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Storage behaviour of 'Reinette du Canada' apple cultivars

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Abstract

Apple (*Malus domestica* Borkh) cultivars 'Reinette du Canada' (RC) and 'Reinette Grise du Canada' (RG) have been declared throughout the European Community as protected designation of origin (PDO) 'Manzana Reineta del Bierzo'. The aim of this research was to find out the influence of storage technique on quality of PDO apple cultivars 'RC' and 'RG', and to evaluate the absence of traditional post-harvest treatments in these high quality cultivars in order to reduce pesticide residues in fruit. Apples were kept in standard cold storage or in controlled atmosphere (CA). At harvest time and during storage, fruit from each treatment and storage technique was analysed to determine quality parameters as well as disorder incidence. CA storage has been useful to delay the maturity process of PDO apple cultivars 'RC' and 'RG' and to reduce the incidence of storage disorders. Apple cultivars had different behaviour so 'RG' cultivar showed lower weight loss (5.1%), shrivelling (6.4%) and bitter-pit (11%) than 'RC' cultivar (8.3%, 60.8% and 34%, respectively) at the end of storage. The response of both cultivars to the treatment was quite different, so 'RG' adapted better than 'RC' to the absence of postharvest treatments. Untreated 'RG' showed more brightness, total soluble solids (TSS) and TSS:titratable acidity values than treated 'RG', factors that could improve consumer acceptance. Effectiveness of postharvest treatment in terms of bitter-pit was lower in 'RG' than in 'RC'. These results indicate that 'RG' would adapt better to storage without the use of chemical postharvest treatments.

Additional key words: cold storage, controlled atmosphere, *Malus domestica,* postharvest treatment, storability.

Resumen

Comportamiento en conservación de cultivares de manzana 'Reineta del Canadá'

Los cultivares de manzana (*Malus domestica* Borkh) 'Reineta del Canadá' (RC) y 'Reineta Gris del Canadá' (RG) han sido declarados en la Unión Europea como Denominación de Origen Protegida (DOP) 'Manzana Reineta del Bierzo'. El objetivo de este trabajo fue averiguar la influencia de la técnica de conservación en la calidad de los cultivares de la DOP 'Manzana Reineta del Bierzo', 'RC' y 'RG', así como evaluar la ausencia de los tradicionales tratamientos postcosecha en estos cultivares de alta calidad con objeto de reducir los residuos finales en el fruto. Las manzanas fueron almacenadas en frío normal o en atmósfera controlada. En recolección y durante la conservación frigorífica se determinaron los parámetros de calidad y la incidencia de enfermedades. La técnica de atmósfera controlada fue útil para retrasar la maduración de los cultivares DOP 'Manzana Reineta del Bierzo' 'RC' and 'RG' y para reducir la incidencia de alteraciones durante conservación. Los cultivares tuvieron diferente comportamiento, de manera que 'RG' mostró menor pérdida de peso (5,1%), arrugamiento (6,4%) y *bitter-pit* (11%) que 'RC' (8,3%, 60,8% y 34%, respectivamente) al final de la conservación. La respuesta de los cultivares ante el tratamiento fue diferente, pues 'RG' se adaptó mejor que 'RC' a la ausencia de tratamientos. 'RG' no tratada mostró mayor brillo, sólidos solubles totales (TSS) y TSS:Acidez titulable que 'RG' tratada, lo cual podría aumentar la aceptación por parte del consumidor. La eficacia de los tratamientos postcosecha en el control de *bitter-pit* fue menor en 'RG' que en 'RC'. Estos resultados indicarían que 'RG' se adaptaría mejor a una conservación sin tratamientos químicos postcosecha.

Palabras clave adicionales: atmósfera controlada, capacidad de conservación, frío normal, *Malus domestica,* tratamientos postcosecha.

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Abreviations used: CA (controlled atmosphere), CS (cold storage), PDO (Protected designation of origin), RC (Reinette du Canada), RG (Reinette Grise du Canada), RH (relative humidity), TA (titratable acidity), TSS (total soluble solids).

Introduction

'Reinette du Canada' (RC) and 'Reinette Grise du Canada' (RG) apple cultivars, have been declared a protected designation of origin (PDO), 'Manzana Reineta del Bierzo' (Commission Regulation (EC) Nº 2601/2001) throughout the European Community. These cultivars have typical Reinette-type characteristics, being fairly large, flattened in shape and with a high degree of skin russet (Marcelo *et al.,* 2008).

Techniques allowed in PDO 'Manzana Reineta del Bierzo' for apple storage are cold storage (CS) and controlled atmosphere (CA) (Marcelo *et al.*, 2002). The advantages of marketing apple as PDO 'Manzana Reineta del Bierzo' are that fruit prizes rise up to 20% compared with ordinary apples, together with an increase in its demand. Significant higher prices may be paid for specialty cultivars compared to traditional varieties (Troncoso and Aguirre, 2007).

During storage, apple and pear fruit are susceptible to wastage due to weight loss and physiological and pathological disorders. Wastage percentage of fruit during storage vary between 8% and 12%, being a 4-6% due to disorders, with rot causing half of them (Viñas *et al*., 2005). Fungicides have been the most effective means of controlling postharvest diseases on fruit for many years. The main control strategy consists of drench application and/or spray treatment on the packing line using fungicides such as Imazalil (Amiri *et al.,* 2008). This fungicide has proved to be effective for controlling diseases caused by fungi in apples (Villatoro *et al.,* 2009). However, there is an increasing concern in the scientific community that small doses of pesticides may have chronic adverse effects on people (Ragsdale and Sisler, 1994). This fact is especially important in high quality products such as PDO brands, where consumers are increasingly demanding fruit without chemical postharvest treatments.

The objectives of this work were: (1) to investigate the effects of storage technique on quality of PDO 'Manzana Reineta del Bierzo' apple cultivars 'RC' and 'RG'; and (2) to evaluate the absence of traditional postharvest treatments on the storability of high quality apple cultivars in order to reduce pesticide residues in fruit.

Material and methods

Apple (*Malus domestica* Borkh) tree cultivars 'RC' and 'RG' were grown in an experimental orchard in Carracedelo, El Bierzo region (lat. 42°33'N, long. 6°44'W) (León, Spain). Fruit was harvested according to days after flowering and firmness and then fruit was taken to the store room. The experiment was laid out in a randomized complete block design taking into account three factors including cultivar, postharvest treatment and storage technique.

Over 200 fruit per cultivar and replicate were picked and once in the store they were randomized and divided into 2 lots for the following post-harvest treatments: (1) non-treated (control); (2) treated with Imazalil 1-[2-(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl]-1H-imidazole (375 µL L^{-1}) + Iprodione [3-(3.5-dichlorophenyl)-N-isopropyl-2.4-dioxoimidazolidine-l-carboximide] (500 µL L^{-1}) (Decco Iberica, Paterna, Spain), Diphenylamine (930 µL L^{-1}) (Citrosol, S.A., Valencia, Spain) and Calcium chloride (2%) (Citrosol, S.A., Valencia, Spain). Treatment was performed by placing the fruit in commercial drenching equipment. Following treatments, fruits were placed in plastic containers and were stored for 30, 60, 90 or 160 days in standard cold storage (CS) at 1°C, RH 95% or in controlled atmosphere (CA) at 1°C, RH 95% (2% CO_2 + 3% O_2).

At harvest time and during storage, three replicates (each of 10 fruit) from each treatment and storage room were analysed to determine weight, fruit colour, flesh firmness, total soluble solids (TSS), titratable acidity (TA) and bitter-pit, shrivelling and rot incidence. Ten fruit per replicate were used to make non-destructive weight loss measurement during storage.

Fruit colour was measured on each fruit with a colorimeter (Minolta, CR-200) and was expressed as L*, a*, b* values. Three determinations were made along the equatorial axis of each fruit.

Flesh firmness was determined using a hand-held Effegi penetrometer fitted with an 11.1 mm diameter plunger. Measurements were taken at three equatorial positions on each fruit at 120° and the results were expressed in newtons.

For determination of TSS and TA, juice from the apple was extracted and filtered. TSS (%) of the juice was measured in each fruit with a hand-held refractometer (Atago, DR-A1). TA was determined in each fruit by titrating 10 mL of juice with NaOH 0.1 N up to pH 8.2. The ratio TSS:TA was determined.

The number of fruit affected by external bitter-pit was recorded, so that the incidence of fruit with bitter-pit could be calculated. In addition, fruit storability was evaluated by determining levels of shrivelling and rot incidence.

Differences in quality parameters between treatment and storage technique were detected using analysis of variance. When Anova analyses provided significant differences, means comparison was based on Tukey test (*$P < 0.05$ or **$P < 0.01$). All analyses were performed with SPSS Version 15.0.1.

Results and discussion

In agreement with works on other apple cultivars (Cavalheiro *et al*., 2003), weight loss was affected by storage time, significantly increasing during fruit storage in all treatments and storage conditions. During storage, significant differences were found in weight loss between storage techniques, CA having lower losses than CS (Fig. 1). According to Akbudak *et al*. (2009), CA storage reduces respiration rates and weight loss of apple cv. 'Granny Smith' during storage. Significant differences were found in weight loss between cultivars and an interaction between cultivar and storage technique was found. 'RC' in CS had bigger losses than 'RG' in CS, so that at the end of storage weight losses of 'RC' in CS (12.4%) were nearly twice as much as weight losses of 'RG' in CS (6.4%). These differences in weight loss between cultivars could be due to differences in water vapour permeability since 'RG' has a thicker skin than 'RC' and it has been proved that apple cultivars lose weight at different rates (Maguire *et al*., 2000; Link and Drake, 2004). Fruit size may affect water vapour permeance too, since mean weight of 'RC' after 160 days of storage was 194.4 g whereas weight of 'RG' fruit was 170.1 g. In general, no differences were found in weight loss between treated and untreated fruit, although it has been stated that weight loss and respiration rate could be reduced following calcium chloride treatment (Navjot and Gurcharan, 2006; Sa-ngunanwongwichit *et al*., 2007). Non-treated 'RC', stored in CS, reached the highest value of weight loss (12.8%) after 160 days of storage, whereas non-treated 'RG', stored in CA, reached the lowest value (3.5%) of weight loss after the same period.

Ground colour of fruit was influenced by cultivar, storage technique and postharvest treatment. 'RC' brightness, measured as parameter L*, was bigger than 'RG' brightness. This difference in L* was also observed by (Marcelo *et al*., 2008). Treatment affected parameter L*, although the two cultivars showed different behaviour. In 'RC', significant differences were rarely found (Table 1), whereas in 'RG', significant differences were discovered throughout storage, untreated apples having more brightness (Table 2), so there was an interaction between the treatment and cultivar accounting for the brightness of the skin. This could be due to the different degree of skin russet of both cultivars, since 'RG' is totally covered in russet and 'RC' is partially covered. Ground colour a* value changed

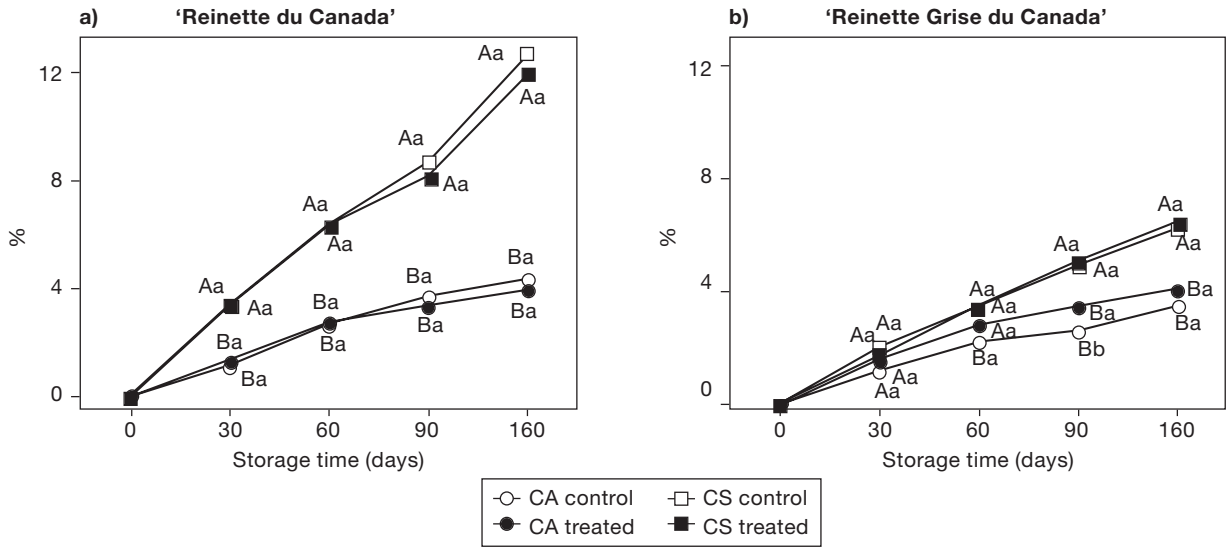

Figure 1. Effect of storage conditions on weight loss of a) 'Reinette du Canada' and b) 'Reinette Grise du Canada' apple cultivars during storage. Different lower-case letters indicate significant differences between control and treatment and different capital letters indicate significant differences between cold storage (CS) and controlled atmosphere (CA) according to Tukey test (*$P < 0.05$).

Table 1. Effect of postharvest treatment and storage technique on quality properties of 'Reinette du Canada' (RC) apple

Quality variable	Storage technique[1]	Treatment	At harvest	Storage period (days)[2]				Storage time[3]
				30	60	90	160	
L*	CA	Control	65.1	65.8Aa	68.2Aa	66.9Aa	63.5Bb	*
		Treated		66.3Aa	68.0Aa	66.3Aa	66.9Ba	*
	CS	Control		65.6Aa	68.4Aa	66.7Aa	67.4Aa	*
		Treated		67.3Aa	68.7Aa	67.1Aa	68.4Aa	*
a*	CA	Control	–12.1	–11.3Ba	–11.8Ba	–9.0Ba	–9.1Ba	**
		Treated		–12.6Bb	–12.6Ba	–11.6Bb	–10.9Bb	*
	CS	Control		–9.4Aa	–9.4Aa	–7.4Aa	–7.2Aa	**
		Treated		–12.3Ab	–11.3Aa	–9.2Ab	–8.0Aa	**
b*	CA	Control	40.5	39.3Aa	40.9Aa	38.2Aa	38.7Bb	NS
		Treated		40.1Aa	40.9Aa	38.8Aa	41.2Ba	NS
	CS	Control		36.8Bb	40.8Aa	37.9Aa	42.8Aa	**
		Treated		40.5Aa	41.4Aa	39.2Aa	43.0Aa	*
Firmness (N)	CA	Control	100.8	101.1Aa	95.9Ab	81.6Ab	66.9Ab	**
		Treated		101.8Aa	115.7Aa	98.0Aa	88.3Aa	**
	CS	Control		69.0Bb	50.4Ba	42.9Ba	29.5Ba	**
		Treated		81.1Ba	51.9Ba	43.0Ba	27.9Ba	**
TSS (%)	CA	Control	14.2	14.4Ab	16.2Aa	16.6Ab	16.7Ab	**
		Treated		15.2Aa	16.1Aa	17.3Aa	17.5Aa	**
	CS	Control		15.0Aa	15.7Ab	16.4Aa	17.2Ab	**
		Treated		15.1Aa	16.3Aa	16.6Ba	18.2Aa	**
TA (%)	CA	Control	1.23	1.06Aa	1.08Aa	0.98Aa	0.82Ba	**
		Treated		1.04Aa	0.99Ab	1.03Aa	0.86Aa	**
	CS	Control		0.94Bb	0.98Ba	0.93Aa	0.90Aa	**
		Treated		1.04Aa	1.03Aa	0.97Ba	0.82Aa	**
TSS:TA	CA	Control	11.5	13.7Bb	15.1Bb	17.0Aa	20.4Aa	**
		Treated		14.7Aa	16.4Aa	16.9Aa	20.7Aa	**
	CS	Control		16.1Aa	16.0Aa	17.7Aa	19.3Ab	**
		Treated		14.9Aa	15.7Aa	17.1Aa	22.5Aa	**
Bitter-pit (%)	CA	Control	0.0	6Aa	26Ba	36Ba	49Aa	**
		Treated		12Aa	12Ab	14Ab	16Ab	*
	CS	Control		6Aa	51Aa	50Aa	55Aa	**
		Treated		14Aa	14Ab	15Ab	14Ab	*

[1] CA: controlled atmosphere. CS: cold storage. [2] For each quality parameter, means within the same storage period and storage technique followed by the same lower-case letters are not significantly different at $*P < 0.05$. Means within the same storage period and postharvest treatment followed by the same capital letters are not significantly different at $*P < 0.05$. [3] NS: not significant. *,**: significant at $P < 0.05$ or $P < 0.01$, respectively.

with storage time, so apples became less green during storage, and with cultivar, so 'RC' apples were greener than 'RG' apples (Tables 1 and 2). Similarly to other works with apples (Rocha *et al.,* 2004; Castro *et al.*, 2007), significant differences were found in a* parameter between storage methods, so that CA fruit had a greater retention of a green background colour (Tables 1 and 2). In general, differences in a* parameter between treatments were found too, so the treatment retained the evolution of colour (Tables 1 and 2). It has been shown that calcium chloride solution delay colour changes in fruit (Sa-ngunanwongwichit *et al*., 2007). During storage, ground colour b* decreased in cv. 'RG', whereas in cv. 'RC' it remained stable in CA fruit. However, it increased in CS fruit at the end of storage, showing that yellowness appeared faster in

Table 2. Effect of postharvest treatment and storage technique on quality properties of 'Reinette Grise du Canada' (RG) apple

Quality variable	Storage technique[1]	Treatment	At harvest	Storage period (days)[2]				Storage time[3]
				30	60	90	160	
L*	CA	Control	56.8	58.2Aa	57.2Aa	58.4Aa	58.8Aa	NS
		Treated		54.4Ab	55.7Ab	57.5Aa	56.3Bb	NS
	CS	Control		56.5Ba	57.9Aa	58.7Aa	57.5Aa	NS
		Treated		54.7Ab	56.5Ab	56.5Ab	56.9Aa	NS
a*	CA	Control	–2.6	–0.3Aa	–0.3Aa	0.2Ba	0.2Ba	**
		Treated		–1.4Ab	–1.5Bb	–0.5Ba	1.0Aa	**
	CS	Control		0.0Aa	0.4Aa	3.0Aa	3.2Aa	**
		Treated		–1.1Ab	0.7Aa	1.5Ab	1.5Ab	**
b*	CA	Control	39.5	31.7Bb	31.4Bb	31.8Ba	31.3Aa	**
		Treated		37.4Aa	35.6Aa	31.0Aa	29.4Ab	**
	CS	Control		39.9Aa	39.7Aa	33.3Aa	31.4Aa	**
		Treated		38.7Aa	32.7Bb	30.2Ab	29.8Ab	**
Firmness (N)	CA	Control	98.0	97.8Aa	87.6Ab	68.8Ab	51.2Ab	**
		Treated		95.8Aa	105.6Aa	91.6Aa	74.8Aa	**
	CS	Control		75.6Ba	45.0Bb	43.7Ba	34.5Ba	**
		Treated		80.0Ba	50.0Ba	41.9Ba	30.8Ba	**
TSS (%)	CA	Control	11.6	13.2Aa	13.4Aa	13.8Aa	13.8Aa	**
		Treated		12.9Aa	13.4Aa	13.2Ab	13.5Aa	**
	CS	Control		13.1Aa	13.8Aa	14.2Aa	14.0Aa	**
		Treated		12.8Aa	13.3Ab	12.6Bb	13.1Ab	**
TA (%)	CA	Control	0.98	0.96Aa	1.01Aa	0.94Aa	0.80Aa	**
		Treated		1.02Aa	1.02Aa	0.88Ab	0.80Aa	**
	CS	Control		0.93Aa	0.92Ba	0.84Ba	0.72Ba	**
		Treated		0.92Ba	0.96Ba	0.87Aa	0.73Ba	**
TSS:TA	CA	Control	11.9	13.8Aa	13.4Ba	14.7Ba	17.3Ba	**
		Treated		12.7Ba	13.1Ba	15.1Aa	17.0Ba	**
	CS	Control		14.2Aa	15.0Aa	16.8Aa	19.6Aa	**
		Treated		13.9Aa	13.9Ab	14.5Ab	18.2Ab	**
Bitter-pit (%)	CA	Control	0.0	0Aa	0Aa	5Aa	15Aa	*
		Treated		3Aa	6Aa	8Aa	9Aa	NS
	CS	Control		0Aa	5Aa	6Aa	12Aa	*
		Treated		6Aa	8Aa	8Aa	7Aa	NS

[1] CA: controlled atmosphere. CS: cold storage. [2] For each quality parameter, means within the same storage period and storage technique followed by the same lower-case letters are not significantly different at $*P < 0.05$. Means within the same storage period and postharvest treatment followed by the same capital letters are not significantly different at $*P < 0.05$. [3] NS: not significant. *,**: significant at $P < 0.05$ or $P < 0.01$, respectively.

CS. This fact made differences between cultivars in b* parameter clearer as storage time passed (Tables 1 and 2). It has been proved that CA delayed the yellowing of the skin (Erkan *et al*., 2004).

During storage, flesh firmness decreased in all storage techniques and treatments. Significant differences were found in firmness between CA and CS throughout storage in both cultivars (Tables 1 and 2). This loss of firmness was stronger in CS than in CA, so CA will be useful to extend the commercial availability of PDO apple. Several works with other apple cultivars have demonstrated that CA is effective to significantly delay the loss of firmness during storage (Erkan *et al*., 2004; Jinhe *et al*., 2005; Lévesque *et al*., 2006). A higher loss of firmness in CS may be related with its higher rate of weight loss compared to CA, as

firmness deterioration is frequently associated with water content loss (Rojas-Graü *et al*., 2008). Significant differences were also found between treated and untreated fruit from 60 days until the end of storage, treated fruit having a higher value of firmness. It has been previously reported that calcium treatments immediately after harvest assure a slower fruit softening during storage (Duque *et al*., 1999; Valero *et al.,* 2002).

As far as TSS is concerned, 'RC' always had higher values than 'RG' (Tables 1 and 2). This lower value of TSS in RG compared to RC has already been observed (Marcelo *et al*., 2008). As previously reported (Guerra and Casquero, 2005), TSS values increased during storage. Although it has been proved that apples subjected to CA storage have substantially higher level soluble solids than apples stored in CS (Erkan *et al*., 2004), in general, significant differences were not found in TSS between storage technique in both cultivars (Tables 1 and 2). Treatment had a different effect on TSS in 'RC' and 'RG'. Although a previous study with apple cv. Reinette du Canada concluded that increasing the calcium content of the fruit showed no effect on TSS (Duque *et al*., 1999), treated 'RC' fruit had higher TSS than untreated fruit (Table 1) and treated 'RG' fruit had lower TSS than untreated fruit, especially in CS (Table 2). Therefore, the absence of postharvest treatments in 'RG' would allow the fruit to reach higher TSS values during storage.

Significant differences were found in TA between storage techniques in 'RG' (Table 2). As previously observed (Erkan *et al*., 2004; Jinhe *et al*., 2005), 'RG' subjected to CA storage had substantially higher levels of titratable acids than apples stored in CS. Although TA of 'RC' was always higher than 'RG' (Table 2), at the end of storage acidity loss in 'RC' was 30.9%, whereas in 'RG' loss of acidity was only 22.2%. That could be related to the fact that initial TA value at harvest was higher for 'RC' (1.23%) than for 'RG' (0.98%), since as observed by Jinhe *et al*. (2005), apple cultivars with a higher TA harvest value like 'Fuji' or 'Granny Smith' show a bigger loss in TA during storage than cultivars like 'Gala' or 'Delicious' with a lower TA value at harvest. In general, no significant differences between treated and untreated fruit were observed in TA during storage (Tables 1 and 2). Duque *et al*. (1999) assured that postharvest calcium treatment did not significantly affect TA of apple cv. 'Reinette du Canada'.

In general, cultivar 'RC' did not show significant differences in TSS:TA between storage techniques nor between treatments, whereas cultivar 'RG' show significant differences in this ratio. 'RG' in CS had higher levels of TSS:TA than apples stored in CA. Untreated 'RG' apples in CS had higher levels of TSS:TA than treated apples (Table 2), so fruit quality expressed as TSS:TA value, which has been found to be more closely related to quality than acid content or TSS alone (Guerra and Casquero, 2009), would be higher in untreated than treated fruit. Significant differences were found in TSS:TA ratio between cultivars during storage, so TSS:TA was higher in 'RC' than in 'RG' (Tables 1 and 2), due to the higher TSS value in 'RC'.

According to Peryea *et al.* (2007) calcium chloride appears to be an economical and effective practice to minimize the risk of bitter pit development. Bitter-pit incidence was higher in untreated fruit than in treated fruit in 'RC' in both storage techniques from 60 days to the end of storage, whereas differences in 'RG' were not significant (Tables 1 and 2). Similar results reported Guerra *et al.* (2007), so calcium preharvest treatment did not decrease bitter-pit incidence during storage in 'RG'. According to Val *et al.* (2008), the lack of effectiveness in the application of calcium may well be due to difficulties in the penetration of Ca through the fruit epidermis. As Val *et al.* (2000) reported, bitter-pit incidence increased during storage, so external bitter-pit incidence in untreated 'RC' at the end of storage was 55% and 49% in CS and CA, respectively. Although it has been stated that reduction of bitter pit may be achieved by storing fruit in CA or modified atmospheres (Khan *et al.*, 2006), in 'Reinette du Canada' cultivars, in general, storage technique did not significantly affect the external bitter-pit incidence (Tables 1 and 2). Bitter-pit incidence during storage was significantly higher in 'RC' than in RG'.

The large variation in water vapour permeance of fruit skin is assumed to be the most important source of variation responsible for the variability of shrivelling incidence (Maguire *et al*., 1999). According to Hertog (2002), shrivelling of apples occurs once weight loss increases to about 3-10%. Shrivelling during storage was already detected in cv. 'RC' stored in CS after 60 days of storage when weight loss was 6.4%, whereas in 'RG' a 6.4% of weight loss at the end of storage was not enough to show symptoms of this disorder. There are high levels of variability in the levels of weight loss and the development of shrivelling among individual apples and grower lines (Maguire *et al*., 2000). As well as differences in weight loss between cultivars, the lower skin thickness and greater size of

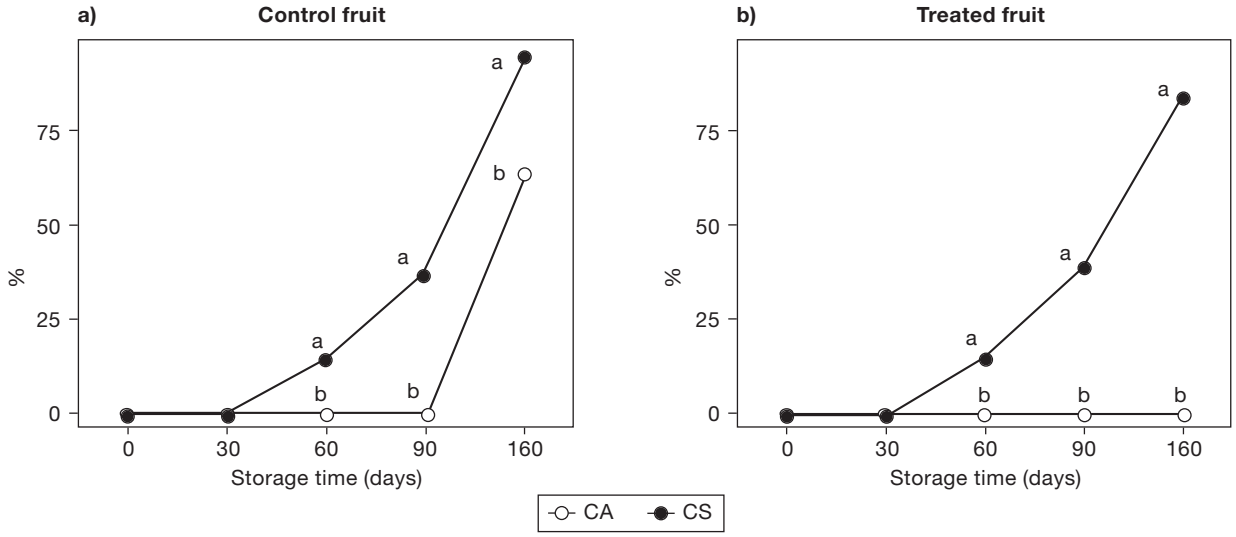

Figure 2. Effect of storage technique on shrivelling of control (a) and treated (b) fruit of 'Reinette du Canada' apple during storage. Different letters indicate significant differences between storage techniques according to Tukey test (*$P < 0.05$).

the fruit in cv. 'RC' could have influenced the level of shrivelling, making it more significant in this cultivar than in cv. 'RG'. After 60 days of storage on, 'RC' showed higher level of shrivelling in CS fruit than in CA fruit (Fig. 2).

At the end of storage post-harvest fungi were detected in CS, whereas there was no significant rot incidence in CA (data not shown). Controlled atmosphere has been found useful to reduce fungal growth, mainly by extending host resistance but also by suppression of fungal pathogens with high CO_2 treatments inhibiting various metabolic functions (Qin *et al.*, 2004). Fruit treatment reduced fungi incidence, but effectiveness of postharvest treatment was higher in 'RC' than in 'RG', so at the end of storage in CS, no rot incidence was detected in 'RC'. After 160 days of storage, treatment reduced rot incidence by 6.1% in 'RC', a 48% more than in 'RG' (4.1%).

Conclusions

CA storage has been useful to delay the maturity process of PDO 'Manzana Reineta del Bierzo' apple cultivars 'RC' and 'RG' and to reduce the incidence of storage disorders such as shrivelling. Apple cultivars had different behaviour so 'RG' cultivar showed lower weight loss, shrivelling and bitter-pit than 'RC' cultivar. The response of both cultivars to the treatment was quite different, so 'RG' adapted better than 'RC' to the absence of postharvest treatments. Untreated 'RG' showed more brightness, TSS and TSS:TA values than treated 'RG', factors that could improve consumer acceptance, and effectiveness of postharvest treatment in terms of bitter-pit was lower in 'RG' than in 'RC', so 'RG' would adapt better to storage without the use of chemical postharvest treatments.

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