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Short communication

Non-destructive measurement of fruit firmness to predict the shelf-life of ‘Hayward’ kiwifruit

Tali Goldberg[a,b,*], Har’el Agra[b], Ruth Ben-Arie[b]

[a] Department of Food Sciences, Faculty of Sciences and Technology, Tel-Hai Academic College, Upper Galilee, 1221000, Israel
[b] Fruit Storage Research Laboratory MIGAL, Galilee Technology Center, P.O.B 831, Kiryat Shmona, 1101600, Israel

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ABSTRACT

Kiwifruit are commercially harvested when mature but firm. The length of the softening process in shelf life (SL) till the fruit becomes edible depends upon several pre-harvest and postharvest factors, such as harvest maturity, environmental conditions (temperature, relative humidity, composition of the atmosphere) and duration of cold storage. The ability to predict the time till softening would be of considerable commercial value, but to date there is no reliable method to do so. We assessed the suitability of the non-destructive measurement of fruit firmness with the Sinclair IQ Firmness Tester (SIQ) to predict the time required for adequate fruit softening for consumption. ‘Hayward’ kiwifruit were harvested at commercial maturity and stored in either regular air (RA) or controlled atmosphere (CA), with or without pre-storage 1-MCP treatment. Fruit softening was monitored during shelf-life at 20 °C by finger pressure, SIQ and with a FTA penetrometer. Highly significant correlations were obtained between SIQ and both firmness assessments. The linear decline in firmness measured by the non-destructive SIQ enables us to construct models that can predict the time till softening, based on the SIQ value at removal from storage under different conditions.

1. Introduction

Loss of fruit firmness is the most prominent characteristic of post-harvest ripening of kiwifruit, which is harvested when mature but still inedible. The commonly used index for harvesting mature fruit is the level of soluble solids (SSC). The progress of fruit ripening is conventionally assessed destructively, using a penetrometer. As the harvested fruit softens the SSC increases and the fruit becomes edible at a firmness below 20 N with above 12.5% SSC (Crisosto and Crisosto, 2001). The length of the softening process depends upon several pre-harvest and postharvest factors (Ritenour et al., 1999; White et al., 2005). The softening pattern as measured after harvest at ambient temperature with a penetrometer, is tri-phasic with a period of rapid softening being preceded and followed by slower rates of declining firmness (MacRae and Redgwell, 1992; White et al., 2005). Softening during storage tends to follow a similar pattern, albeit at slower rates (Hopkirk et al., 1996; Burdon et al., 2013). However, the softening pattern of 'Hayward' kiwifruit treated with propylene to accelerate ripening was biphasic, when measured with a penetrometer (Asiche et al., 2018). Various models have been suggested to describe the rate of kiwifruit softening and thereby to predict the storage potential of the fruit (Benge et al., 2000; Schotsmans et al., 2008; Jabbar et al., 2014; Hertog et al., 2016), but they are complex and much effort is required to obtain sufficient data. Comparison of various non-destructive methods (acoustic, compression, NIR and impact) for measuring fruit softening indicates that each method is probably assessing a different textural attribute, as the correlations with the destructive method although significant, are not always high. Hence the softening patterns may also differ (Hopkirk et al., 1996; De Ketelaere et al., 2006; Feng et al., 2014; Hertog et al., 2016). Li et al (2016) have recently shown that the decline in ‘Hayward’ firmness during storage as measured by the impact method with two different devices is more or less linear.

Fruit firmness and the rate of kiwifruit softening vary greatly, both between and within batches (Jabbar et al., 2014), especially during shelf-life. Since the conventional methods for assessing the progress of fruit ripening, with penetrometer and refractometer, are destructive, they require a large number of fruit. Although Hertog et al. (2016) employed a non-destructive method for firmness assessment at harvest, their mechanistic model required the estimation of the physiological state of the fruit as obtained by destructive measurement of additional parameters. Should the loss of hardness during shelf-life be linear, the predictability of the time till consumption would be high. The objective of this study was to assess the suitability of the non-destructive measurement of fruit firmness by response to impact with the Sinclair IQ

* Corresponding author
E-mail addresses: talig@migal.org.il (T. Goldberg), harelagra@gmail.com (H. Agra), ruth.benarie@gmail.com (R. Ben-Arie).

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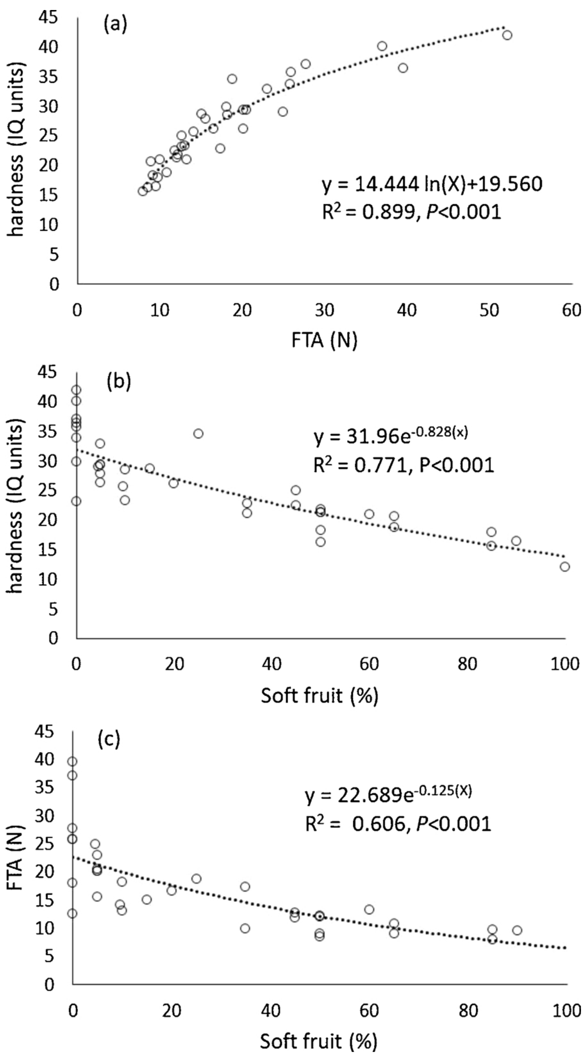

Fig. 1. Regression curves between (a) pericarp firmness measured with fruit texture analyzer (FTA) and non-destructive hardness measure by impact (SIQ) (logarithmic curve), (b) soft fruit (evaluated by figure pressure) and SIQ (exponential curve) and (c) soft fruit and FTA (exponential curve). Each data point represents a 20-fruit sample.

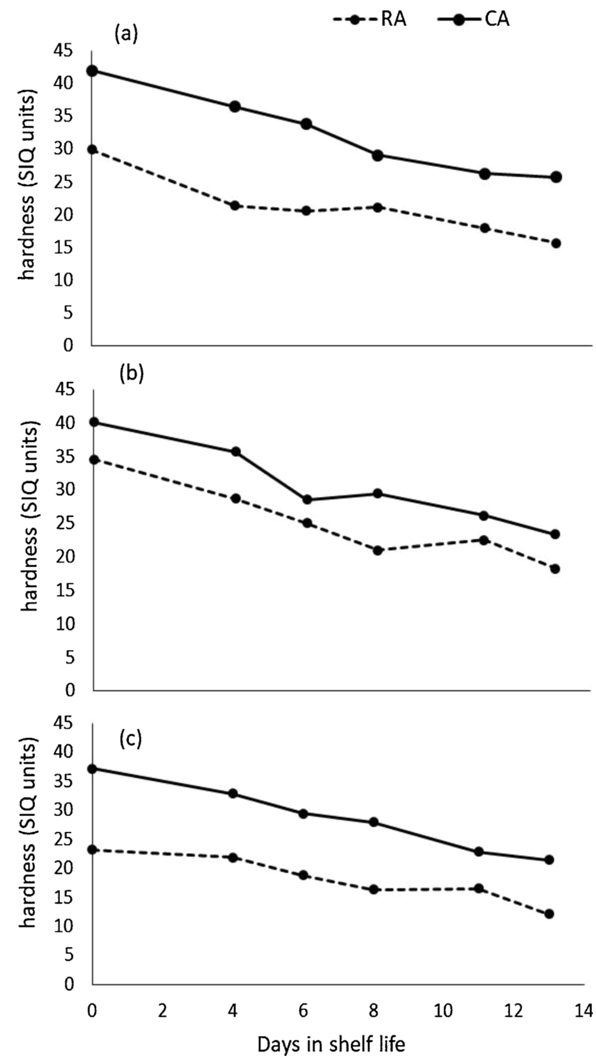

Fig. 2. Softening of kiwifruit in shelf life described by non-destructive hardness measure by impact (SIQ) after storage for (a) four months, (b) five months (treated with 1-MCP) and (c) six months (treated with 1-MCP), in regular atmosphere (RA, dashed lines) and controlled atmosphere (CA, complete lines). Each data point represents a 20 fruit sample.

Firmness Tester at removal from storage, for predicting the length of the shelf-life period of 'Hayward' kiwifruit following storage under different conditions.

2. Material and methods

2.1. Experiment procedure

'Hayward' mature kiwifruit were harvested from an orchard in the Upper Galilee, Israel, during the 2014 season. On the day of harvest fruit maturity was assessed on four replicates of 10 fruit by the following parameters: (1) non-destructive hardness, expressed as the response of the kiwifruit to impact of the Sinclair instrument, IQ units (Sinclair Systems International- Fresno, CA, U.S.A) (hereafter SIQ); (2) Fruit pericarp firmness, determined destructively on two opposite peeled sides at the equator of each fruit, using a penetrometer (Fruit Texture Analyzer [FTA] GUSS Ltd, Western Cape, South Africa), fitted with an 8 mm plunger; (3) total soluble solids (SSC) (NR-101, J.P. Selecta, Spain); (4) pH and titratable acid content (Titrino 719S, Metrohm, Switzerland). SCC, acid content and pH were measured on the composite juice extracted from ten fruit per replicate. Additional fruit for storage were dipped for 20 s in 0.1% Scholar (active ingredient Fludioxonil, Syngenta Inc.) and cured for 48 h at ambient temperature to simulate commercial practice, aimed at ensuring a minimum loss of fruit due to decay development. The fruit were stored for four, five or six months at -0.5 °C in regular air (RA) or in controlled atmosphere (CA) with 2% O_2 + 3% or 5% CO_2, 120 fruit for each storage-period in each atmosphere. The fruit destined for five and six months' storage, were exposed before storage to 0.6 µl L^{-1}1-MCP, (AgroFresh Inc., SmartFresh Quality System), in a sealed chamber for 24 h at 0 °C. After removal from cold storage, fruit pericarp firmness and SIQ measurements were conducted at 20 °C, on fruit equilibrated overnight at this temperature. Shelf life (20 °C, 65% RH) measurements were conducted after four, six, eight, 11 and 13 days on 20 fruit for each storage-period × atmosphere. In addition, fruit firmness was monitored by finger pressure (Ben-Arie and Sonego, 1985; Padda et al., 2011). 'Soft fruit' (%) was defined as the percentage of fruit that responded to finger pressure in each 20-fruit replicate.

2.2. Statistical analysis

Using the results of each day × atmosphere × storage-period (N = 36) we performed regression curve estimations (SPSS) to evaluate and quantify the connections between SIQ, fruit pericarp firmness and