

Post-Harvest Warehouse Management of *Actinidia arguta* Fruits

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In the baby kiwifruit food chain, the extent of losses caused by high perishability of the edible skin is a barrier for these fruit's position in the fresh market. Thus, maintaining the overall quality in the warehouse is fundamental for the market channel. The wrapping technique with a stretch film represents a fine opportunity for maintaining fruit quality. Hortgem Rua® and Hortgem Tahi® cultivars of kiwifruits were evaluated during storage at $1 \pm 1^\circ\text{C}$ for up to 60 days. The stretch wrap film used to protect the fruit has shown to limit the weight loss maintained by the pulp of both cultivars that were firmer (2.39 N and 2.13 N) and had lower gumminess values (280.92 and 213.57 for Hortgem Rua® and Hortgem Tahi®, respectively). Considering sensorial attributes, the wrapped samples also maintained overall quality, especially in terms of fruit colour (luminosity), consistency and taste.

INTRODUCTION

It is well-recognized that storage practices can widely influence the quality of fruits in the post-harvest chain [Wang *et al.*, 2015]. The research plays an important role, especially for new fruit cultivars, including *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq. Among fresh and perishable fruits, the baby kiwifruits are consumed without peeling, similarly to berries. Due to the rapid transformation to softening, skin wrinkling, water loss and fruit decay [Latocha *et al.*, 2014], baby kiwifruits require efficient storage tools in the supply chain management [Giuggioli *et al.*, 2017; White *et al.*, 2005]. When compared to other Actinidiaceae (*A. deliciosa*, and *A. chinensis*), the baby kiwifruit can be stored for a shorter period of time, namely for 1–2 months at 0°C [Baudino *et al.*, 2017; Lim *et al.*, 2016; Strik & Hummer, 2006]. Previous studies have attempted to identify the best method for increasing the shelf-life, by utilizing 1-methylcyclopropene (1-MCP) [Wang *et al.*, 2015], edible coating [Fisk *et al.*, 2008; Kaya *et al.*, 2016] or by identifying the optimal harvest date for improving storability [Oh *et al.*, 2017]. According to the current social and economic scenarios, the driver of the innovation and the key point to improve the performance of all preserving techniques is the sustainability requirement to satisfy the competitiveness asset of the supply chain. In addition, it is reported that some storage methods involving the management of the atmosphere in the storage room (controlled atmosphere) are more expensive when compared to other tools [Wang *et al.*, 2015]. The warehouse storage represents a critical point in the fresh fruit supply chain

[Peano *et al.*, 2017], but the use of packaging and pallet bags strategies has been reported just as useful to maintain the safety and quality of different species, such as blueberry, strawberry, raspberry, and plums [Peano *et al.*, 2015, 2017; DeEll, 2002].

With the pallet bag, it is possible to store large quantities of products and facilitate their transfer from the warehouse to a truck or a container for shipment [Bouchery *et al.*, 2017]. Additionally, using pallet bags to store different kinds of fruits in the same cold-room helps to avoid possible cross-contaminations with other products. While the pallet bag approach has its benefits to the storage of kiwifruit, the stretch wrap film in the warehouse is easier to manage. The pallet bag system, for example, requires the use of a plastic bag, a vacuum system, and a CO_2 injection if the products need a modified atmosphere storage, hence the use of a stretch wrap film could be promising and more economical in terms of cost and time.

Considering the importance of packaging storage techniques and the limited studies about the effect of this practice in the post-harvest storage warehouse of *Actinidia arguta*, the goal of the present research was to evaluate the effects of the wrapping technique with a stretch film. This was based on an easy and economic tool used to preserve the quality traits, phenolics content, and textural parameters of two different baby kiwifruit cultivars (Hortgem Rua® and Hortgem Tahi®) stored for up to 60 days.

MATERIALS AND METHODS

Fruit source, experimental design and sampling procedure

The baby kiwifruits orchard is located in Revello (Cuneo, Piedmont, Italy). The fruits of *Actinidia arguta* (Siebold

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et Zucc.) were from two different cultivars: Hortgem Rua® and Hortgem Tahī® marketed with the NERGI® brand [Baudino *et al.*, 2017]. They are newly patented cultivars originating from New Zealand [McNeilage *et al.*, 2003, 2004]. All fruits from each cultivar were collected at the harvesting maturity stage and stored inside a plastic fruit box (270 x 370 x 165 cm) (CPR System, Bologna, Italy). The fruits were transported to the Agrifrutta Cooperative warehouse (Peveagno, Cuneo, Piedmont, Italy) for storage at 1°C which rapidly decreased the core temperature of the fruits. Selected fruits of medium weights: 10.1–15.0 g for Hortgem Tahī® and 13.1–15.0 g for Hortgem Rua®, were packed inside a plastic punnet with lids made from R-PET material (INFIA s.r.l., Cesena, Italy). Punnet dimensions were 17.2 x 13.2 x 4.0 cm and contained 0.125 kg of fruit; lid dimensions were 17.8 x 13.6 cm. The experimental storage unit was a mini pallet loaded with 20 stacked crates wrapped with a polyethylene stretch film (Retarder s.r.l., Cuneo, Italy). The stretch wrap film was used to create a barrier protection against the cool air forced into the room. It was not hermetically sealed and, for this reason, changes in the atmosphere were not expected. Control samples were maintained in a normal atmosphere in a controlled cold room (1±1°C; 95% humidity). Three replicates were considered for each control. All fruits were stored for up to 60 days. Quality control was performed at the day of package processing (day 0) and after 20, 40, and 60 days of storage. At each time-point, 20 punnets (control and stretch) were randomly selected and the following parameters were determined: weight loss, quality indicators (total soluble solids, total acidity, and dry matter), total color difference, textural indicators (firmness and gumminess), and total phenolics content. A sensory analysis was also performed to better judge the fruits.

Weight loss, quality parameters, and total colour difference

Weight loss (%) was determined using an electronic balance (model SE622, VWR Science Education, Radnor, Pennsylvania, USA), with a 0.01 g accuracy. The weight was monitored throughout the storage time and it was calculated as the difference between the initial and final punnet weights. Content of total soluble solids (TSS) was determined with a digital refractometer Atago® Pal-1 (Atago Co. Ltd., Tokyo, Japan) and expressed as °Brix. For each quality control, the instrument was calibrated with distilled water. The total acidity (TA) was measured using an automatic titrator (Titritino 702, Methrom, Herisav, Switzerland) and determined potentiometrically using 0.1N NaOH to the end point of 8.1 in 5 mL of juice diluted in 25 mL of distilled water. The raw juice obtained by squeezing fruits in a mixer (Moulinex-Ju2000) was centrifuged at 1000 rpm for 5 min using a Rotofix 32-A Centrifuge (VWR, Milan, Italy). The supernatants were used for analyses. Results were expressed as g of citric acid equivalents per 100 mL of juice (g CA/100 mL) [Allegra *et al.*, 2017; Briano *et al.*, 2015].

Dry matter (DM) content of baby kiwifruits was measured in 10 whole fruits. The fruits were placed in an oven at 70±2°C for 24 h. Their initial and final weights were measured using an electronic balance and the value was expressed as g/100 g, according to McGlone *et al.* [2003].

Color parameters were quantified in the L^* , a^* , b^* color space. L^* refers to the lightness and ranged from $L^* = 0$ (black) to $L^* = 100$ (white). Negative and positive values of a^* indicate green and red colour, respectively, while positive and negative b^* indicate yellow and blue color, respectively [McGuire, 1992]. Color was assessed for 20 fruits in the middle part of the fruit using a tristimulus colour analyser (model CR-400, Konica Minolta, Langenhagen, Germany).

Change in fruit colour during the storage period was reported by the total colour difference (ΔE^*) index (equation 1), based on the evaluation of colour changes from the beginning of day 0 (L_0 , a_0 , b_0) [Alexandre *et al.*, 2012]:

$$\Delta E^* = (\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2})^{1/2} \quad (\text{Equation 1})$$

Textural parameters

A texture profile analysis (TPA) performed with a Texture Analyser TA.XT.PLUS (Stable Micro Systems, WINOPAL Forschungsbedarf GmbH, Steinheim, Austria) (30 Kilo Load Cell) was used to evaluate the firmness (N) and the gumminess (g^*s) parameters. A compression test was performed with a 30-mm aluminium flat tipped probe (P/3) to a 10% strain, with a pre-test speed of 1 mm/s, test speed 1 mm/s, post-test speed 5 mm/s, and 5 g trigger force. In the case of gumminess, a 75 mm aluminium compression plate (P/75) was used and the following parameters were applied: strain (25%), pre-test speed (1 mm/s), test-speed (5 mm/s), and trigger force (5 g).

Total phenolics content

Total phenolics content (TPC) of extracts of kiwifruits was determined. Fruits (10 g) were added to 25 mL of an extraction mixture which contained 500 mL of methanol, 23.8 mL of de-ionized water, and 1.4 mL of 37% hydrochloric acid. The mixture was kept in dark at room temperature for 1 h and afterwards thoroughly homogenized for 2 min with an ULTRA TURRAX (IKA, Staufen, Germany) and centrifuged for 15 min at 3000 rpm. The supernatant was transferred into glass test-tubes and stored at -20°C until analyzed. The total phenolics content of samples was measured using the Folin & Ciocalteu phenol reagent (Merck KGaA, Darmstadt, Germany). The absorbance of the blue color developed was measured at 765 nm following the method of Slinkard & Singleton [1977]. The results were expressed as mg of gallic acid equivalents per 100 g of fresh fruits (mgGAE/100 g).

Sensory analysis

The quality of baby kiwifruit was evaluated by means of sensory analysis, involving 10 panellists previously trained using commercial samples. Panellists received 10 whole fruits for each sample and provided descriptions of their taste, appearance, overall acceptability, luminosity (one of the colour parameters), and consistency.

Evaluations took place in individual testing booths at room temperature. All the attributes were evaluated by using a 5-point scale (5 = excellent, 4 = good, 3 = fair, 2 = poor, and 1 = unusable) which was adopted from Meilgaard *et al.* [2006].

Statistical analysis

All statistical analyses were performed using SPSS Statistics 24 software package (2017, IBM, Milan, Italy) for Mac. All data sets (cultivar Hortgem Rua® and Hortgem Tahī®) for the quality analysis were subjected to the analysis of variance (ANOVA) with Tukey's post hoc test. A statistically significant difference was indicated by $P \leq 0.05$. A principal component analysis (PCA) with Varimax rotation with Kaiser normalization was entered to underline the relationships between the different qualitative parameters measured and results of the sensory analysis. The PCA was performed using standardized data due to the reduction of the dimensionality in the multivariate data. Two PCAs were obtained for each cultivar, *i.e.* Hortgem Rua® and Hortgem Tahī®.

RESULTS AND DISCUSSION

Weight loss

The baby kiwifruit weight loss is reported in Figure 1. The loss in weight was progressively increasing with the post-harvest time and statistically significant differences were observed for each sample during the storage time. Samples of both cultivars stored in the mini pallet wrapped with the stretch film had limited weight loss of the product when compared to the control samples. The control samples of both cultivars showed a similar trend of losing the maximum weight at the end of the storage time (9.03% and 9.64% for Hortgem Rua® and Hortgem Tahī®, respectively). The best performance of the stretch wrap film to control fruits management was observed for the Hortgem Tahī®. In fact, at the end of the 60-day storage period, the weight loss was only 3.57%, while at the same time point, the weight loss noted in fruits of cv. Hortgem Rua® reached 6.40%. Considering the limit of the commerciality at 6% weight loss [Briano *et al.*, 2017; Almenar *et al.*, 2007], the use of wrapped mini pallet had a positive effect upon fruit management and on reducing peel wrinkling already after 20 days and up to 60 days of storage in the warehouse.

Quality parameters

Changes in fruit quality parameters during storage were evaluated by measuring total acidity (TA) and determining contents of total soluble solids (TSS) and dry matter (DM) (Table 1). For the collected samples wrapped with stretch film, it was possible to observe an increase in the TSS concentration during the storage time due to the weight loss of fruits. The highest TSS values were observed for all fruits at the end of the 60-day storage period. Effects resulting from storage time and different management in the warehouse on TA were similar for both tested cultivars. Statistically significant differences ($P < 0.05$) were observed during the storage time and a decrease of values was observed for all samples. For both cultivars, the lowest fruit acidity was reported at the end of the storage time for the samples maintained in the stretch wrap film.

The storability of the kiwifruits is well-recognized to be correlated with the DM content [Harker *et al.*, 2009; Jordan *et al.*, 2000]. Statistically significant differences ($P < 0.05$) were observed during the storage time for fruits of both cultivars and for each sample. A general decrease in DM content was observed for all samples and the lowest DM content was achieved at the end of the storage time for all baby kiwifruits. Similar values were observed among wrapped fruits and control ones at each control time, suggesting the limited influence of the stretch film on maintaining high levels of DM content during storage.

Total color difference

The external aspect and colour are important attributes for the edibility of these fruits that are eaten with the peel. The total colour difference (ΔE^*) index, which is a combination of *L*, *a* and *b* values, was used to evaluate the discoloration of fruits (Figure 2). The ΔE^* value increased statistically in the storage time, meaning a progressive ripening of the fruits for all the samples, but this trend was limited for all fruits wrapped with the stretch wrap film. At the end of storage time, the minimum ΔE^* value was achieved for the wrapped samples of the cv. Hortgem Rua® (11.80). Due to the best maintenance of weight loss (water content), these fruits actually maintained the highest luminosity (data not shown). Wrapped samples

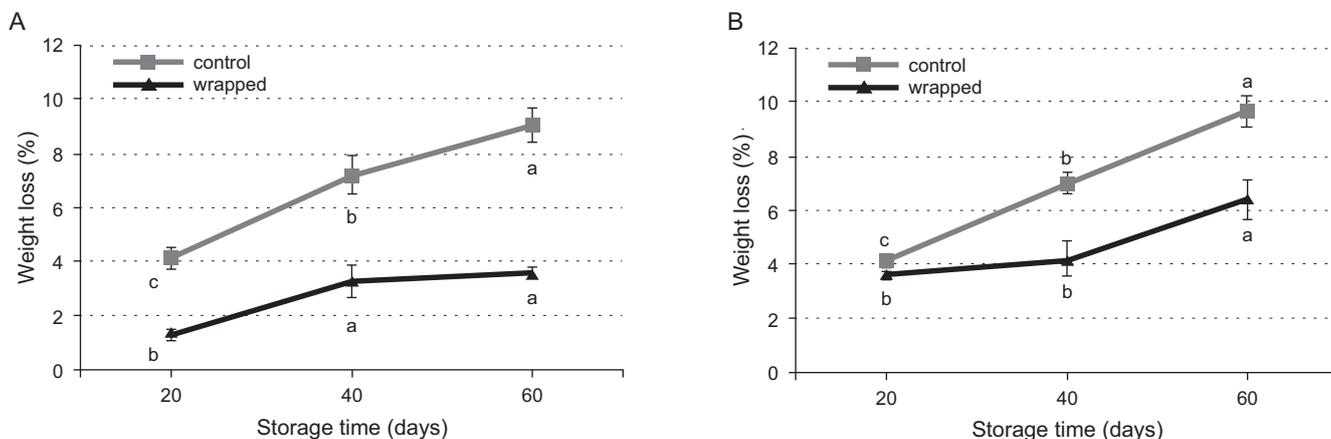


FIGURE 1. Weight loss of baby kiwifruits of Hortgem Rua® (A) and Hortgem Tahī® (B) cultivars during storage.

All data are expressed as average value and the standard error as bars. Different letters on the line indicate significant differences among every harvesting time ($P < 0.05$).

TABLE 1. Total soluble solids (TSS), total acidity (TA), and dry matter (DM) of the kiwifruits of Hortgem Rua® and Hortgem Tahī® cultivars during storage.

Quality parameters	Cultivar	Samples	Storage time (days)			
			0	20	40	60
TSS (°Brix)	Rua®	Control	9.90±0.10 ^c	13.68±0.12 ^b	14.57±0.13 ^a	14.23±0.12 ^a
		Wrapped	9.90±0.10 ^c	13.90±0.21 ^b	13.73±0.13 ^b	14.96±0.12 ^a
	Thai®	Control	11.00±0.22 ^c	14.20±0.23 ^b	14.57±0.10 ^b	15.07±0.14 ^a
		Wrapped	11.00±0.22 ^c	14.87±0.14 ^a	13.73±0.31 ^{ab}	14.80±0.11 ^a
TA (g CA/100mL)	Rua®	Control	0.90±0.00 ^a	0.72±0.12 ^b	0.42±0.41 ^c	0.61±0.31 ^c
		Wrapped	0.90±0.00 ^a	0.64±0.22 ^b	0.58±0.01 ^c	0.59±0.11 ^c
	Thai®	Control	1.20±0.50 ^a	0.89±0.06 ^b	0.73±0.02 ^c	0.77±0.01 ^c
		Wrapped	1.20±0.50 ^a	0.92±0.52 ^b	0.92±0.55 ^b	0.59±0.12 ^c
DM (g/100g)	Rua®	Control	18.43±1.30 ^a	17.97±0.91 ^a	15.86±0.21 ^b	15.74±0.11 ^b
		Wrapped	18.43±1.30 ^a	17.75±0.81 ^a	15.58±0.01 ^b	15.67±0.01 ^b
	Thai®	Control	19.39±1.10 ^a	19.88±0.02 ^a	18.25±0.11 ^b	16.53±0.36 ^c
		Wrapped	19.39±1.10 ^a	18.11±0.20 ^b	17.15±0.62 ^{bc}	15.68±0.29 ^d

All data are expressed as average values and the standard deviation determined for different fruits. Different letters within the same line indicate significant differences among every harvesting time (Tukey test; $p < 0.05$).

of the cv. Hortgem Tahī® have shown a higher loss in luminosity (ΔE^* value of 15.10) probably due to the higher development of anthocyanin during the ripening process, as suggested by previous studies [Montefiori *et al.*, 2009].

Textural parameters

Although knowledge about the importance of the softening models of baby kiwifruits has increased in recent years [Giuggioli *et al.*, 2017], the evolution of texture parameters under packaging conditions, such as the wrapping of mini pallet, has not been reported. Changes in firmness and gumminess values are reported in Table 2. As expected, a decrease in texture parameters of kiwifruits was observed in all samples of Hortgem Rua® and Hortgem Tahī® due to the dehydration associated with

the storage time [Wang *et al.*, 2015]. The best control of moisture loss was associated to the stretch wrap film that positively influenced the maintenance of fruit firmness. At each control time, the stretch film maintained a higher value of firmness for fruits of Hortgem Rua® than control samples. At the end of storage, 2.39 N of firmness was registered for the wrapped baby kiwifruits against 1.60 N of the unwrapped fruits. The same trend was observed for the cv. Hortgem Tahī® after 60 days of storage, where the average value of 2.13 N was observed against 1.79 N. The evolution of the dimensional gumminess (hardness x cohesiveness) parameters was similar to the firmness behaviour of unwrapped samples of both cultivars (control) showing the lowest gumminess values, suggesting a strong correlation with the moisture content. After 60 days of storage, gumminess

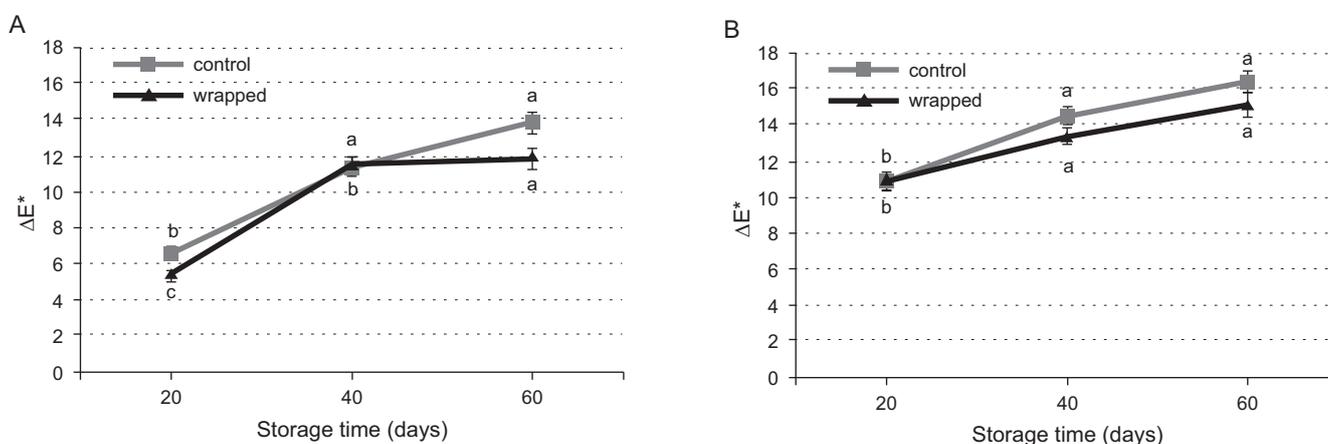


FIGURE 2. Evolution of the total colour difference (ΔE^*) of baby kiwifruits of Hortgem Rua® (A) and Hortgem Tahī® (B) cultivars during storage. All data are expressed as average value and the standard error as bars. Different letters on the line indicate significant differences among every harvesting time ($P < 0.05$).

TABLE 2. Textural parameters and total phenolic content (TPC) of the kiwifruits of Hortgem Rua® and Hortgem Tahī® cultivars during storage.

Quality parameters	Cultivar	Samples	Storage time (days)			
			0	20	40	60
Firmness (N)	Rua®	Control	6.21±0.50 ^a	3.56±0.21 ^b	1.21±0.48 ^c	1.60±0.19 ^c
		Wrapped	6.21±0.50 ^a	3.84±0.13 ^b	1.90±0.36 ^c	2.39±0.19 ^c
	Thai®	Control	7.93±0.30 ^a	2.72±0.25 ^b	2.44±0.26 ^c	1.79±0.30 ^c
		Wrapped	7.93±0.30 ^a	2.91±0.06 ^b	2.10±0.48 ^b	2.13±0.48 ^b
Gumminess	Rua®	Control	1152.90±1.71 ^a	681.95±0.86 ^b	502.10±0.46 ^c	213.57±1.11 ^d
		Wrapped	1152.90±1.71 ^a	656.66±0.52 ^b	531.77±0.96 ^c	280.92±1.21 ^d
	Thai®	Control	936.32±1.43 ^a	800.27±1.01 ^b	416.97±1.85 ^c	211.08±0.91 ^d
		Wrapped	936.32±1.43 ^a	691.58±1.21 ^b	432.83±1.24 ^c	221.58±0.87 ^d
TPC (mgGAE/100 g)	Rua®	Control	189.90±1.32 ^a	190.90±0.91 ^b	167.01±2.50 ^c	154.88±0.92 ^d
		Wrapped	189.90±1.32 ^b	182.24±0.70 ^b	191.52±0.50 ^b	249.57±0.13 ^a
	Thai®	Control	187.51±0.91 ^c	225.13±0.11 ^b	291.81±0.10 ^a	298.79±0.57 ^a
		Wrapped	187.51±0.91 ^b	220.72±0.81 ^b	280.50±0.20 ^a	290.50±0.48 ^a

All data are expressed as average values and the standard deviation determined for different fruits. Different letters within the same line indicate significant differences among every harvesting time (Tukey test; p<0.05).

of fruits of cv. Hortgem Rua® and Hortgem Tahī® wrapped with the stretch film was 280.92 and 213.57, respectively. The decrease in the gumminess for all the control samples depended also on the shrivelling of these fruits.

Total phenolics content

Fruits of *Actinidia arguta* are a rich source of phenolic compounds [Latocha et al., 2014]. Changes in total phenolics con-

tent are reported in Table 2. It is possible to observe the difference among the two cultivars. According with previous studies [Latocha et al., 2014; Krupa et al., 2011], the cv. Hortgem Tahī® showed a higher total phenolics content when compared to Hortgem Rua®. For both cultivars, the total phenolics content was increasing with the time of storage and it was not possible to observe the effect of the stretch wrap film on the regular evolution of these bioactive compounds in the samples.

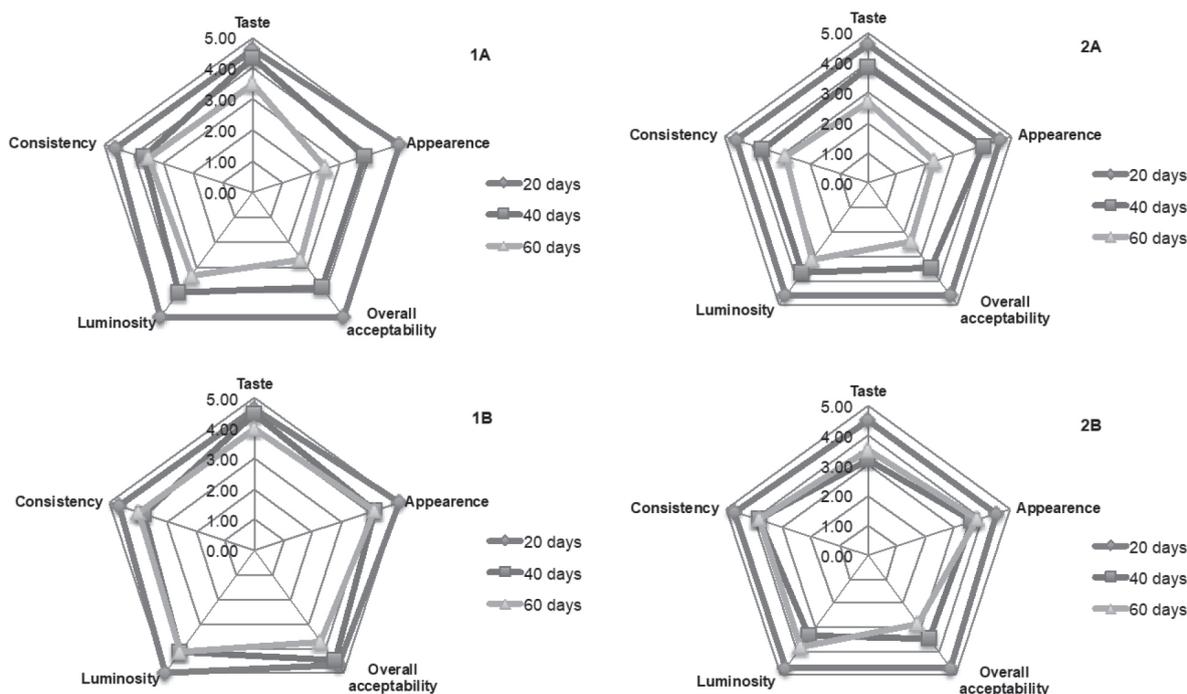


FIGURE 3. Sensory analysis of control and wrapped kiwifruits of Hortgem Rua® (respectively 1A and 2A) and Hortgem Tahī® (1B and 2B) cultivars stored up to 60 days in the warehouse.

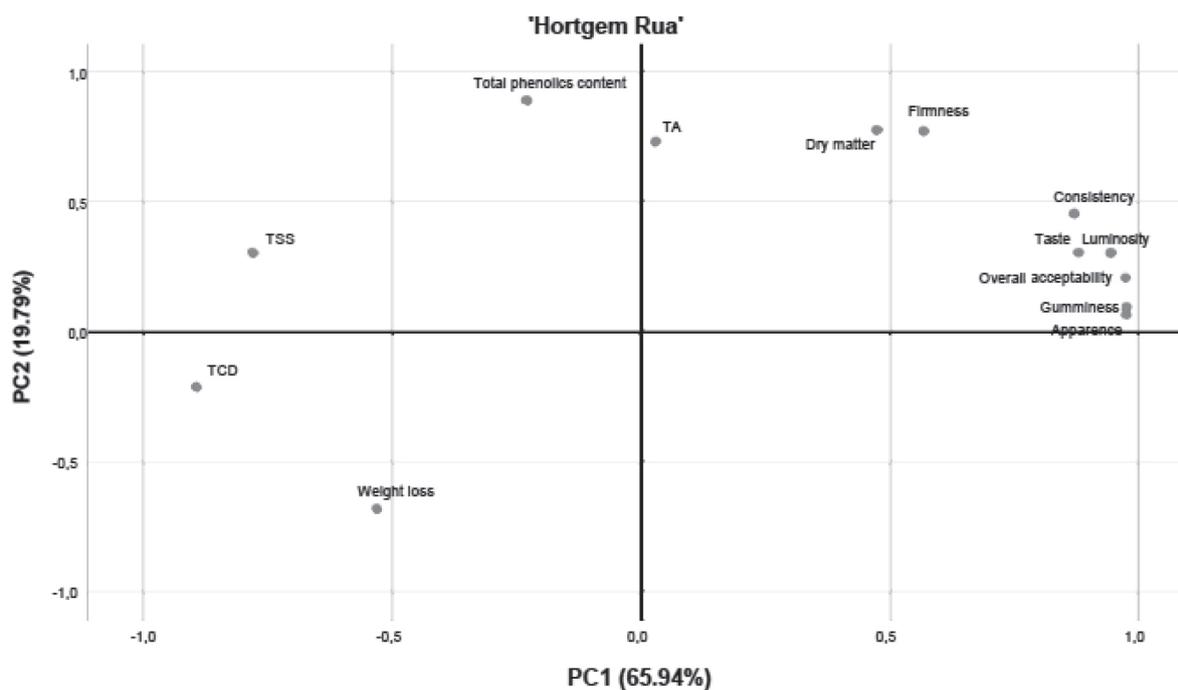


FIGURE 4. PCA of all parameters analyzed for kiwifruits of 'Hortgem Rua'® cultivar.

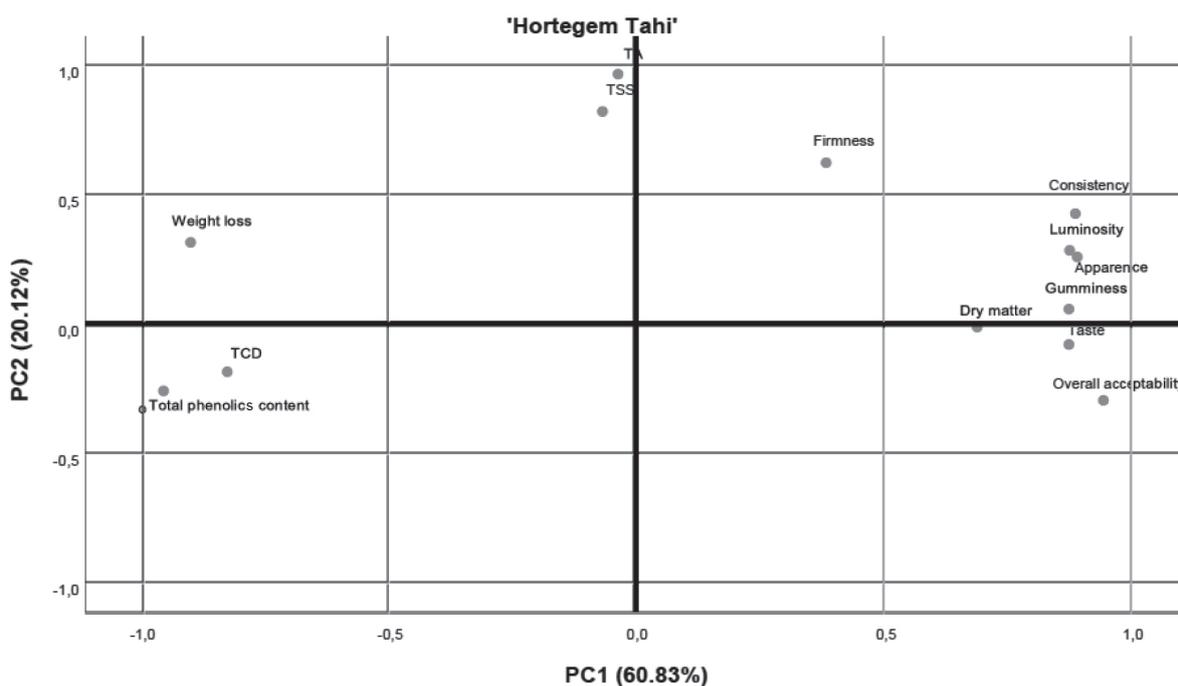


FIGURE 5. PCA of all parameters analyzed for 'Hortgem Tahī'® cultivar.

Sensory evaluation

To support the instrumental measurements of quality, the sensory evaluation was conducted by the panellists in order to judge the overall quality of baby kiwifruits in terms of consumers' point of view. The overall sensory quality scores of samples of Hortgem Rua® and Hortgem Tahī® fruits (Figure 3) decreased successively when the storage time elapsed, achieving the lowest score profile after 60 days. Fruits of both of cultivars wrapped with the stretch film maintained

the best overall quality, especially in terms of fruit luminosity, consistency, and taste. The sensory quality of the control samples of both cultivars diminished (which reduced their marketability) due to the reduction in freshness as a consequence of severe water loss (Figure 1). According to García-Ramos *et al.* [2003], the cultivar Hortgem Tahī® has a strong flavor and is appreciated more for the taste when compared to Hortgem Rua®.

PCA

Principal component analysis (PCA) was carried out on the correlation matrix produced from the quality parameters and the scores of the sensory analysis of baby kiwifruits of both cultivars stored. The PCA plots for the cultivar Hortgem Rua® and Hortgem Tahi® are reported in Figures 4 and 5, respectively. The cumulative variance contribution of all the principal components was 85.73% for the cv. Hortgem Rua® which contributed most to the first (PC1) and the second (PC2) principal component (65.94% and 19.79% respectively). In the case of the cv. Hortgem Tahi®, the cumulative variance contribution of all the principal components was 81.04% (60.83% for the PC1 and 20.21% for the PC2, respectively). For Hortgem Rua®, the PC1 was described by the gumminess, the weight loss, and all the parameters considered in the sensory evaluation. For the Hortgem Tahi®, the dry matter, gumminess, total phenolics content, and all the sensory parameters explained the PC1. As can be seen, it is possible to affirm that the textural parameter and the sensory evaluation attributes of the two cultivars belonged to the PC1. This shows how the external judgement is the driver of the consumer acceptance of the baby kiwifruits according to previous studies on *Actinidia arguta* [Latocha et al., 2011].

CONCLUSION

The short storage life of berry fruits (*Actinidia arguta*) is a critical point for their marketability, but a simple storage tool in the warehouse can be employed to support the economic sustainability of the storage process. The post-harvest management of these fruits can follow the berries supply-chain, thus using a stretch wrap film for the pallet storage could be a promising solution to maintain the quality of fruits for a long time. The baby kiwifruits represent a new product in the commercial channel of distribution and are particularly appreciated for the edibility of the whole fruit. Because of the fruits external sensitivity, the storage management in the warehouse is fundamental. Samples of Hortgem Tahi® and Hortgem Rua® fruits stored for up to 60 days with the stretch wrap film have maintained good quality characteristics when compared to the control samples, especially in terms of weight loss and textural properties. The firmness, gumminess, and sensory attributes have the greatest impact on consumer acceptance of the baby kiwifruits. Improving the chain value of these fruits could be a promising choice for the storage in the mini pallet material from the green chemistry as experimentally made for other species.

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