maturity progressed, it was inconsistent. The fruit were deemed ready for harvest at 28.1% DM and 3.18 Brix° as they reached acceptable ripeness without shrivelling. The results showed that DM is a reliable maturity indexing tool for avocado. TSS is a quick and cheap alternative tool, and its adoption would greatly reduce the cost and time spent on maturity indexing.

**Keywords:** Maturity indices, avocado, dry matter content, moisture content, total soluble solids

## INTRODUCTION

The avocado industry has shifted to newly developed cultivars not only to fill the counter-season window period but also to protect its export market share. The newly developed cultivars such as 'Maluma Hass', 'Lamb Hass' and 'GEM' produce better fruit size compared to the commercially dominant cultivar 'Hass'. These cultivars also require simple pruning and significantly less chemical use compared with other cultivars (Ernst and Ernst, 2015). However, there is a lack of information on the maturity indices of new avocado cultivars. Avocado optimum ripening behav-

our and postharvest quality are largely correlated with harvesting at the physiological maturity stage. Improper maturity at harvest is the main cause of uneven ripening (Ferrer *et al.*, 2005; Shezi, 2020). Other fruits do ripen but their peels have poor colour change which is also considered as uneven ripening because it results in technical difficulties as some may consider the fruit to be unripe whereas it is ripe and mature.

Identification of avocado physiological maturity is challenging because external changes during maturation do not characterise the stage of maturity (Mag-

waza and Tesfay, 2015; Ncama *et al.*, 2018). However, the use of dry matter content (DM), mesocarp moisture content (MC), and mesocarp oil content (OC) has been reported to strongly correlate with optimum postharvest quality and best eating quality of the avocado fruit (Clark *et al.*, 2007; Hofman *et al.*, 2013). These parameters change significantly during maturation of avocado; the fruit OC increases with maturity while the mesocarp MC decrease with maturity. The DM also increases with maturity. The DM is usually an alternative parameter to the oil content and this is due to the ease of determining it compared to OC, while there is a strong correlation ( $R^2 = 0.99$ ) found between the two parameters (Carvalho *et al.*, 2014).

Although maturity indexing of avocado has been extensively researched, the possibility of using alternative indices such as total soluble solids (TSS), titratable acidity (TA), pH, and TSS/TA ratio has not been adequately explored. Reliable maturity prediction models based on TSS, TA, and pH have been reported on pomegranate (Khodabakhshian *et al.*, 2017), strawberries (Saad *et al.*, 2022), and mango fruit (Rungpichayapichet *et al.*, 2017). A reliable maturity index in avocado fruit is characterised by having a gradual change over time. A gradual change forms an increasing or a decreasing pattern over time (Magwaza and Tesfay, 2015). While the possibility of using TSS, TA, TSS/TA, and pH as maturity indices for avocado has been previously tested (Özdemir *et al.*, 2009; Ahmed *et al.*, 2010; Salameh *et al.*, 2022), the results have not been entirely satisfactory. This could be attributed to the dominance of the heptose (C7) sugars in avocado fruit, as compared to the hexose (C6) sugars which are known to contribute more in TSS, and hence the sweetness of most fruits (Shezi *et al.*, 2023). The mechanism of hexose sugars formation is the same for all fruits, and this justifies its high potential to contribute to avocado TSS as it does in other fruits. Thus, there is a need to test these maturity indices for other cultivars as the response seems to vary depending on cultivar and production region.

### Aim and objectives

The overall aim of this study was to develop reliable and science-based maturity indices for 'Lamb Hass' avocado cultivar, and re-evaluating whether the currently used maturity indices for 'Hass' cultivar still hold true.

The objectives of this study were to:

- Determine and evaluate the efficacy/reliability of developed harvest maturity indices in postharvest fruit quality of the 'Lamb Hass' cultivar.
- Develop a growing degree days (GDD) model for maturity indexing of 'Hass' and 'Lamb-Hass' avocado cultivar.
- Identify the best and most reliable protocol for determining dry matter content of avocado fruit.

\*The report will only cover the work we did on 'Lamb Hass'.

## MATERIALS AND METHODS

### Objective 1 – Maturity parameters and postharvest fruit ripening

#### Experimental site

The experiments were carried out at Everdon Estates, a commercial avocado farm of Westfalia fruit (Pty) Ltd in Howick, KZN. The 'Lamb Hass' avocado fruit cultivar was used to study the growth and determination of reliable science-based maturity indices.

#### Fruit growth attributes

Ten 'Lamb Hass' avocado trees were randomly selected for the fruit maturity evaluation. It was initially planned that maturity would be evaluated at sixteen distinct developmental stages starting from 4 February 2024 to mid-November 2024, but due to the delays beyond our control, the experiment started much later. Therefore, the data collection started towards the end of July (Table 1). For each maturity stage, 20 fruit were randomly harvested from the tagged trees and immediately transported in a ventilated vehicle to the postharvest laboratory of the University of KwaZulu-Natal. Upon arrival at the laboratory, 10 fruit were analysed for maturity indices (DM, MC, TSS, and pH). The other 10 fruit were left to ripen in the laboratory at room temperature (21 °C) and minimum maturity was evaluated on the ability of these fruit to ripen normally without shrivelling and developing a watery texture.

#### Moisture content and dry matter content

Fruit MC was determined by measuring the fresh mass of a core sample measured using a digital weighing balance (RADWAG, WTB 2000 Precision Balance) and removing the free water of the cored portion by drying the fruit sample using an oven freeze-dryer. The MC and DM were calculated using the following equations:

$$MC \% = \left[ \left( \frac{M_f - M_d}{M_f} \right) \times 100 \right]$$

MC = mesocarp moisture content  
M<sub>f</sub> = fresh mass of the core sample  
M<sub>d</sub> = dry mass of the core sample

$$DM \% = \left[ \left( \frac{M_d}{M_f} \right) \times 100 \right]$$

DM = dry matter content  
M<sub>f</sub> = fresh mass of the cored sample  
M<sub>d</sub> = dry mass of the cored sample.

#### Oil content

Mesocarp oil concentration was determined using the method of Meyer and Terry (2008) with slightly modification. Briefly, 1 g of lyophilised tissue and 5 ml *n*-hexane as an extraction solvent were used. Oil concentrations were expressed as percentage (w/w) DW.

#### Total soluble solids

TSS (°Brix) of freshly harvested fruit was determined

according to Jha *et al.* (2006) with slight modifications. A garlic press was employed to extract the juice of the hard-cored sample and TSS of the mesocarp was determined using a digital refractometer (PR-101 ATAGO, Topac Inc, Cohasset, USA).

### pH

For measuring pH values, 5 g of the sample was homogenized with 50 ml of deionized water, and a digital pH meter (Mettler Toledo, Switzerland) was used to measure the pH values.

### Fruit storage and ripeness evaluation

After each harvest, 10 fruit were stored for 21 days at 5.5 °C, followed by storage at room temperature. The number of days to ripen each fruit was recorded and the mean calculated. Fruit firmness was determined using a hand-held firmness tester (Bareiss, Germany). Two firmness readings were taken in the equatorial regions by rotating the fruit 180°. Fruit with firmness readings of 0.2 to 0.6 kg were deemed ripe.

**Table 1:** Description of different harvesting times for 'Lamb Hass' avocado fruit during the 2024 growing season

Harvest	Date	DAFB
H1	25 July 2024	233
H2	15 August 2024	248
H3	28 August 2024	263
H4	12 September 2024	278
H5	26 September 2024	298
H6	10 October 2024	308
H7	23 October 2024	323
H8	07 November 2024	338
H9	21 November 2024	352

### Objective 4 – Reliable protocol for determining dry matter content

There have been concerns that some of the commonly used methods for assessing dry matter content are inconsistent and they may fail to accurately predict the maturity status of the fruit. Therefore, we assessed three of the commonly used methods with the aim of identifying the rapid and most reliable method which could be recommended to avocado growers (Fig. 1).

### Oven drying method

The oven was preheated to 65 °C. Approximately 100 g of avocado mesocarp sample was weighted into a shallow, ovenproof container using a digital balance. The container was left undisturbed at the centre of the oven for 24 hours. The temperature was monitored using an oven thermometer. After five hours, the oven was allowed to cool and the dried avocado weight was determined. The sample was re-dried for another 30 minutes and then reweighted up to a constant mass to ensure that the sample is fully dried.

The following equation was used to calculate the dry matter content:

$$DM = \left( \frac{\text{Weight of dry sample}}{\text{Weight of fresh sample}} \right) \times 100$$

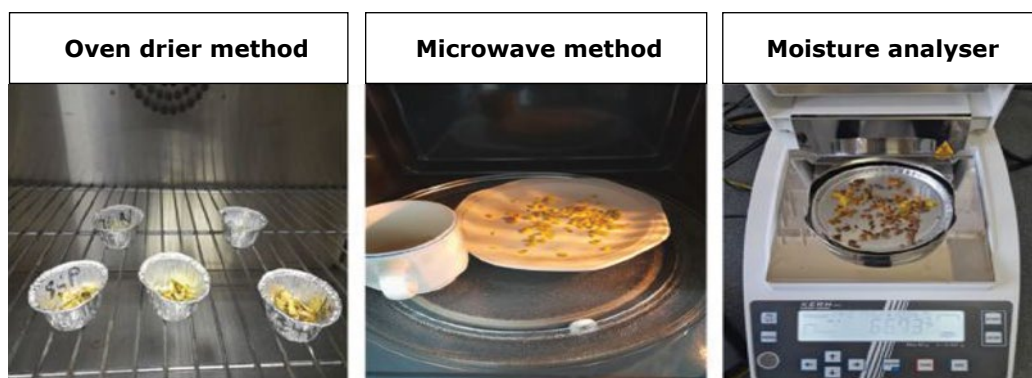
### Microwave drying method

A domestic microwave oven with 800 W maximum intermittent output power and frequency of 2450 MHz was used. Approximately 100 g of avocado mesocarp sample was weighted into a microwave proof container using a digital balance. The microwave was set to run for 20 minutes at medium or low. The sample was reheated and reweighted until it reached a constant weight. Importantly, a container of water was placed next to the sample to avoid damaging the microwave or compromising the sample. The time it took to dry the sample was thereafter recorded. The following equation was used to calculate the dry matter content:

$$DM = \left( \frac{\text{Weight of dry sample}}{\text{Weight of fresh sample}} \right) \times 100$$

### Moisture analyser method

Moisture analysis of the mesocarp is one of the cheapest and most rapid methods for measuring dry matter content. This method could be very convenient for packhouses as it is simple and time-efficient. However, the reliability of this method is yet to be tested on avocado fruit. To test this method, approximately 50 g of avocado mesocarp was used to measure the % dry matter content using the MA 50.R Moisture Analyzer (RADWAG, Radom 26-600, Poland). The machine gives the results in % dry mass, mass (g) after drying, as well as the ratio of % moisture content to dry mass.



**Figure 1:** Different methods of assessing dry matter content in avocados.

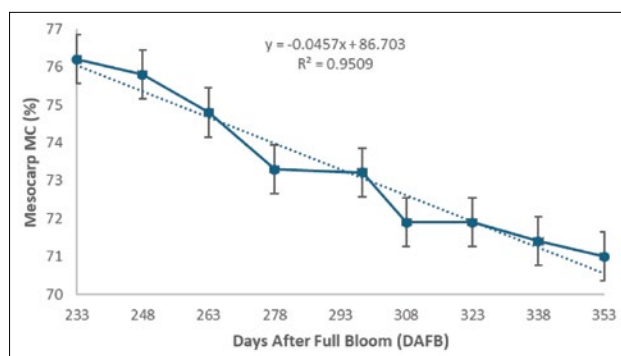
## Completed and planned work

Objective	Work completed to date	Planned work for the remainder of the project
Determine and evaluate the efficacy/reliability of developed harvest maturity indices in postharvest fruit quality of the 'Lamb Hass' cultivar.	To date, we have analysed the patterns of fruit growth and selected maturity parameters, including moisture content (MC), dry matter (DM), TSS, and pH. All these were done for 'Lamb Hass' avocados. This analysis was done for the KZN region.	Oil content and carbohydrates analysis is ongoing for the last season. We have already started with 'Hass' harvesting for the KZN region. This year we will be including 'Lamb Hass' from Mpumalanga and Limpopo.  <i>Although we measured the oil content, the results did not give the trends we expected. The experiment will be repeated as we suspect there were errors with the protocol used.</i>
Develop growing degree days (GDD) model for maturity indexing of 'Hass' and 'Lamb Hass' avocado cultivars.	Data loggers were installed at Everdon Estates – the temperature is continuously being monitored. Installation of data loggers will also be done in Limpopo and Mpumalanga when we start harvesting.	At the end of the season, correlation and regression analysis will be done with the aim of developing a GDD model for maturity indexing.
Identify the best and most reliable protocol for determining dry matter content of avocado fruit.	This objective has been achieved, findings are included in this report.	The experiments will be repeated this year for validation purposes.

## RESEARCH FINDINGS

As expected, MC decreased with the advancement in maturity or DAFB (Fig. 2). On the other hand, DM increased with maturity (Fig. 3). The increase in DM content is largely due to the increase in mesocarp oil content which drastically increases during maturity. In fact, Carvalho *et al.* (2014) indicated that DM content is regarded as the alternative maturity parameter due to its strong correlation to oil content ( $R^2 = 0.99$ ).

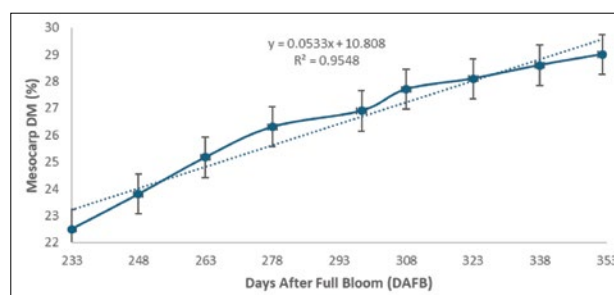
The MC or mesocarp DM are the most reliable and widely accepted maturity indices of avocado fruit (Magwaza and Tesfay, 2015). Due to their consistent habit of occurrence during fruit development, MC and DM are globally accepted as the best parameters and are strongly correlated with optimum posthar-



**Figure 2:** The moisture content (MC) % of 'Lamb Hass' avocado mesocarp harvested at different days after full bloom (DAFB) for maturity indexing. Data presented as mean  $\pm$  standard error; n = 10.

vest and eating quality of avocado fruit (Hofman *et al.*, 2013). Moreover, DM has a strong and positive correlation with the oil content and is much easier to determine compared to other indices which are not only time-consuming, but also expensive.

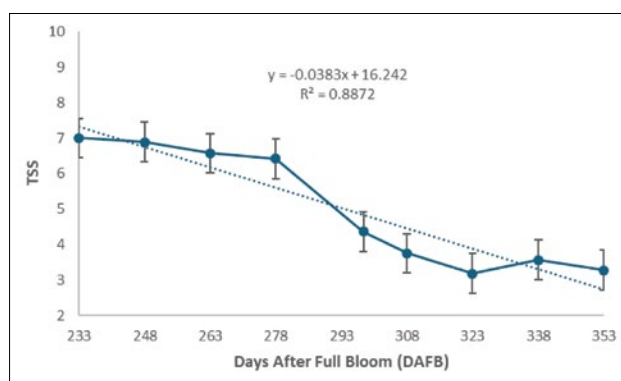
In this study, the fruit were deemed ready for harvest at 28.1% DM. At this DM, the fruit took 6 days to ripen at shelf life without shrivelling, following cold storage of 21 days at 5.5 °C (Table 2). This DM was slightly lower than 29.4% reported by Mwelase *et al.* (2021) on the same farm. However, their harvesting intervals were inconsistent and much wider compared to the two-week interval used in the current study. Interestingly, New Zealand evaluation trials identified 27% as the minimum harvest DM for 'Lamb Hass' avocados (Dixon *et al.* (2008). These differences could also be linked to different weather patterns as influenced by seasonal variations.



**Figure 3:** The dry matter content (DM) % of 'Lamb Hass' avocado mesocarp harvested at different days after full bloom (DAFB) for maturity indexing. Data presented as mean  $\pm$  standard error; n = 10.

**Table 2:** Days to ripen of 'Lamb Hass' avocado after 21 days of cold storage at 5.5 °C and 7 days shelf life

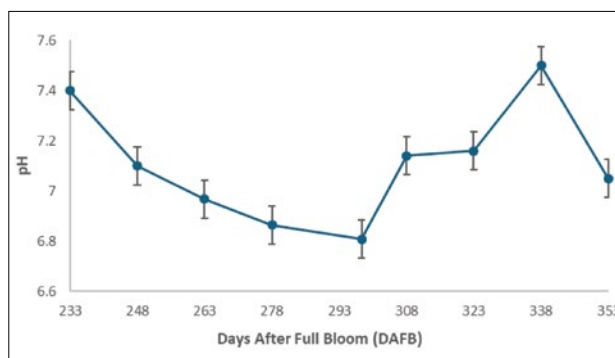
Harvest	Date	Days to ripen
H1	25 July 2024	Did not ripen
H2	15 August 2024	Did not ripen
H3	28 August 2024	Did not ripen
H4	12 September 2024	Did not ripen
H5	26 September 2024	Did not ripen
H6	10 October 2024	Did not ripen
H7	23 October 2024	6
H8	07 November 2024	4
H9	21 November 2024	4



**Figure 4:** The total soluble solids (Brix) of 'Lamb Hass' avocado mesocarp harvested at different days after full bloom (DAFB) for maturity indexing. Data presented as mean ± standard error; n = 10.

TSS is one of the commonly used maturity indices in the horticultural industry. In this study, TSS decreased as maturity advanced (Fig. 4). Although TSS suddenly increased after 338 DAFB, it generally decreased with advancement in fruit maturity. The fruit was deemed ready for harvest at 3.18 Brix°. An inverse relationship between TSS and oil content in 'Hass' has been reported (Liu *et al.*, 1999). These researchers showed that as the fruit ripens, TSS sharply declines. This was noted for the peel, flesh, as well as the seed. Similarly, Ahmed *et al.* (2010) showed that TSS steadily decreases as 'Fuerte' fruit ripens. Although this research study is still in the early stages, the results seem to agree with some of the previous studies.

The pH-based maturity indices have previously been developed for some horticultural crops such as pomegranates and mango fruit. However, research is still very limited in avocado fruit with regards to pH as a maturity indexing parameter. Initially, pH decreased



**Figure 5:** The pH of 'Lamb Hass' avocado mesocarp harvested at different days after full bloom (DAFB) for maturity indexing. Data presented as mean ± standard error; n = 10.

as fruit advanced in maturity. However, after 293 DAFB, there were significant fluctuations in pH values (Fig. 5). Our results are similar to those of Özdemir *et al.* (2009) who did not find any reliable or consistent trends in pH between different maturity stages of 'Bacon', 'Fuerte', and 'Zutano' avocado cultivars. For the next season's data collection, pH will be eliminated as a possible maturity indexing parameter.

The DM values measured by the three methods notably varied (Table 3). Throughout the sampling time, the microwave method had a lower DM content. On the other hand, the DM content from the oven drier and moisture analyser method did not significantly differ. Notably, the standard error under the oven drier was quite high for 'Lamb Hass' avocados. This cast doubt on the accuracy and reliability of this method. For 'Hass' avocados, the moisture analyser recorded a higher DM, but the standard error was quite high. The oven drier method is the commonly used method by the South African industry. This could increase the risk of uneven ripening of South African avocados after reaching the overseas market. Based on our results, more tests should be undertaken at different harvest maturities to validate the accuracy and reliability of these methods.

### Conclusions

Our research findings have shown DM as a reliable maturity indexing tool for 'Lamb Hass' avocados. The findings also showed the potential of TSS as a maturity index of avocado fruit. The pH greatly fluctuated; it can therefore not be used as a maturity index. Although the moisture analyser is a quick method for measuring DM, more tests are required to validate its accuracy. Although the project faced numerous hurdles during the season, we made notable progress in

**Table 3:** Assessing the reliability of different protocols for determining the dry matter content of avocado fruit. Data presented as mean ± standard error; n = 10

Cultivar	Harvest	Dry matter assessment method		
		Moisture analyser	Microwave	Oven drier
Hass	H1	29.72 ± 2.77	27.25 ± 0.05	28.56 ± 0.89
Lamb Hass	H1	29.71 ± 0.70	28.68 ± 0.49	29.16 ± 1.39
	H2	30.31 ± 0.68	28.96 ± 0.51	29.98 ± 1.21

addressing the key objectives of the study and are hopeful to report on all objectives at the end of the second season.

## REFERENCES

- AHMED, D.M., YOUSEF, A.R. & HASSAN, H.S.A. 2010. Relationship between electrical conductivity, softening and color of Fuerte avocado fruits during ripening. *Agriculture and Biology Journal of North America*, 1(5): 878-885.
- CARVALHO, C., VELÁSQUEZ, M. & VAN ROOYEN, Z. 2014. Determination of the minimum dry matter index for the optimum harvest of 'Hass' avocado fruits in Colombia. *Agronomia Colombiana*, 32: 399-406. <https://doi.org/10.15446/agron.colomb.v32n3.46031>
- CLARK, C., WHITE, A., JORDAN, R. & WOOLF, A. 2007. Challenges associated with segregation of avocados of differing maturity using density sorting at harvest. *Postharvest Biology and Technology*, 46: 119-127.
- ERNST, Z. & ERNST, A. 2015. The strategic role of new cultivars: a case study of 'Maluma'.
- FERRER, A., REMÓN, S., NEGUERUELA, A.I. & ORIA, R. 2005. Changes during the ripening of the very late season Spanish peach cultivar Calanda: feasibility of using CIELAB coordinates as maturity indices. *Scientia Horticulturae*, 105: 435-446.
- HOFMAN, P., BOWER, J. & WOOLF, A. 2013. Harvesting, packing, postharvest technology, transport and processing. *The avocado: botany, production and uses*, 489-540.
- KHODABAKHSHIAN, R., EMADI, B., KHOJASTEHPOUR, M., GOLZARIAN, M.R. & SAZGARNIA, A. 2017. Non-destructive evaluation of maturity and quality parameters of pomegranate fruit by visible/near infrared spectroscopy. *International Journal of Food Properties*, 20(1): 41-52.
- LEE, S.-K. 1981. A review and background of the avocado maturity standard. *California Avocado Society Yearbook*, 65: 101-109.
- LIU, X., ROBINSON, P.W., MADORE, M.A., WITNEY, G.W. & ARPAIA, M.L. 1999. 'Hass' avocado carbohydrate fluctuations. II. Fruit growth and ripening. *Journal of the American Society for Horticultural Science*, 124(6): 676-681.
- MAGWAZA, L.S. & TESFAY, S.Z. 2015. A review of destructive and non-destructive methods for determining Avocado fruit maturity. *Food and Bioprocess Technology*, 8: 1995-2011.
- RUNGPICHAYAPICHET, P., NAGLE, M., YUWANBUN, P., KHUWIJITJARU, P., MAHAYOTHEE, B. & MÜLLER, J. 2017. Prediction mapping of physicochemical properties in mango by hyperspectral imaging. *Biosystems Engineering*, 159: 109-120.
- SALAMEH, M., NACOUZI, D., LAHOUD, G., RIACHY, I. & EL KAYAL, W. 2022. Evaluation of Postharvest Maturity Indices of Commercial Avocado Varieties Grown at Various Elevations Along Lebanon's Coast. *Frontiers in Plant Science*, 13: 895964.
- SHEZI, S., MAGWAZA, L.S. & NCAMA, K. 2023. Importance of maturity indexing in postharvest management of selected subtropical and temperate fruits. In *Postharvest Management of Fresh Produce* (pp. 59-79). Academic Press.