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Chlorogenic acid retention in white and purple eggplant after processing and cooking

María J. Zaro [a, *], Leidy C. Ortiz [a], Sonia Keunchkarian [b], Alicia R. Chaves [a], Ariel R. Vicente [a, c], Analía Concellón [a, d]

[a] CIDCA (Centro de Investigación y Desarrollo en Criotecnología de Alimentos), UNLP-CIC-CONICET, Argentina
[b] LIDMA (Laboratorio de Investigación y Desarrollo de Métodos Analíticos), Facultad de Ciencias Exactas, Universidad Nacional de La Plata, Argentina
[c] LIPA (Laboratorio de Investigación en Productos Agroindustriales), Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata, Argentina
[d] CIC (Comisión de Investigaciones Científicas de la Pcia. de Buenos Aires), Argentina

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ABSTRACT

The stability of vegetable antioxidants in response to processing and cooking treatments may be affected by the variety. However, the information available in the literature is very limited. In this work we determined the influence of the eggplant variety (white – cv 'Cloud Nine' and purple – cv 'Lucia') on pulp chlorogenic acid content (5-O-caffeoyl-quinic acid; CQA) and antioxidant capacity (AC) in response to common pre-processing (cutting, salting or blanching), processing (air-vacuum- solar- and freeze-drying, slow- and fast-freezing) and cooking methods (microwaving, baking, grilling, steaming, boiling or pressure cooking). Fresh purple 'Lucia' eggplants showed higher AC and CQA content (16%) than white 'Cloud Nine' fruit. Fruit pre-processing caused significant losses of AC, with the effect being higher in the purple cultivar. Hot air- and sun-drying almost depleted CQA in both cultivars. In contrast, white eggplants retained higher AC upon freezing and microwaving. Wet cooking methods (boiling and pressure cooking) markedly increased fruit AC indicating that these preparation procedures improved antioxidant extractability. The eggplant cultivar has a major influence in antioxidant retention during processing and cooking; the white variety 'Cloud Nine' proved in general, more suitable for processing in terms of antioxidant retention than the purple 'Lucia' genotype.

1. Introduction

In the last years there has been interest in the study of antioxidants in foods, given their role in the prevention of a number of chronic diseases (Martin, Zhang, Tonelli, & Petroni, 2013). Vegetables are among the richest sources of antioxidants, but due to their relatively short postharvest life in fresh they are also incorporated to the diet in processed forms (Vicente, Ortiz, Sozzi, Manganaris, & Crisosto, 2014). Processing can stabilize perishable foods, but also induce changes in their physical and chemical properties (Muthukumarappan & Tiwari, 2010). Several vegetables are also subjected to a cooking step which may also affect their composition (Faller & Fialho, 2009).

Some studies have reported increases in the antioxidant capacity (AC) of processed vegetables compared to their raw counterparts (Chang, Lin, Chang, & Liu, 2006; Ferracane et al., 2008; Pellegrini et al., 2009). However, in most cases vegetable nutritional quality has been shown to decrease after processing and cooking (Faller & Fialho, 2009). The changes occurring are largely dependent on the nature and schedule (time, temperature) of the treatment applied (Rickman, Barrett, & Bruhn, 2007). However, they may be also modulated by the properties of the plant material. Chaovanalikit and Wrolstad (2004) reported that the loss of phenolic compounds of two cherry cultivars subjected to brining treatments showed marked differences. Georgé et al. (2011) found higher losses of phenolics in yellow tomato than in red varieties upon freeze-drying. Moreover, the stability of phenolic compounds during frozen storage varied between early- and late-harvested raspberries (González, de Ancos, & Cano, 2003).

Eggplants (*Solanum melongena* L.) are very popular vegetables worldwide (Gramazio et al., 2014). American purple fruit are the most commonly marketed type, though white cultivars have

* Corresponding author. CIDCA, Calle 47 y 116, CP 1900, La Plata, Argentina.
E-mail address: maria.zaro@agro.unlp.edu.ar (M.J. Zaro).

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gained acceptability in recent years. Eggplants have received great attention due to their high AC (Whitaker & Stommel, 2003). Though purple pigmented eggplants contain potent antioxidant anthocyanins (delphinidin derivatives), their participation in total fruit AC is limited given that the peel represents less than 5% of the total fruit weight (Plazas et al., 2013a; Prohens et al., 2013). Flavonoids only represent about 10–15% of total phenolics (Zaro, Keunchkarian, Chaves, Vicente, & Concellón, 2014) and hydroxycinnamic acid derivatives, particularly free chlorogenic acid (CQA, 5-O-caffeoylquinic acid) has been found to be the major phenolic antioxidant regardless of the genotype (Plazas et al., 2013b; Zaro et al., 2014). CQA steady-state content in eggplant is influenced by both genetic and environmental factors, including the fruit developmental stage, cultivar, crop management and postharvest handling conditions (Concellón, Zaro, Chaves, & Vicente, 2012). Moreover, eggplants are quite versatile vegetables and could be subjected to a number of different processing and cooking methods which may further affect fruit AC (Nisha, Abdul Nazar, & Jayamurthy, 2009). Understanding the influence of cultivar on antioxidant retention upon processing and cooking may be highly relevant for selecting better genotypes for industrial purposes and/or to determine the more appropriate preparations methods to prevent losses of bioactive compounds. The aim of the present work was to determine the influence of the eggplant variety (white 'Cloud Nine' and purple 'Lucia') on CQA and AC retention in response to the most common processing and cooking methods.

2. Materials and methods

2.1. Plant material and sample preparation

Purple and white eggplants (*S. melongena* L.) cv. Lucía and Cloud Nine, respectively, grown in greenhouses in La Plata (Argentina) were harvested at commercial maturity and immediately transported to the laboratory. Fruits were selected and then washed for 3 min in water containing 100 mg L^{-1} NaClO (pH 6.5), drained and transversally cut with a sharp knife into 8 mm-thick slices. For each pre-processing, processing and cooking methods described below at least 12 slices from the equatorial region of 6 different fruits were used. The fruit pulp was then frozen in liquid N_2 and stored at −80 °C until used for AC and CQA determinations. Three experiments with fruit from independent harvests were analyzed for every processing method.

2.2. Pre-processing treatments

(1) Cutting and delayed-processing: Eggplant slices were placed in a dish and left at room temperature (20 °C) for 60 min to simulate the holding time before processing (Table 1).
(2) Salting: Eggplant slices were placed for 90 min in a plastic tray and covered with salt (300 g) on both sides (Table 1).
(3) Blanching: Eggplant slices were blanched in boiling tap water for 1.5 min in a stainless-steel pot (food/water ratio 1:10 (w/v)) (Table 1). After the treatment samples were immediately cooled in ice.

2.3. Processing methods

(1) Air-drying: Eggplant slices were placed in perforated stainless steel trays and dried in a laboratory tunnel dryer equipped with an *in situ* weighing system (Demarchi, Quintero Ruiz, Concellón, & Giner, 2013) at 50 (AD_{50}) or 70 °C (AD_{70}) (air speed of 2.5 m s^{-1}) (Table 1). Samples were weighed automatically every 60 min until constant weight.
(2) Vacuum-drying: Fresh eggplant slices were vacuum-dried at 70 °C (5 kPa) (Table 1) in a vacuum oven (DZF-6021, Yiheng, China).
(3) Solar-drying: Fresh eggplant slices were placed into a small-scale solar dryer (60 × 40 × 15 cm). Slices were supported on a metal grid for 16 h of effective solar time, over 2 consecutive days (Table 1).

For all methods samples were drying to a final moisture content of 100 ± 10 g/kg (Doymaz, 2011).

(4) Freeze-drying: Eggplant fruit slices were frozen at −80 °C and then freeze-dried (Heto FD 4, Waltham, Belgium) (Table 1).
(5) Slow-freezing: A domestic freezer (F1606, Diplomatic, Argentina) was used. Eggplant slices were placed in plastic trays and frozen until reaching an internal temperature of −20 ± 2 °C (Table 1).
(6) Fast-freezing: Eggplant slices were frozen in a prototype plate freezer (Campañone, Roche, Salvadori, & Mascheroni, 2006), until reaching an internal temperature of −20 ± 2 °C (Table 1).

2.4. Cooking methods

(1) Microwaving: A domestic microwave (JT 359, Whirpool, Argentina) was used. Eggplant slices were placed in a dish and covered with PVC film (20 μm thick) and heated (350 W) for 10 min (Table 1).
(2) Baking: Eggplant slices were placed in a steel tray and cooked for 40 min at 140 °C (20 min on each side) in an electric oven (FM 87 C, Ariston, Italy) (Table 1).
(3) Grilling: Eggplant slices were placed in a grilling plate for 14 min (7 min on either side) (Table 1).
(4) Steaming: Samples were cooked in a vertical steamer (Exotic Ama 351, Moulinex, China). The steam chamber was previously equilibrated for 5 min, then the samples were cooked for 10 min(Table 1).
(5) Pressure cooking: Eggplant slices were prepared in a stainless-steel pressure cooker (food/water ratio 100 g/L) for 2 min (Table 1).

Table 1
Summary of different pre-processing, processing and cooking conditions (time and temperature) tested.

Pre-processing			Processing			Cooking		
	t (min)	T (°C)		t (h)	T (°C)		t (min)	T (°C)
Cutting + delay (CD)	60	20	Air-drying (AD_{50})	6	50	Steaming (ST)	10	100
Blanching (BL)	1.5	100	Air-drying (AD_{70})	4.5	70	Pressure cooking (PR)	2	121
Salting (SA)	90	20	Vacuum-drying (VD)	4	70	Boiling (BO)	8	100
–	–	–	Solar-drying (SD)	16	40	Microwaving (MI)	10	175
–	–	–	Slow-freezing (SF)	3	−20	Baking (BA)	40	140
–	–	–	Fast-freezing (FF)	1.5	−20	Grilling (GR)	14	175
–	–	–	Freeze-drying (FD)	48	−80	–	–	–

(6) Boiling: Eggplant slices were cooked in boiling tap water in a covered stainless-steel pot (food/water ratio 100 g/L) for 8 min (Table 1).

Immediately after each cooking method samples were cooled on ice.

2.5. Analytical measurements

2.5.1. Dry matter

Eggplant slices (3 g) were dried on vacuum oven at 70 °C and 2.5 kPa for 48 h until constant weight. Results were used to calculate the AC and CQA content on dry weight basis. Six replicates were done for each cultivar and treatment.

2.5.2. Antioxidants extraction

Frozen fruit tissue was ground in a mill and 1 g of powder was transferred to a tube containing 5 mL ethanol. The suspension was mixed for 30 min and then centrifuged at 14,000 × *g* for 10 min at 4 °C. The supernatant was collected and the pellet was re-extracted with 5 mL ethanol and centrifuged as described above. The supernatants were pooled and used for AC determinations. A portion of the same extract was concentrated using a rotary evaporator (R-124 Labortechnik AG, Büchi, Switzerland) at 40 °C, the residue was re-suspended in 2 mL of 100 mL L^{-1} methanol and used for the analysis of CQA content by HPLC. Three replicates were performed for each cultivar and treatment assayed.

2.5.3. Antioxidant capacity

The $ABTS^{\bullet+}$ assay was performed as described by Arnao, Cano, and Acosta (2001). Fifty microliters of ethanolic fruit extracts prepared as described above were added to 1 mL of $ABTS^{\bullet+}$ working solution (absorbance of 0.700 ± 0.02 at 734 nm), incubated for 6 min and the absorbance at 734 nm was measured in a spectrophotometer (UV-mini 1240, Shimadzu, Japan). Trolox® was used as antioxidant standard and results were calculated on a dry weight basis and subsequently expressed as percent retention of Trolox Equivalent Antioxidant Capacity (TEAC) relative to the initial content. Measurements were done in triplicate.

2.5.4. Chlorogenic acid

Sample preparation was performed according to Concellón et al. (2012). Chromatographic analyses were carried out on an HPLC system (HP 1100 Agilent Technologies, Hewlett Packard, USA) employing a C18 reverse phase column (750 × 4.6 mm, XSelect CSH C18, Waters, USA). The elution was performed using as mobile phase mixtures of A (4 mL L^{-1} formic acid) and B (methanol). The gradient used was 0–15 min: 5–35% B; 15–35 min: 35–65% B. The flow rate was set at 0.5 mL min^{-1}, the injection volume was 20 μL and the detection was set at 320 nm. A calibration curve was done with a standard CQA. . Results were calculated on dry basis and subsequently expressed as percent retention of CQA relative to the initial content. Measurements were done in triplicate for each cultivar and treatment.

2.6. Statistical analysis

The experiments were carried out in a completely randomized design. Results were subjected to analysis by ANOVA and means were compared by a Fisher test at $P < 0.05$.

3. Results and discussion

3.1. Appearance and antioxidant characteristics of fresh eggplant slices

Anthocyanins are potent antioxidants present in the peel of purple eggplants at high concentration (Wu et al., 2006). However, since the peel represents only a small proportion of fruit weight its contribution to total fruit AC is limited. Consequently, in this work we focused on the evaluation of the retention of pulp antioxidants in pigmented and not pigmented cultivars. We use the TEAC method, a commonly employed test that specifically evaluates the ability of the hydrophilic antioxidants to scavenge radical, to determine de AC. Further, we assayed specifically the CQA content by HPLC method, due the high correlation between this determination and the spectrophotometric measure of total phenolic content observed in previous works for eggplant fruit (Plazas et al., 2013b). TEAC of purple eggplant was higher than that of white fruit (Fig. 1A). CQA content was 16% higher in colored eggplants (Fig. 1B). Fig. 1C and D represented the characteristic appearance of fresh purple and white eggplant slices, respectively.

3.2. Antioxidant retention of eggplant slices subjected to different pre-processing methods

Enzymatic browning is one of the main problems during eggplant processing, starts immediately after cutting and rapidly increases as fruits are exposed to air (Mishra, Gautam, & Sharma, 2013). This is relevant at the industry level, where there may be some delay between cutting and further processing steps. In general, the industry could use additional antioxidants to minimize oxidative browning during holding steps. However, due to consumer concerns there is a trend to reduce the use of food additives. Incipient browning was detected in both cultivars after cutting and delayed processing (Fig. 2A). A 1 h delay caused a 25% drop of AC regardless of the genotype (Table 2). In white eggplants, the decrease in TEAC occurred with no changes in the CQA content (Table 3), suggesting that other phenolics are preferentially metabolized by browning reactions. Although the extent of browning has been related with the level of phenolic, results found herein show that eggplant browning is limited by tissue integrity rather than with either substrate or enzyme availability (Concellón,

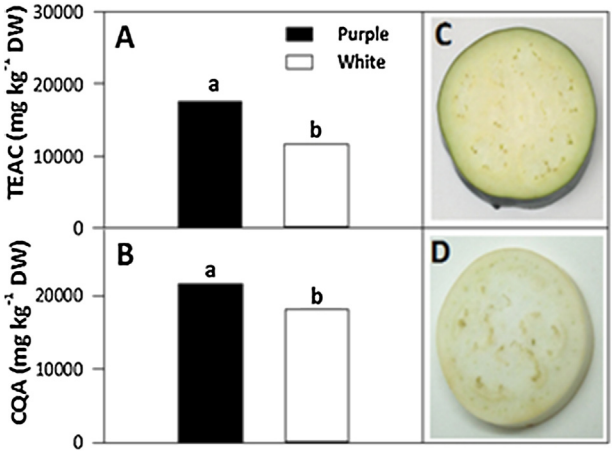
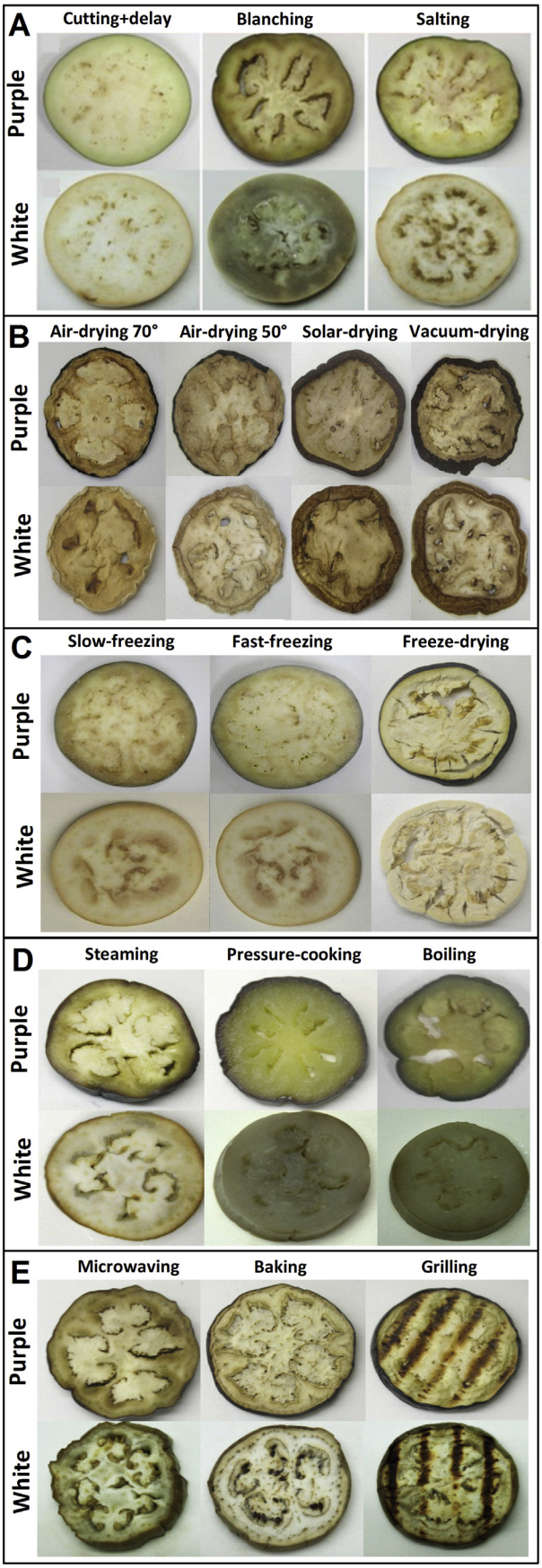


Fig. 1. A) Pulp antioxidant capacity (TEAC), **B)** chlorogenic acid (CQA) content and appearance of fresh **C)** purple 'Lucia' and **D)** white 'Cloud Nine' eggplant slices. Values with different letters indicate significant differences according to a Fisher least significant difference test ($P < 0.05$) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).



Añón, & Chaves, 2007; Mishra et al., 2013). The lack of browning differences between cultivars, despite of their variable level of CQA content, supports this.

Blanching is one of the most common pre-treatments used to control enzymatic browning by thermal inactivation of polyphenol oxidases (PPOs) and peroxidases (PODs) (Fernández Fraguas, 2009). Significant loses of antioxidants were found in blanched slices. However, for both genotypes AC drop was lower than that of CQA (Tables 2 and 3). This may be to a partial solubilization of bound phenolics during treatment as shown in other products also rich in CQA (Pellegrini et al., 2009). In turn, the significant losses of CQA found in blanched slices, with retention values of 80% and 50% in white and purple eggplants, respectively (Table 3), occurred in absence of enzymatic browning (Fig. 2A). Despite of this, some color changes were found in blanched eggplants probably due to the formation of iron-CQA complexes, similar to what occurs in the darkening of boiled potatoes (Wang-Pruski & Nowak, 2004).

Salting is a pre-processing treatment traditionally applied prior to domestic eggplant cooking. It is used to reduce the level of the bitter glycoalkaloids solasonine and solamargine (Blankemeyer, Mcwilliams, Rayburn, Weissenberg, & Friedman, 1998). However, the influence of this practice on the content of antioxidant compounds has not been reported. The salting treatment partially dehydrated the fruit (Fig. 2A) and caused a significant loss of AC. This was more evident in purple eggplants in which TEAC and CQA content dropped by as high as 50% (Tables 2 and 3). The correlation between the drop of TEAC and CQA points to caffeoyil-quinnic derivatives as the main phenolics compounds lost during the osmotic dehydration treatment. Noteworthy, no antioxidant losses were detected in white eggplants, indicating the effects of the vegetable matrix. Consequently the selection of cultivars must consider the availability and content of these compounds under the final use conditions.

3.3. Antioxidant retention of processed eggplant slices

3.3.1. Drying

Drying is one of the most widespread preserving procedures in the food industry. It markedly increases product shelf life while decreasing packaging and transport costs (Chang et al., 2006). Fruits and vegetables drying is a common strategy to extend produce consumption throughout the year. However, in some cases it has been shown to reduce the nutritional value (Gümüşay, Borazan, Ercal, & Demirkol, 2015). In eggplant, the influence of air- and vacuum-drying on purple cultivars was reported (Akpinar & Bicer, 2005; Brasiello et al., 2013; Doymaz, 2011). However, no works have determined differences in antioxidant retention among cultivars. Drying caused significant tissue shrinkage and induced substantial browning (Fig. 2B). High losses (80–98%) of TEAC and CQA content occurred regardless of the drying method (Tables 2 and 3). In this case the effect of the treatments was higher than that of the fruit genotype. Drying at 50 °C (AD_{50}) caused greater losses of phenolics antioxidants than at 70 °C (AD_{70}). Though dehydration at milder temperatures may appear *a priori* better in terms of retention of phenolics, it will extend the drying period and may in some cases lead to higher losses in non-blanched tissues due to enzymatic browning (Kerkhofs, Lister, & Savage, 2005; McSweeney & Seetharaman, 2015). Instead, higher drying temperatures inactivating or at least inhibiting PPO-mediated

Fig. 2. Appearance of slices of purple 'Lucia' and white 'Cloud Nine' eggplants subjected to pre-processing **(A)**, drying **(B)**, freezing **(C)**, wet cooking **(D)** and dry cooking **(E)** methods (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

Table 2
Trolox equivalent antioxidant capacity retention (%) in purple 'Lucia' and white 'Cloud Nine' eggplant pulp after different pre-processing, processing (drying and freezing) or cooking (wet and dry) methods. C: control; CD: Cutting + delay, BL: Blanching; SA: Salting; AD_{70}: air-drying at 70 °C; AD_{50}: air-drying at 50 °C; VD: Vacuum drying; SD: Solar drying; SF: Slow freezing; FF: Fast freezing; FD: Freeze-drying; ST: Steaming; PR: Pressure cooking; BO: Boiling; MI: Microwaving; BA: Baking; GR: Grilling. Values with different letters within a processing condition indicate significant differences based on a Fisher test at a level of significance of $P < 0.05$ ($n = 3$). The least significant difference (LSD) is shown.

	Pre-processing			Drying			Freezing			Wet cooking			Dry cooking	
	Purple	White		Purple	White		Purple	White		Purple	White		Purple	White
C	100a	100a	C	100a	100a	C	100a	100a	C	100d	100d	C	100b	100b
CD	84b	75b	AD_{70}	21b	22b	SF	41c	57b	ST	165a	144b	MI	83bc	129a
BL	77b	100a	AD_{50}	9d	11cd	FF	57b	96a	PR	102cd	174a	BA	69c	71c
SA	58c	97a	SD	20b	12cd	FD	47bc	29d	BO	120bc	139b	GR	122a	137a
	–	–	VD	13c	12cd		–	–		–	–		–	–
LSD = 10.8			LSD = 3.8			LSD = 9.6			LSD = 18.2			LSD = 17.5		

Table 3
Chlorogenic acid retention (%) in purple 'Lucia' and white 'Cloud Nine' eggplant pulp after different pre-processing, processing (drying and freezing) or cooking (wet and dry) methods. C: control; CD: Cutting + delay, BL: Blanching; SA: Salting; AD_{70}: air-drying at 70 °C; AD_{50}: air-drying at 50 °C; VD: Vacuum drying; SD: Solar drying; SF: Slow freezing; FF: Fast freezing; FD: Freeze-drying; ST: Steaming; PR: Pressure cooking; BO: Boiling; MI: Microwaving; BA: Baking; GR: Grilling. Values with different letters within a processing condition indicate significant differences based on a Fisher test at a level of significance of $P < 0.05$ ($n = 3$). The least significant difference (LSD) is shown.

	Pre-processing			Drying			Freezing			Wet cooking			Dry cooking	
	Purple	White		Purple	White		Purple	White		Purple	White		Purple	White
C	100a	100a	C	100a	100a	C	100a	100a	C	100e	100e	C	100b	100b
CD	74c	97 ab	AD_{70}	14b	12c	SF	45d	49c	ST	128b	122bc	MI	80d	111a
BL	48d	82bc	AD_{50}	1.9de	2.3de	FF	51c	57b	PR	112cd	141a	BA	54e	62e
SA	52d	87abc	SD	12c	1.6e	FD	42d	14e	BO	77f	109de	GR	89c	104 ab
	–	–	VD	3.4d	2.2de		–	–		–	–		–	–
LSD = 15.9			LSD = 1.5			LSD = 2.6			LSD = 11.7			LSD = 7.9		

oxidation of phenolics may be beneficial for certain commodities.

3.3.2. Freezing

Freezing has been shown to cause lower losses of phenolic antioxidant than other thermal processing, but the freezing rates could have large impact on antioxidant stability (Rickman et al., 2007). Changes in antioxidants during eggplant freezing were reported by Otero, Solas, Sanz, Elvira, and Carrasco (1998) and Wu, Ogawa, and Tagawa (2008). However, in these works the influence of the genotype was not assessed. Both slow and fast freezing resulted in higher losses of AC and CQA in purple eggplants (Tables 2 and 3). However slow-freezing caused more browning than fast-freezing upon thawing (Fig. 2C). White eggplants showed a tendency to brown in the core region as opposed to purple fruit which showed a higher tendency to brown below the peel (Fig. 2C).

Freeze-drying is generally assumed to yield premium products with high quality and shape retention (Ratti, 2001). In eggplant, freeze-drying favored some radial tissue cracking (Fig. 2C) and though it did not induced browning it caused a marked drop of fruit antioxidants (Tables 2 and 3). Some works in other species have reported reductions in phenolics antioxidants during freeze-drying operations (Shofian et al., 2011). This has been associated with cellular decompartmentalization during pre-freezing step (Chang et al., 2006), followed by the reaction of phenolics with proteins in the dehydration process, which could subsequently affect their extractability (Martín-Cabrejas et al., 2009). Abascal, Ganora, and Yarnell (2005) concluded that systematic research is needed to determine that freeze-drying does not affect the composition of the plant material, especially regarding on phenolics and volatiles. In contrast to most other processing methods tested, improved antioxidant retention was found in purple freeze-dried eggplants (Table 2). CQA retention reached only 50 and 30% in purple and white fruits, respectively (Table 3). Yellow and red tomatoes have been also shown to respond differently to freeze-drying. Georgé et al. (2011) suggested in this case that the differences in carotenoid types could affect the stability of other antioxidants within the plant matrix.

3.4. Antioxidant retention of cooked eggplant slices

3.4.1. Wet and dry cooking methods

Although usually studies evaluated the antioxidant properties of raw vegetables, some cooking procedures are mandatory in many species. We tested a number of different wet (Fig. 2D) and dry cooking methods (Fig. 2E). TEAC values and CQA content increased significantly after wet cooking procedures: steaming, pressure cooking and boiling (Tables 2 and 3). This effect could be in part due to an increased extractability of phenolics in wet cooked soft tissues. The availability of tomato antioxidants has also been reported to increase after heat treatments by Hedrén, Diaz, and Svanberg (2002). Our results are consistent with those of Ferracane et al. (2008) in phenolics rich artichoke heads, who found an increase in AC upon cooking. The rise in TEAC and CQA in eggplants could be in part due to the release of phenolic compounds bound to the cell walls. Addressing this would require further studies. The changes in AC varied not only depending on the cooking method but also on the cultivar. For boiling and pressure cooking white eggplants showed higher levels of TEAC and CQA than purple fruit (Tables 2 and 3).

Dry cooking methods showed a slightly different performance (Tables 2 and 3). Grilled eggplants showed higher TEAC than raw fruit. Das et al. (2011) also showed that grilled eggplant presented higher cardio-protective capacity that uncooked fruit. This was suggested to result from *the novo* synthesis of Maillard intermediates with antioxidant properties (Lo Scalzo et al., 2010). Moreover, white fruit showed higher TEAC than purple eggplants

after microwaving and grilling. Finally, baking was the only dry cooking treatment causing significant reductions in TEAC and CQA (Tables 2 and 3).

4. Conclusion

All the pre-processing treatments tested (cutting, blanching and salting) led to relatively high losses of antioxidants in eggplant fruit. The decrease on AC was a function of the genotype; white 'Cloud Nine' fruit showing in most cases a better performance than purple 'Lucia' eggplants. The processing method and schedule exerted a significant effect on the CQA retention. Drying reduced fruit AC by 80–100%, with no differences between cultivars. Similarly to other commodities, fast freezing decreased antioxidant losses compared to slow freezing, but unexpectedly freeze-drying also caused high losses of CQA. Interestingly, wet cooking methods and grilling increased eggplant AC on a dry weight basis. The white cultivar also kept higher AC than dark fruit upon cooking. Though further work considering a greater range of genotypes is necessary, results show that the eggplant variety has large influence on the extractability and stability of pulp phenolic antioxidants in response to pre-processing, processing and cooking conditions. This should be taken into account when selecting genotypes for processing on the basis of their potential health promoting properties.

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