Hydrocooling of cultivars Chimarrita and Maciel peaches

Pré-resfriamento de pêssegos das cultivares chimarrita e Maciel

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Abstract

Cultivars Chimarrita and Maciel peaches (*Prunus persica*) were hydrocooled in water at 6.7ºC or 5ºC, respectively. Flesh temperature drops were monitored for 3 minutes. After hydrocooling, the peaches were stored at 0.5ºC for 7, 14, 21 or 28 days in cold rooms. For the control treatment the peaches were stored at 0.5ºC immediately after harvest. Fruit quality was evaluated at harvest, after retrieval from cold storage and after up to five more days at 20ºC. Hydrocooled peaches were more dehydrated, but both hydrocooled and control fruit showed some shriveling after 3 days at 20ºC following cold storage. Decay incidence was higher in cv. Chimarrita control peaches, though no significant differences were detected in cv. Maciel peaches. Flesh firmness was higher in cv. Chimarrita hydrocooled peaches during storage, while cv. Maciel peaches did not vary significantly. Extractable juice contents was lower in cv. Chimarrita hydrocooled peaches after 21 days of cold storage. In cv. Maciel peaches no significant differences with regards to extractable juice were determined.

Keywords: chilling injuries, cold storage, precooling, stone fruits, woolliness.

Resumo

Pêssegos (*Prunus persica*) das cultivares Chimarrita e Maciel foram pré-resfriados em água a 6.7ºC ou 5ºC, respectivamente. A redução das temperaturas de polpa foi monitorada por até 3 minutos e após esta operação, os pêssegos foram transferidos para unidades de refrigeração a 0.5ºC por 7, 14, 21 ou 28 dias. Para o tratamento controle os pêssegos, logo após a colheita, foram transferidos para a unidade de armazenagem a 0.5ºC. A qualidade dos frutos foi determinada na retirada da armazenagem e após até cinco dias em temperatura de 20ºC. Os pêssegos pré-resfriados apresentaram maior grau de desidratação, mas em ambos tratamentos, pré-resfriados ou tratamento controle, enrugamento de epiderme foi perceptível quando mantidos por 4 ou mais dias a 20ºC posteriores a armazenagem refrigerada. A incidência de podridões foi maior em pêssegos do tratamento controle da cv. Chimarrita enquanto que em pêssegos da cv. Maciel as diferenças em percentuais de podridões não foram significativas. O conteúdo de suco extraível foi menor em frutos da cv. Chimarrita após 21 dias em armazenamento refrigerado. Em pêssegos da cv. Maciel as diferenças de suco extraível nao foram significativas.

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Palavras-chave: **danos de frio, armazenagem refrigerada, pré-resfriamento, frutas de caroço, lanosidade.**

INTRODUCTION

Peaches (*Prunus persica* L.) need to be cold stored immediately after harvest in order to increase shelf life and to maintain quality characteristics (Crisosto et al., 2004). Peaches are a climacteric fruit species that ripen promptly after harvest demanding practices to preserve value along the postharvest handling chain (Hussain *et al.* 2008). Immediate field heat removal by means of hydrocooling treatments is a procedure recognized as effective to reduce metabolic rates and, in consequence, prolong shelf life (Pervitasari *et al*., 2021).

Hydrocooling is one of the most used cooling methods. Because of high heat-transfer rates may result in cooling times ten times faster in comparison to room cooling and about three times faster when compared to forced air cooling (Teruel *et al.*, 2001). Fast cooling is regarded as the most important process to maintain postharvest quality of produce as it removes quickly the field heat (Carnelossi *et al.*, 2019). An additional advantage of hydrocooling in comparison to other cooling methods is that there is some cleaning of products by removal of chemical residues and debris (Tokarskyy *et al*., 2015).

Apart the use in many fruit species, for peaches there are controversial results on the effects of precooling on fruit metabolism and their final quality. One of the main reasons, which has led to the avoidance of hydrocooling of peaches in commercial operations in Brazil, derives from high incidence of fungi already in the orchard, especially brown rot (*Monilinia fructicola*). Hydrocooling could enhance significantly postharvest decay occurrence. Kluch *et al.* (2003), for example, determined higher decay incidence in hydrocooled cv. Chiripá peaches. On the other hand, Bernat *et al.* (2017) concluded that hydrocooling reduced the recent brown rot infections in peaches, but when infections had established on fruit before 48 hours of the hydrocooling process, then no reduction in percentages of decayed fruit was determined.

Moreover, one more concern is the possibility of chilling injury occurrence. Susceptibility of peaches to chilling injuries is well documented (Lurie and Crisosto, 2005) and, eventually, a pre-cooling treatment could enhance the incidence and the intensity of these injuries. Brackman *et al.* (2009) reported peel damages on cv. Chiripá peaches hydrocooled at 1°C. Neves *et al.* (2013) observed that delaying cold storage by 24 hours was effective in the control of chilling related disorders such as woolliness and leatheriness on white pulp peach cultivars. In cucumbers, DeEll *et al.* (2000) detected some chilling stress when fruits were hydrocooled in water at temperatures below 6°C.

The lower temperatures of any of the available cooling methods to remove field heat of produce is a stress condition and, as such, may result in external or internal damages and, consequently, losses in quality (Elsisi *et al.*, 2020). The efficacy of the cooling procedure depends on the limitations of every product and on temperature ranges and duration of the cooling method (Manganaris *et al.*, 2007)

The present trials were conducted to test the hypothesis that fast hydrocooling could be used to remove field heat of the peach cultivars Chimarrita and Maciel without inducing chilling injuries or negatively affecting storage life when precooling the fruit at little higher temperatures as those already mentioned in the literature.

MATERIAL AND METHODS

Peaches of the cultivars Chimarrita and Maciel were harvested mid-December from a private grove located 80 km west of Porto Alegre, the capital city of the State of Rio Grande do Sul, the southernmost state in Brazil. After harvest, the peaches were selected for freedom from defects, hydrocooled and cold stored.

The peaches, 32 fruit at the time, placed in 10 kg-plastic boxes were hydrocooled during 3 minutes in a 1,000 L-container filled up to one third of its capacity. Chimarrita peaches were cooled in water at 5°C and Maciel at 6.7°C. For the control treatment, the peaches were harvested and immediately transferred to the cold rooms already at 0.5°C. Flesh temperature drops of hydrocooled and control treatments were monitored

with PT100 temperature sensors connected to a data logger (Novus, Porto Alegre, RS) during 3 minutes or 45 minutes, respectively.

After treatments, the hydrocooled peaches were transferred to cold storage rooms at 0.5ºC and 90% relative humidity for 7, 14, 21 or 28 days plus 1 to 5 more days at 20ºC. At harvest, after retrieval from cold storage and ripening at 20°C, fruit samples were analyzed for weight losses and decay incidence. Peaches were considered decayed when lesion diameter was greater than 0.3 cm.

Percentage of epidermal red color was determined visually. Flesh firmness (N) was determined on two opposite equatorial sites with a hand-held penetrometer equipped with a 7.9 mm Magness-Taylor plunger. Total soluble solids (ºBrix) were determined with a table refractometer and titratable acidity (% malic acid) was quantified via potentiometric titration up to pH 8.1 with 0.1M sodium hydroxide solution (w/v).

Extractable juice was estimated subjectively and objectively. In the subjective method, the peaches were cut along the longitudinal axis into two halves and one half was hand-squeezed and classified in classes of juice intensity on a hedonic scale, where class 1 corresponded to high juice contents (abundant juice liberation); 2 = moderate (moderate juice liberation); 3 = low (slight juice liberation); and 4 = juiceless (without juice). For objective determinations, the Lill and Van der Mespell (1988) method modified by Seibert *et al.* (2008) was used. Small parts of mesocarp tissues were homogenized through a 5 mL disposable syringe, collected into a centrifuge tube, weighted and centrifuged at 12.000 x *g* for 20 min. The supernatant juice was weighted and the weight expressed as a percentage of sample weight.

Chilling injuries were assessed after cutting the peaches into two halves to visualize flesh disorders. Internal browning was determined by observing pulp color and classifying it as class 1 = healthy (pulp with no browning); 2 = slight (0-25% of the pulp brown); 3 = moderate (25-50% of the pulp brown); or 4 = Severe (>50% of the pulp brown). Peaches with pulp of a corky appearance and firmness beyond 40 N after the transfer period to 20°C were classified as leathery.

Through hand squeezing halves of peaches, woolliness intensity was determined based on a subjective scale: 1 = healthy (abundant juice liberation); 2 = slightly woolly (moderate juice liberation); 3 = moderately woolly (slight juice liberation); 4 = severe woolliness (without juice). Woolliness was also determined objectively via the method described in Seibert *et al.* (2008).

An extractable juice content *versus* firmness curve was calculated. Therefore, extra peaches were harvested and stored at 20ºC. Firmness and extractable juice content were collected daily from 30 peaches during 4 days to run a correlation and regression analysis on freshly harvested, non-chilled fruits. Peaches maintained at 20ºC were considered as not chilled fruit, a control for the chilling injury temperature of 0.5ºC.

A woolliness index was calculated for each storage period according equation 1.

$$X = 100 - [100 \times (\text{juice content at } 0.5ºC \text{ or } 20ºC) \div (\text{juice content at harvest})]$$

[equation 1]

When X = 0, then the fruit is a juicy fruit with adequate juice content and X = 100 indicates a totally dry fruit. Juicy peaches without signs of woolliness, flesh browning and leatheriness were classified as healthy and marketable.

The experiment was conducted in a completely randomized design with 4 replicates and 16 peaches as experimental unit. The SANEST program (Zonta *et al.*, 1986) was used for analysis of variance and means were compared by the Tukey test at $p < 0.05$.

RESULTS AND DISCUSSION

Cultivar Maciel peaches, a yellow-fleshed non-melting cultivar, were harvested with 27.6°C flesh temperature. After 3 min of hydrocooling with water at 6.7°C flesh temperature had dropped to an average of

9.0°C to 13.9°C. Flesh temperature of control peaches dropped about 8°C during the first 45 minutes of cold room cooling at 0.5°C.

Cultivar Chimarrita peaches, a white-fleshed melting cultivar, were harvested with 24.5°C flesh temperature and after the hydrocooling treatment at 5°C flesh temperature had dropped to 11.5°C to 12°C. In control fruit, *i. e.* under room cooling, flesh temperature dropped only 4.6°C to 5.8°C in the first 45 minutes of cold storage at 0.5°C. Sargent *et al.* (2017) observed that applying room cooling of peaches could take about 20 hours or more to the fruit reach the 7/8 of cooling and therefore regarded this cooling procedure as the slowest method to cool peaches. Opara and Pathare (2014) concluded that delaying cooling results in higher moisture losses and increased sensitivity of the peaches to bruising. Makule *et al.* (2022) indicate that a one-hour delay in field heat removal of produce at a temperature of 35^{0}C may shorten the storage time in about one day.

There were no significant differences in weight losses amongst hydrocooled and room cooled peaches of both cultivars at retrieval from storage, though, after the transfer period to air, hydrocooled peaches showed higher percentages of weight losses (Table 1). In cv. Chimarrita peaches, some wrinkled shoulders were visually detected.

Table 1
Weight and decay losses (%) of hydrocooled (HC) cv. Chimarrita and cv. Maciel peaches after up to 28 days of cold storage at 0.5ºC plus a two-days ripening period at 20ºC.

Cv. Chimarrita peaches									
Storage at 0.5ºC					Ripening at 20ºC				
Days at 0.5ºC	Weight losses		Decay incidence		Days at 0.5º+20ºC	Weight losses		Decay incidence	
	Control	HC	Control	HC		Control	HC	Control	HC
---	---	---	---	---	0 + 2	4.4 a	4.5 a	0.0 a	0.0 a
7	28 a[1]	2.1 a	9.0 a	1.6 a	7 + 2	6.5 b	11.2 a	23.8 a	11.1 b
14	3.1 a	3.9 a	0.0 a	3.1 a	14 + 2	6.1 b	9.6 a	9.4 a	0.0 b
21	6.9 a	8.6 a	7.6 a	8.6 a	21 + 1	3.4 a	2.8 a	2.5 a	0.0 a
28	12.0 a	8.0 a	35.4 a	16.3 b	28 + 1	3.0 a	3.3 a	0.0 a	3.6 a
Average	6.2 a	5.6 a	13.0 a	7.4 b	Average	4.7 b	6.3 a	7.1 a	2.9 b
VC [2] (%)	47.7		52.2			24.2		109.9	

Cv. Maciel peaches									
Storage					Ripening				
Days at 0.5ºC	Weight losses		Decay incidence		Days at 0.5º+20ºC	Weight losses		Decay incidence	
	Control	HC	Control	HC		Control	HC	Control	HC
---	---	---	---	---	0 + 3	5.4 a	6.9 a	0.0 a	0.0 a
7	1.8 a	2.2 a	0.0 a	0.0 a	7 + 3	6.7 a	7.1 a	0.0 a	0.0 a
14	3.7 a	4.8 a	0.0 a	0.0 a	14 + 4	5.8 a	8.4 a	3.6 a	3.6 a
21	4.6 a	5.6 a	1.8 a	0.0 a	21 + 5	9.9 a	12.5 a	32.2 a	28.6 a
28	6.8 a	7.7 a	1.8 a	1.8 a	28 + 4	6.4 a	9.2 a	7.2 a	14.3 a
Average	4.3 b	5.1 a	0.9 a	0.5 a	Average	6.8 b	8.8 a	8.6 a	9.3 a
VC (%)	20.1		6.5			19.8		37.3	

[1] Data followed by the same letter along the lines inside each evaluation period (storage or ripening) and variable (weight or decay losses) do not differ significantly (Tukey test at $p<0.05$).

[2] VC = Coefficient of variation.

Incidence of decay was very low in cv. Maciel peaches during storage and increased during the transfer period to air at 20°C. The differences though, were not statistically significant. Cv. Chimarrita peaches showed a higher decay occurrence after 28 days of cold storage at 0.5° and after ripening at 20°C following 7 or

14 days of cold storage (Table 1). Average values of decay incidence were higher in control fruit indicating that decay is not attributable to hydrocooling. A result not in accordance to the results of Kluch *et al.* (2003).

Some hydrocooled cv. Chimarrita fruit showed epidermal cracks after the ripening period following 28 days at 0.5ºC. Brackmann *et al.* (2009) observed in hydrocooled cv. Chiripá fruit peel damages that the authors associated to the contact of the ice of the slurry with the fruit epidermis.

Titratable acidity was low in both cultivars and there were no significant differences in total soluble solids (Table 2). Average values of flesh firmness of hydrocooled cv. Chimarrita peaches were significantly higher than firmness values of control fruit (Figure 1A; 1B). Flesh firmness of hydrocooled and control peaches of the cv. Maciel did not differ (Figure 1C and 1D). During cold storage, there was little variation in firmness values. A drop from 53.3N to 44.5N after 28 days at 0.5°C. During the ripening period at 20°C following 14 and more days of cold storage, cv. Maciel peaches had a corky flesh that probably caused the increases of firmness values. Firmness values determined by hand-held penetrometers, though, should be interpreted with some caution according to Kao *et al.* (2012). The authors emphasized that standard firmness measurement devices may not accurately determine different texture variations.

Table 2

Quality and ripening variables determined at harvest after cold storage at 0.5°C or ripening at 20°C of hydrocooled cv. Chimarrita and cv. Maciel peaches.

Variable		Cv. Chimarrita		Cv. Maciel	
		Control	Hydrocooling	Control	Hydrocooling
Weight (g)	Harvest	126.7 a [1]	127.0 a	126.1 a	134.3 a
	Storage	135.6 a	127.1 b	123.1 a	127.0 a
Diameter (cm)	Harvest	6.4 a	6.3 a	6.1 a	6.3 a
	Storage	6.3 a	6.1 b	6.1 a	6.2 a
Skin color (%)	Harvest	54.0 a	58.0 a	10.0 a	15.0 a
	Storage	55.0 a	51.0 a	10.0 a	15.0 a
TSS (ºBrix)	Harvest	12.5 a	11.9 a	10.5 a	11.4 a
	Storage	12.1 a	12.2 a	10.5 a	10.9 a
	Ripening	11.8 b	12.7 a	10.8 a	11.2 a
TA (%malic acid)	Harvest	0.434 a	0.406 a	0.514 a	0.574 a
	Storage	0.290 a	0.280 a	0.503 a	0.485 a
	Ripening	0.313 a	0.323 a	0.370 a	0.387 a

[1] Data followed by the same letter along the lines inside each variable and cultivar do not differ significantly (Tukey test at $p<0.05$).

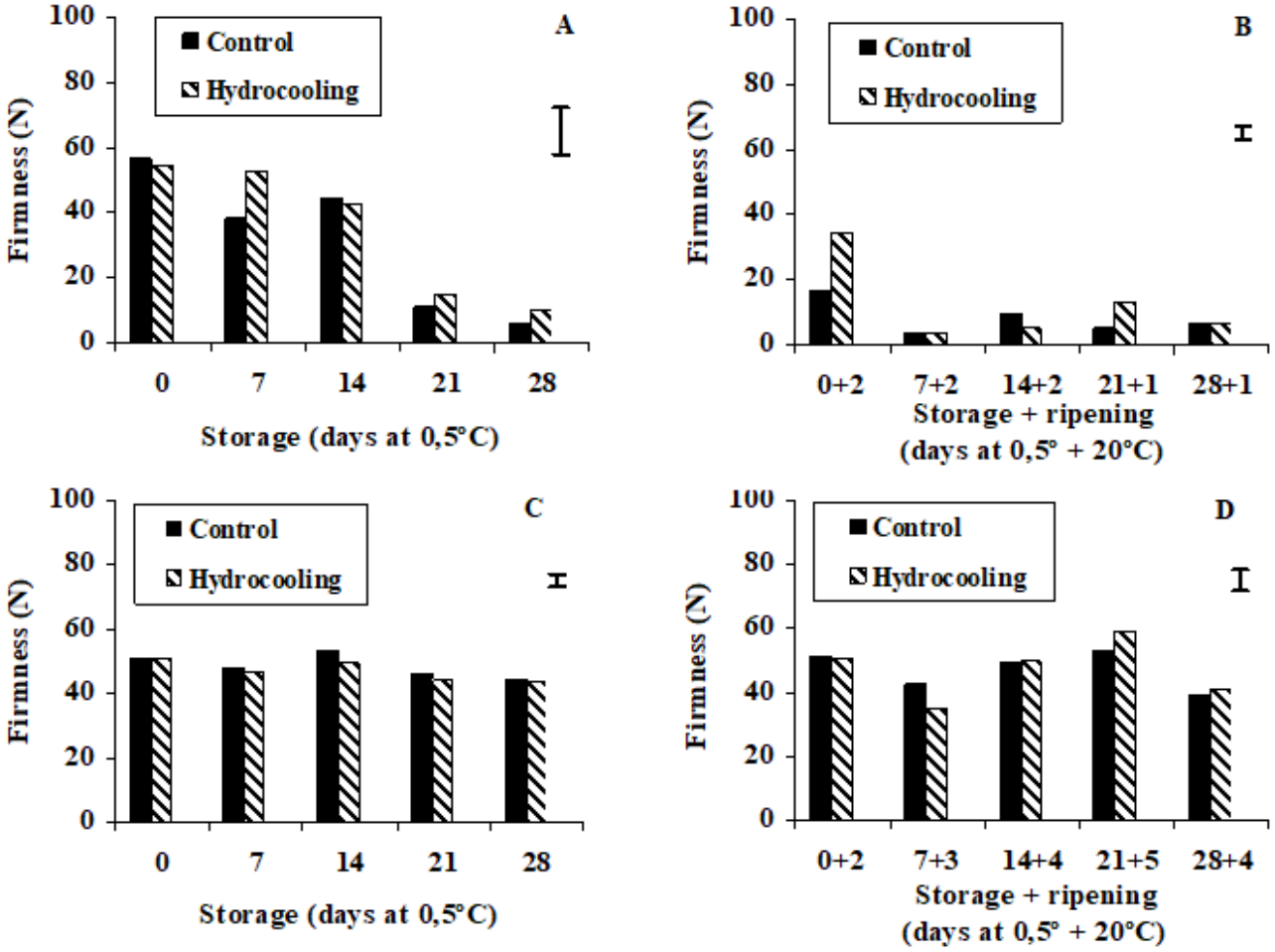

Figure 1

Flesh firmness after up to 28 days of cold storage at 0.5°C plus up to five more days of ripening at 20°C of hydrocooled cv. Chimarrita (A e B) and cv. Maciel (C e D) peaches.

Vertical bars indicate Least Significant Difference ($p<0.05$).

Juiciness was similar in both cultivars and, after 14 or more days of cold storage, values were very low (Table 3 and 4). Hydrocooled cv. Chimarrita peaches had significantly lower juice contents at the end of the storage period. Juice contents of hydrocooled fruit reduced from 30% at harvest to 3% after 28 days at 0.5°C. In control fruit lowest juice contents was determined after 14 days of storage. During the transfer period to air at 20°C hydrocooled peaches, again, were less juicy (Figure 2B). Reduction in juiciness of the peaches coincided with higher juice viscosity.

Table 3

Juiciness based on a hedonic scale varying from 1 = abundant juice liberation to 4 = juiceless fruit, internal browning, leatheriness and healthy fruits (%) determined subjectively in hydrocooled (HC) cv. Maciel peaches after ripening at 20°C.

Days at 0.5º+20º C	Juiciness		Internal browning (% fruits)		Leatheriness (% fruits)		Healthy fruits (%)	
	Control	HC	Control	HC	Control	HC	Control	HC
0 + 2	2.8 a [1]	2.9 a	0 a	0 a	0 a	0 a	100 a	100 a
7 + 3	2.6 a	2.4 a	0 a	0 a	0 a	0 a	100 a	100 a
14 + 4	3.1 a	3.2 a	45 a	35 a	45 a	35 a	38 a	35 a
21 + 5	3.6 a	3.7 a	80 a	70 a	75 a	95 a	17 a	10 a
28 + 4	3.3 a	3.1 a	95 a	100 a	40 a	37 a	5 a	0 a
Average	3.1 a	3.1 a	44 a	41 a	32 a	33 a	52 a	49 a

[1] Data followed by the same letter along the lines inside each variable do not differ significantly (Tukey test at $p<0.05$).

Table 4

Juiciness based on a hedonic scale varying from 1 = abundant juice liberation to 4 = juiciless fruit, woolliness and healthy fruits (%) in hydrocooled (HC) cv. Chimarrita peaches determined subjectively after cold storage at 0.5ºC plus a ripening period at 20ºC.

Storage periods	Juiciness		Woolliness (% fruits)				Healthy (% fruits)			
	Ripening		Storage		Ripening		Storage		Ripening	
	Control	HC	Control	HC	Control	HC	Control	HC	Control	HC
0	1.2 a [1]	1.3 a	---	---	---	---	100 a	100 a	100 a	100 a
7	1.3 a	1.6 a	0 a	0 a	0 a	0 a	100 a	100 a	100 a	100 a
14	3.4 a	3.0 a	0 a	0 a	100 a	60 b	100 a	100 a	0 a	40 a
21	3.1 a	4.0 a	60 b	90 a	80 a	100 a	40 a	10 b	20 a	0 a
28	3.3 a	3.1 a	80 b	100 a	90 a	60 a	20 a	0 b	10 a	40 a
Average	2.5 a	2.6 a	35 b	45 a	67,5 a	55 a	72 a	62 b	46 a	56 a

[1] Data followed by the same letter along the lines inside each variable and evaluation period do not differ significantly (Tukey test at $p<0.05$).

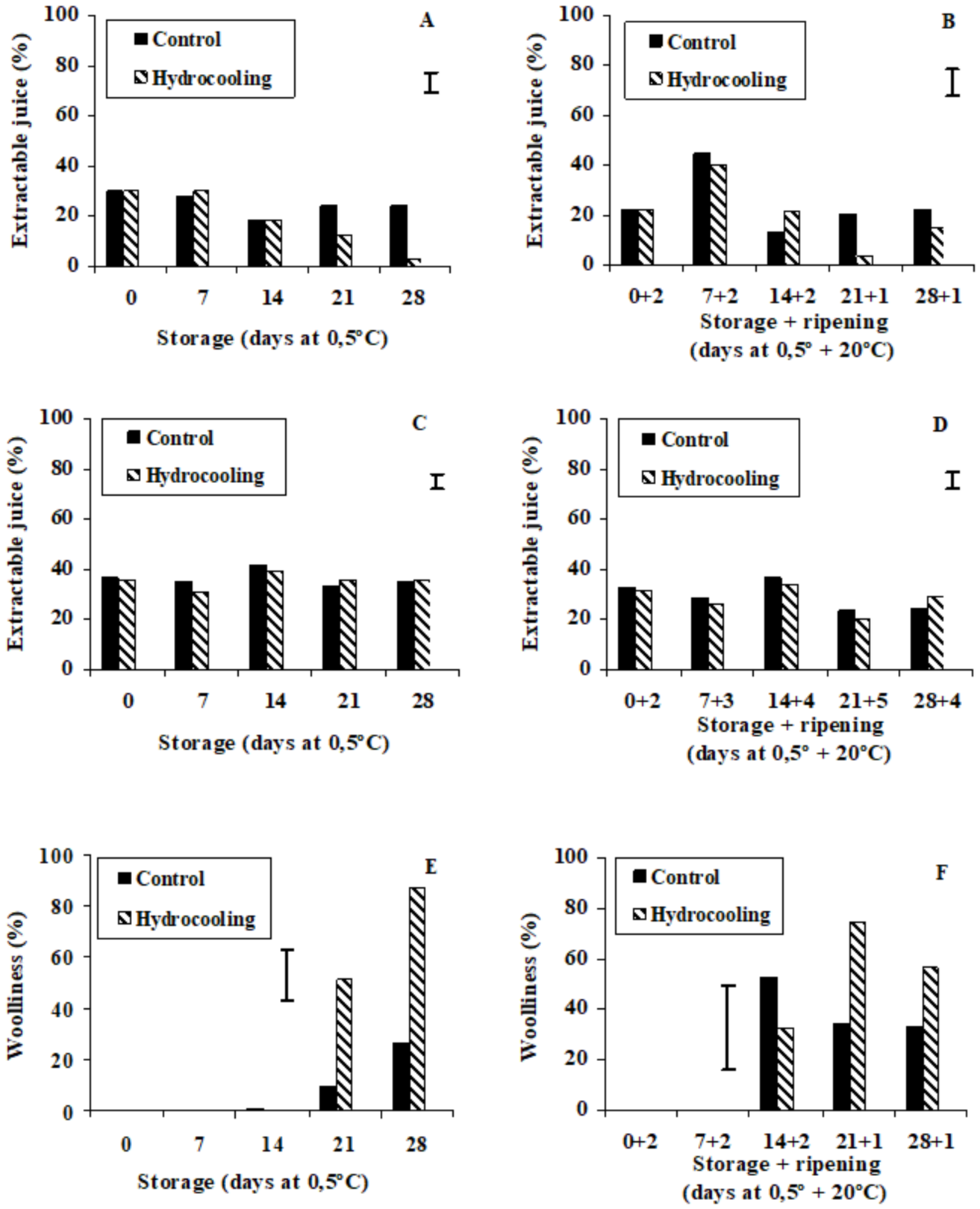

Figure 2

Extractable juice contents and woolliness of hydrocooled cv. Chimarrita (A, B, E, F) and cv. Maciel (C, D) peaches after up to cold 28 days of cold storage at 0.5ºC plus up to two more days of ripening at 20ºC.

Vertical bars indicate Least Significant Difference ($p<0.05$).

Juice contents of cv. Maciel peaches did not differ amongst treatments (Figure 2C and 2D). After 5 days at 20°C, following 21 days of cold storage juice contents was reduced to 20 and 23%, which also coincided with increases in flesh firmness. Infante *et al.* (2009) observed that softer flesh of cv. September Sun peaches was associated with high apparent juice content.

Both cultivars showed varying susceptibility to chilling temperatures. While cv. Maciel peaches developed internal browning and firmness retention, cv. Chimarrita peaches showed high incidence of woolliness. Internal browning was observed in cv. Maciel peaches during the transfer period to 20°C following at least 14 days of cold storage in both, hydrocooled and control fruit (Table 3). After 28 days at 0.5°C plus four more days at 20°C, in 80% of the peaches symptoms of internal browning were severe. Cáceres *et al.* (2016) indicate that flesh browning is a chilling injury symptom frequently observed when peaches and nectarines are stored for periods of 21 or more days. According to Lurie and Crisosto (2005), the occurrence is genetically and environmentally determined, though the genetic origin is not completely understood.

Cv. Chimarrita peaches developed injuries related to cold storage after the transfer period to 20°C. Following 14 days of cold storage, all the control fruit and 60% of the hydrocooled peaches were woolly (Table 4). After 21 and 28 days at retrieval from cold storage woolliness symptoms could be easily visualized.

Normally chilling injuries are only visible after a transfer period of one or two days at higher temperatures (Brackmann *et al*., 2009). Even though, Von Mollendorf *et al.* (1992) detected woolliness symptoms in 5% and 20% of cultivar Independence nectarines at retrieval from -0.5°C or 3°C, respectively. Retamales *et al.* (1992) visualized chilling injuries in cv. Autumn Grand nectarines immediately after cold storage. The authors considered the cultivar as very susceptible to the disorder.

Cv. Chimarrita peaches, besides the high susceptibility of the cultivar to chilling temperatures, were at advanced ripening stages at the end of the cold storage periods. Flesh firmness values were below 15.0 N. Tatsuki *et al.* (2021) indicate, however, that most consumers prefer peaches with firmness below 10N.

Objective woolliness determinations were in accordance to visual evaluations. Storage periods up to 14 days at 0.5°C do not result in injuries, but after 21 days of cold storage the incidence is high, moreover in hydrocooled fruit (Figure 2A). Comparing juiciness and woolliness indexes (Figures 2A, 2B, 2E, 2F), it is possible to relate increases in woolliness rates to reductions in grades of juiciness (Neves *et al.*, 2013) and, again, the effects are more pronounced in hydrocooled fruit.

Cv. Maciel peaches were not woolly and were not of a dry appearance. Cv. Maciel is a non-melting cultivar and in such cultivars flesh firmness drops are naturally more limited (Kao *et al*., 2012). Along the storage period, firmness was higher than 35.5 N and woolliness symptoms were not observed. However, Crisosto *et al.* (1999) stated that in some yellow-fleshed non-melting peach cultivars woolliness symptoms might be observed.

The main physiological distinction between melting and non-melting cultivars lies on the capability to degrade cell wall pectins (Kao *et al.*, 2012). More precisely, in the activity of the enzymes polygalacturonase (Callahan *et al*., 2004) and pectinmethylesterase (Manganaris *et al.*, 2006). In order to loose firmness the pectins of the middle lamella need to be depolymerized under a synchronized pattern of the involved enzymes.

Hydrocooled and not hydrocooled cv. Maciel fruit showed symptoms of firmness retention after 14 days of storage. At this time, 45% of the control peaches and 35% of hydrocooled peaches had a corky flesh, evidenced by high firmness values (Table 3). The percentages of damaged fruit increased with storage time. Seventy five percent of the control fruit and 95% of hydrocooled fruit showed symptoms of firmness retention after 21 days of storage and the disorder, according to statements of Ju *et al.* (2000) and *Ju et al.* (2001), affects the amounts of juice contents which result from lower ethylene production rates. The authors determined lower ACC (1-aminocyclopropane-1-carboxylic acid) oxidase activity and, therefore, a significant influence on all ethylene-dependent processes.

Ju *et al.* (2001) observed that cv. Snow Giant peaches harvested with 58 N of flesh firmness after 3 weeks of storage at 0°C reduced firmness to 30 N. These values are similar to those observed in the present work on cv. Maciel peaches. Same behavior of chilled fruit was observed by Lurie and Crisosto (2005).

Healthy peaches with no chilling injuries were considered saleable (Tables 3 and 4). After up to 14 days of storage, cv. Chimarrita peaches had no indications of chilling disorders. The disorder became more evident after 21 days at 0.5°C. Woolliness was the major symptom. Hydrocooled fruit were the most affected. Results of cv. Maciel peaches were similar.

According to the present results, 14 days should be the maximum storage period at 0.5°C of hydrocooled cv. Chimarrita and cv. Maciel peaches allowing two to three more days at 20°C, after which peaches could be commercialized with no problems. After 21 days of storage at 0.5°C, 25% of cv. Chimarrita peaches were overripe and flesh firmness had dropped below 13.3 N at retrieval from cold storage.

CONCLUSIONS

Hydrocooling reduces significantly flesh temperature of cv. Maciel and cv. Chimarrita peaches and is a viable technique to remove field heat before cold storage.

Hydrocooling does neither enhance percentages of decay incidence nor result in higher dehydration rates.

Cv. Maciel peaches are more prone to firmness retention and flesh browning after prolonged cold storage and hydrocooling has no influence on the manifestation of these chilling injuries. Cv. Chimarrita peaches are highly susceptible to woolliness when exposed to low temperatures beyond 21 days at 0.5°C and hydrocooling influences the occurrence of woolliness and the reduction of juiciness.

REFERENCES

Bernat, M., Segara, J., Casals, C., Teixidó, N., Torres, R., and Usall, J. 2017. Relevance of the main postharvest handling operations on the development of brown rot disease on stone fruits. *Journal of the Science of Food and Agriculture*, 97(15): 5319-5326. https://doi.org/10.1002/jsfa.8419

Brackmann, A., Weber, A., Giehl, R. F. H., and Eisermann, A. C. 2009. Pré-resfriamento sobre a qualidade de pêssegos 'Chiripá'. *Ciência Rural*,39(8): 2354-2360. https://doi.org/10.1590/S0103-84782009005000192.

Cáceres, D., Diaz, M., Shinya, P., and Infante, R. 2016. Assessment of peach internal flesh browning through colorimetric measures. *Postharvest Biology and Technology,* 111: 48-52. https://doi.org/10.1016/j.postharvbio.2015.07.007.

Callahan, A., Scorza, R., Bassett, C., Nickerson, M., and Abeles, F. 2004. Deletions in an endopolygalacturonase gene cluster correlate with non-melting flesh texture in peach. *Functional Plant Biology*, 31: 159-168. https://doi.org/10.1071/FP03131

Carnelossi, M. A. G., Sena, E. O. A., Berry, A. D., and Sargent, S. A. 2019. Effect of Forced-air Cooling, Hydrocooling, or their Combination on Fruit Quality of Two Southern Highbush Blueberry Cultivars. *HortScience*, 54 (1): 136–142. https://doi.org/10.21273/HORTSCI13181-18.

Crisosto, C. H., Mithchell, F. G., and Ju, Z. 1999. Susceptibility to chilling injury of peach, nectarine, and plum cultivars grown in California. *HortScience*, 34: 1116-1118. https://doi.org/10.21273/HORTSCI.34.6.1116.

Crisosto, C. H., Gardner, D., Andris, H. L., and Day, K. R. 2004. Controlled delayed cooling extends peach market life. *HortTechnology*, 14(1): 99-104. https://doi.org/10.21273/HORTTECH.14.1.0099

DeEll, J. K., Vigneault, C., and Lemerre, S. 2000. Water temperature for hydrocooling field cucumbers in relation to chilling injury during storage. Postharvest Biology and Technology, 18 (1): 27-32. https://doi.org/10.1016/S0925-5214(99)00057-5.

Elsisi, S. F., Taha, A., and Omar, M. N. 2020. Cucumber Hydrocooling Treatment and its Relationship to Quality Properties during Cold Storage. *Journal of Soil Sciences and Agricultural Engineering*, 11 (9): 521-528. https://doi.org/10.21608/jssae.2020.119598.

Hussain, P. R., Meena, R. S., Dar, M. A., and Wani, A. M. 2008. Studies on enhancing the keeping quality of peach (*Prunus persica Bausch*) Cv. Elberta by gamma-irradiation. *Chemistry*, 77 (4): 473-481. https://doi.org/10.1016/j.radphyschem.2007.08.003.

Infante, R., Meneses, C., and Crisosto, C. H. 2009. Preconditioning treatment maintains taste characteristic perception of ripe 'September Sun' peach following cold storage. *International Journal of Food Science & Technology*, 44 (5): 1011-1016. https://doi.org/10.1111/j.1365-2621.2008.01864.x

Ju, Z., Duan, Y., and Ju, Z. 2000. Leatheriness and mealiness of peaches in relation to fruit maturity and storage temperature. *Journal of Horticultural Science & Biotechnology,* 75 (1): 86-91. https://doi.org/10.1080/14620316.2000.11511205.

Ju, Z., Duan, Y., Ju, Z., and Guo, A. 2001. Different responses of 'Snow Giant' and 'Elegant Lady' peaches to fruit maturity and storage temperature. *Journal of Horticultural Science & Biotechnology*, 76 (5): 575-580. https://doi.org/10.1080/14620316.2001.11511413.

Kao, M. W. S., Brecht, J. K., Williamson, G., and Huber, D. 2012. Ripening development and quality of melting and non-melting peach cultivars. *HortScience*, 47 (7): 879-885. https://doi.org/10.21273/HORTSCI.47.7.879

Kluch, H. D. W., Mello, A. M. de, Feitas, S. T., and Brackmann, A. 2003. Efeito do pré-resfriamento e condições de armazenamento sobre a qualidade físico-química e lanosidade de pêssegos cv. Chiripá. *Revista Brasileira de Agrociência*, 9 (3): 269-272. Available at: file:///C:/Users/Dell/Downloads/590-1071-1-PB%20(1).pdf

Lill, R. E., and Van Der Mespel, G. J. A. 1998. Method for measuring the juice content of mealy nectarines. *Scientia Horticulturae*, 36 (3-4): 267-271. https://doi.org/10.1016/0304-4238(88)90061-1

Lurie, S., and Crisosto, C. H. 2005. Chilling injury in peach and nectarine. *Postharvest Biology and Technology*, 37 (3): 195-208. https://doi.org/10.1016/j.postharvbio.2005.04.012

Makule, E., Dimoso, N., and Tassou, S. A. 2022. Precooling and Cold Storage Methods for Fruits and Vegetables in Sub-Saharan Africa - A Review. *Horticulturae*, 8 (9): 776. https://doi.org/10.3390/horticulturae8090776

Manganaris, G. A., Ilias, I. F., Vasilakakis, M., and Mignani, I. 2007. The effect of hydrocooling on ripening related quality attributes and cell wall physicochemical properties of sweet cherry fruit (*Prunus avium* L.). *International Journal of Refrigeration*, 30 (8): 1386–1392. https://doi. org/10.1016 /j.ijrefrig. 2007 .04.001.

Manganaris, G. A., Vasilakakis, M., Diamantidis, G., Mignani, I. 2006. Diverse metabolism of cell wall components of melting and non-melting peach genotypes during ripening after harvest or cold storage. *Journal of the Science of Food and Agriculture*, 86: 243-250. https://doi.org/10.1002/jsfa.2310.

Neves, L. C., Campos, A. J. de, Prill, A de S., and Roberto, S. R. 2013. Woolliness and leatheriness in late season peach cultivars submitted to both delayed storage and to cold storage. *Acta Scientiarum, Agronomy*, 35 (3): 363-369. https://doi.org/10.4025/actasciagron.v35i3.13347

Opara, L. U., and Pathare, B. P. 2014. Bruise damage measurement and analysis of fresh horticultural produce - A review. *Postharvest Biology and Technology*, 91: 9-24. https://doi.org/10.1016/j.postharvbio.2013.12.009

Pervitasari, A. N., Kim, J. H., Cho, K., Choi, D., Yun, S. K., Kim, D., Kim, D. H., and Kim, J. 2021. Effects of hydrocooling and 1-MCP treatment on the quality changes of peach fruit during storage. *Horticultural Science and Technology*, 31: 769-780. https://doi.org/10.7235/HORT.20210068.

Retamales, J., Cooper, T., Streif, J., and Kania, J. C. 1992. Preventing cold storage disorders in nectarines. *Journal of Horticultural Science*, 67: 619-626. https://doi.org/10.1080/00221589.1992.11516291.

Sargent, S. A., Berry, A. D., Brecht, J. K., Santana, M., Zhang, S., and Ristow, N. 2017. Studies on quality of southern highbush blueberry cultivars: Effects of pulp temperature, impact and hydrocooling. *Acta Horticulturae*, 1180: 497-502. https://doi.org/10.17660/ActaHortic.2017.1180.70

Seibert, E., González, S., Orellana, A., Luchsinger, L., and Bender, R. J. 2008. Efecto de acondicionado prévio al almacenaje refrigerado sobre la calidad de ciruelas ′Constanza′. *Bragantia*, 67 (1): 233-242. https://doi.org/10.1590/S0006-87052008000100028

Tatsuki, M., Sawamura, Y., Yaegaki, H., Suesada, Y., and Nakajima, N. 2021. The storage temperature affects flesh firmness and gene expression patterns of cell wall-modifying enzymes in stony hard peaches. *Postharvest Biology and Technology*, 181: 111658. https://doi.org/10.1016/j.postharvbio.2021.111658.

Teruel, B., Cortez, L., and Neves, L. 2001. Estudo comparativo do resfriamento de laranja Valência em três sistemas de resfriamento. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 5 (3): 481-486. https://doi.org/10.1590/S1415-43662001000300019

Tokarskyy, O., Schneider, K. R., Berry, A., Sargent, S. A., and Sreedharan, A. 2015. Sanitizer applicability in a laboratory model strawberry hydrocooling system. *Postharvest Biology and Technology*, 101: 103-106. https://doi.org/10.1016/j.postharvbio.2014.12.004.

Von Mollendorf, L. J., Jacobs, G., and De Villiers, O. T. 1992. The effects of storage temperature and fruit size on firmness, extractable juice, woolliness and browning in two nectarine cultivars. *Journal of Horticultural Science*, 67 (5): 647-654. https://doi.org/10.1080/00221589.1992.11516295.

Zonta, E. P., Silveira, P., and Machado, A. A. 1986. Sistema de análise estatística (SANEST 3.0). Pelotas, Instituto de Física e Matemática, UFPel, 399p.

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