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Quality of Brussels sprouts (*Brassica oleracea* L. *gemmifera* DC) as affected by blanching method

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Abstract

In this work, pre-blanching of Brussels sprouts was performed – using different heating media – as well as various blanching times, in order to minimize quality factors losses and browning incidence in subsequent stages of product processing and storage. Sprouts were firstly treated for 5 min, either in water at 50 °C or by microwaves, and then blanched in boiling water for 3 or 2 min, respectively. Other samples were directly blanched by immersion in water (100 °C) for 1, 3 or 4 min. Thermal history, surface colour, texture, total chlorophyll, radical scavenging activity, ascorbic acid and total flavonoids content were determined. Microwaves pre-blanching showed no deleterious effects on total chlorophyll, radical scavenging activity, total flavonoids and ascorbic acid content of Brussels sprouts and the moderate heat treatment induced by this method may be considered to be a useful tool to improve health properties of Brussels sprouts.

Keywords: Blanching; Surface colour; Texture; Antioxidant compounds

1. Introduction

It is a well known fact that – although freezing allows vegetables preservation for long periods of time – certain quality attributes like texture, flavour and nutrients content are affected during frozen storage of untreated vegetables. This is due to the action of enzymes, which remain active even at temperatures below 0 °C. As an example, in Brussels sprouts kept at constant controlled temperatures, changes in quality indexes related to colour, flavour and overall appearance become to be clearly evident between 8 and 12 storage weeks at −12 °C, 24 and 32 weeks at −15 °C, and 32 and 40 weeks at −18 °C (Lyon, McEwan, Taylor, & Reynolds, 1988).

The usual technique to inactivate enzymes is blanching prior to freezing. Blanching consists in heating at high temperature (generally in water at 85–100 °C or with steam, less frequently with microwaves, radiofrequency or infrared radiation). Short times of exposure are effective to reduce the incidence of degradation reactions during storage. However, blanching also produces modifications in cellular structure and composition (Philippon, 1984). Several assays are needed to find the most adequate technology and processing time for each particular product, in order to inactivate the enzyme/s responsible for the main quality damage, minimizing, at the same time, undesirable losses of quality attributes. In that respect, it is important to identify which is the main enzyme that determines the spoilage and its inactivation kinetic in the studied species and variety (Barrett & Theerakulkait, 1995; Philippon, 1984; Williams, Lim, Chen, Pangborn, & Whitaker,

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1986). Generally, peroxidase is used as an indicator enzyme since it exhibits a high thermal resistance. Its total destruction ensures inactivation of the other existent enzymes. Nevertheless, cited studies demonstrate that this enzyme is not generally responsible for the main degradation reactions, but other more sensible enzymes, e.g. lipoxygenase. Therefore, blanching until total peroxidase inactivation generally implies over-processing with consequent unnecessary quality losses, mainly of texture. For example, it is recommended to blanch Brussels sprouts until a loss of peroxidase activity of 89.5–92.5% is achieved (Williams et al., 1986).

Brussels sprouts are vegetables normally frozen with the aim of favouring their consumption, since they have a characteristic flavour and texture and excellent nutritional properties. Their spherical shape makes blanching difficult since, to reach the effective temperature at the head centre and to ensure enzymatic inactivation, the most external parts of Brussels sprouts must be processed for long times at high temperatures. This produces unavoidably a 'cooking' process that affects mainly the structure, besides inducing other physical and chemical changes (Canet, Gil, Alique, & Alonso, 1991). It has been reported that maintaining flavour without producing appreciable colour damage is one of the limiting features of blanching process of this vegetable (Dietrich, Huxsoll, & Guadagni, 1970). Thereby, many time and temperature combinations have been applied in Brussels sprouts blanching, either in water or with steam (Canet et al., 1991; Dietrich et al., 1970; Wathelet, Mabon, Foucart, & Marlier, 1996). It was determined that blanching times needed to totally inactivate enzymes were approximately 10 min in water at 97 °C (Canet et al., 1991) and ca. 6–8 min with steam (Dietrich et al., 1970). However, such conditions produced important texture losses as well as lixiviation, in the water treatment case.

Thus, different combined treatments involving shorter exposing periods in boiling water or steam have been also employed. Dietrich and Newmann (1965) suggested that pre-blanching (a heating previous to blanching) at 50 °C would reduce blanching time and/or organoleptic quality loss of the final product.

In most of the cited works, enzymatic activity as well as colour and texture attributes were measured, but not in all cases ascorbic acid or other antioxidant compounds content variations were followed during processing.

It is well known that in normal conditions, production of reactive oxygen species (ROS) such as singlet oxygen, superoxide radical, hydrogen peroxide and hydroxyl radical, is low in plant cells, but different damage factors can modify cellular homeostasis and notoriously stimulate the generation of that species (Mittler, 2002). Plants have developed a complex antioxidant system in order to prevent ROS injurious effects. This system involves enzymatic as well as non-enzymatic compounds (Lascano, Melchiorre, Luna, & Trippi, 2003). Non-enzymatic elements of plant antioxidant system are mainly represented by ascorbate, glutathione and several phenolic compounds (Tewari, Kumar, Sharma, & Bisht, 2002). Importance of analyzing stability of antioxidant components during processing lies on their beneficial effects for health and their implication in prevention of cancer and cardiovascular diseases (Ewald, Fjelkner-Modig, Johansson, Sjöholm, & Akesson, 1999).

The objective of the present work was to study the influence of several blanching methods on different Brussels sprouts quality factors, such as colour, texture and concentration of antioxidant compounds, with the aim of determine the conditions that maximize retention of that features.

2. Materials and methods

2.1. Plant material

Brussels sprouts (*Brassica oleracea* L. *gemmifera* DC) cultivar Oliver, field-grown in the horticultural belt of La Plata city (Buenos Aires Province, Argentina) were used. Sprouts were harvested early in the morning and immediately carried to the laboratory, where they were selected according to a uniform size and absence of physical damage and disease symptoms. External leaves and approximately 2 mm of the insertion zones were eliminated. Each sprout head weighed near 25.1 ± 3.4 g and measured approximately 35.8 ± 0.22 mm width and 49.2 ± 0.16 mm height.

2.2. Treatments

Treatments were selected according to literature data cited in Section 1. The exposition times were chosen in order to determine the minimum and maximum periods needed to avoid deleterious changes (mainly browning of tissues) and to retain quality attributes and nutritional components of interest.

Two types of pre-treatments were applied, according to the heating media: (a) immersion in water at 50 °C for 5 min followed by blanching in boiling water for 3 min (PB) or (b) microwave heating in an oven (BGH Quick Chef Sensor Infrared Model 17950, Argentina) at 700 W for 5 min, followed by blanching in boiling water for 2 min (MW). These are both referred to as *combined treatments*.

Also, three different periods were assayed for direct blanching of Brussels sprouts by immersion in water (100 °C): (c) 1 min (B1), (d) 3 min (B3) or (e) 4 min (B4). To minimize temperature lowering of the blanching bath, approximately 250 g of the product were dipped in 5 L boiling water. After complete treatment application, samples were immediately cooled by immersion in an ice-water bath for 3 min. Non-treated samples of fresh Brussels sprouts were maintained as controls (C). Treatments were carried out at least twice.

2.3. Determinations

2.3.1. Thermal history of samples

Sample temperature was measured by type *T* thermocouples (Omega®, New Jersey, USA) inserted at 1.5 cm from the base of each sprout and connected to a Keithley KDAC 500 data acquisition and control system. An additional thermocouple was used to register the temperature of the water near the sample. The system allows temperature to be controlled with an accuracy of ±0.5 °C.

2.3.2. Texture

Firmness of Brussels sprouts was measured with a texturometer TA-XT2i (Stable Micro Systems Ltd., Godalming, Surrey, UK) operating in the compression mode and using a 25 kg load cell. The equipment was fitted with an aluminium compression plate (75 mm in diameter) and samples were laterally compressed at a constant rate of 1 mm s^{-1}. Curves of force (N) as a function of deformation (mm) were automatically recorded by the Texture Expert® Exceed software. The force necessary to compress 3 mm the sprouts heads was registered. Each informed value corresponds to the mean of at least 10 determinations. Results were expressed as relative values (%) and were calculated as the ratio between the maximum force (N) registered for each treatment (i) and the maximum force (N) corresponding to fresh Brussels sprouts (controls).

2.3.3. Surface colour

Colorimetric measurements were performed in three different positions on sprouts heads as well as in the cut zones (bases) and were carried out with a Minolta colorimeter CR 300 Series (Osaka, Japan) calibrated with a standard white plate ($Y = 93.2$, $x = 0.3133$, $y = 0.3192$). The CIE Lab scale was used, taking into account the L^*, a^* and b^* co-ordinates. Also, hue angle ($h = \tan^{-1}(b^*/a^*)$) and Chroma $C = [(a^{*2} + b*^2)]^{1/2}$ were calculated. Each informed value corresponds to the mean of at least 10 determinations. Results were expressed as relative values (%) and were calculated as the ratio between the parameter registered for each treatment (i) and the one corresponding to fresh Brussels sprouts (controls).

2.3.4. Chemical analysis

For each treatment and control samples, approximately 250 g of product were homogenized, frozen in liquid N_2 and immediately crushed in a laboratory mill (Janke & Kunkel Ika Labortechnik A10, Staufen, Germany). Samples of the frozen powdered material were taken to obtain the corresponding extracts.

Total chlorophyll content. Extractions were carried out in 80% v/v acetone at 0 °C from 0.6 g of the frozen powder obtained. After centrifugation at $9000 \times g$ for 10 min at 4 °C, aliquots of the extracts were taken to determine chlorophyll content by spectrophotometry. Absorbance readings were conducted at 646.8 and 663.2 nm. Total chlorophyll, chlorophyll *a* and chlorophyll *b* concentrations were determined according to Lichtenthaler (1987). Four replicates of extractions were performed. Results were expressed as relative values (%) and were calculated as the ratio between the chlorophyll content (μg g^{-1} fresh tissue) registered for each treatment (i) and the one corresponding to fresh Brussels sprouts (controls).

Radical scavenging activity. Extractions were carried out in 5 mL ethanol 96° from 1 g of the frozen-crushed tissue. The radical scavenging activity of the extracts was determined by reaction with the stable radical 2,2-diphenyl-1-picrylhydrazyl (DPPH·), using a modified version of the method proposed by Brand-Williams, Cuvelier, and Berset (1995). Concentration of the extracts was varied in the reaction mixtures, containing a fixed volume of a DPPH· solution (25 ppm) and completing final volume with ethanol. The reaction was allowed to progress and absorbance was measured at 515 nm after a constant value was reached. Then, remaining DPPH· concentration was calculated through a calibration curve obtained in a range of concentrations. Finally, the DPPH· concentration was plotted as a function of the extract volume in the reaction mixture, in order to calculate EC_{50} (effective mean concentration) for each sample. Extractions and determinations were carried out in duplicate. Results were expressed as relative values (%) and were calculated as the ratio between the radical scavenging activities (μmol DPPH·/100 g fresh tissue) registered for each treatment (i) and the one corresponding to fresh Brussels sprouts (controls).

Ascorbic acid content. Samples were taken from the frozen-crushed material, which were weighed accurately to 1 g each, and extracted in 5 mL aqueous solution of citric acid 3% w/v. After 10 min, they were centrifuged at $9000 \times g$ for 10 min at 4 °C. Aliquots (1 mL) of supernatants from each extract were centrifuged again in an Eppendorf 5415C centrifuge for 2 min at 14,000 rpm. Ascorbic acid quantification was carried out in a Waters Model 6000A (Milford, MA, USA) high-performance liquid chromatograph, fitted with an UV–VIS detector, according to the method proposed by Wimalasiri and Wills (1983). A C18 column Ultrasphere ODS (Beckman Instruments, Inc., San Ramón, CA, USA) was employed (particle diameter, 5 μm; internal diameter, 4.6 mm; length, 25 cm). The mobile phase was a 70:30 mixture of acetonitrile:water with 0.01 M $NH_4H_2PO_4$ and pH adjusted to 4.3 with orthophosphoric acid. Flow rate was 2 mL min^{-1} and detection was carried out at 254 nm. For identification and quantification, a standard ascorbic acid solution was employed. Extractions and determinations were carried out by duplicate. Results were expressed as relative values (%) and were calculated as the ratio between the ascorbic acid content (mg/100 g fresh tissue) registered for each treatment (i) and the one corresponding to fresh Brussels sprouts (controls).

Total flavonoids content. It was determined by the technique described by Kim, Jeong, and Lee (2003). Samples (10 g of frozen tissue) were extracted with 25 mL ethanol 96° and extracts were concentrated at reduced pressure (30 mm Hg, 40 °C) in a rotary evaporator R-124 (Büchi

Labortechnik AG, Flawil, Switzerland) until dryness. Residues were resuspended in doubly distilled water. To prepare reaction mixtures, a test tube was added with 1500 μL of doubly distilled water and 500 μL of the concentrated samples. Reagents were added sequentially: at zero time a volume of 150 μL of 5% $NaNO_2$; after 5 min, 150 μL of 10% $AlCl_3$ and finally, after 11 min, 500 μL of 1 M NaOH. Solutions were mixed by stirring in a vortex and then absorbance at 510 nm was measured. A standard curve was constructed based on catechin concentrations in the range of 7–37 μg mL^{-1}. Extractions and determinations were conducted in duplicate. Results were expressed as relative values (%) and were calculated as the ratio between the total flavonoids content (mg catechin/100 g fresh tissue) registered for each treatment (i) and the one corresponding to fresh Brussels sprouts (controls).

2.4. Statistical analysis

Data were subjected to analysis of variance (ANOVA). Comparison of means was conducted with the Fisher's least significant difference (LSD) test, at a significance level $p = 0.05$.

3. Results and discussion

3.1. Thermal history of samples

Thermal history of Brussels sprouts cores for different treatments is shown in Fig. 1. As can be seen, temperatures reached by sprouts samples at the thermal centre with PB and B4 treatments were the highest ones and were of the same order (83 and 80 °C, respectively). Canet et al. (1991) worked on sprouts of a size comparable to our assays and performed blanching in water at 97 °C. In that case, temperatures about 80 °C were achieved at the thermal centre when immersion time was 8 min, while 83 °C temperature values were reached when immersion was applied for 9 min. This implies that slightly lower blanching bath temperatures would require considerably longer exposition times, with the subsequent risk of lixiviation of nutrients compounds.

In the case of pre-blanching with microwaves (MW), when treatment was finished a temperature value of 74.4 °C was attained at sample core. Canet et al. (1991) performed a similar treatment of pre-blanching of Brussels sprouts in a microwave oven (5 min) followed by blanching in water at 97 °C (2 min). These authors reported a higher core temperature, equal to 86 °C.

In our assays, for B1 and B3 treatments, reached temperatures (41 °C and 66 °C, respectively) were too low and – as will be seen later – these core temperatures were not adequate to control browning of inner tissues.

3.2. Texture

Texture variations registered for different treatments are shown in Fig. 2. The maximum force measured in compression corresponded, in average, to 45.1 N for just harvested sprouts. When pre-blanching was applied, a significant

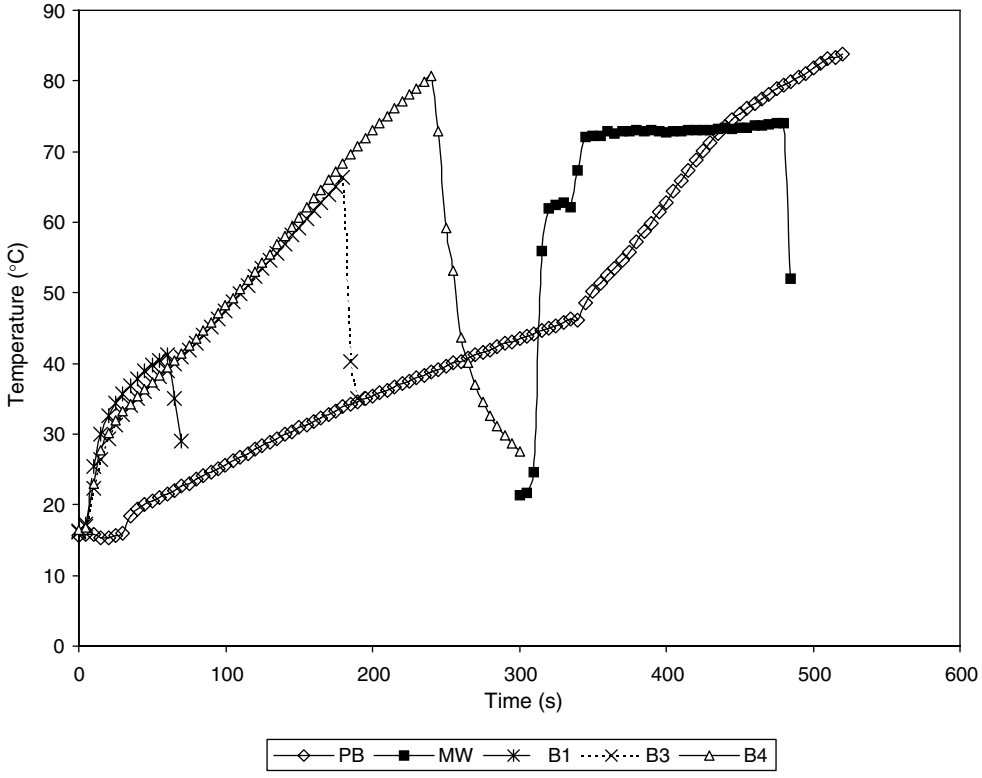

Fig. 1. Thermal histories of blanched Brussels sprouts.

reduction of firmness was observed: 84% and 81% for the water immersion (PB) and microwaves (MW) methods, respectively. Differences between both treatments were not significant ($p > 0.05$).

In relation to direct blanching, firmness decreased in a way approximately proportional to exposition time. For B1, firmness reduction was 60% respect to the control. Maximum force for this treatment resulted significantly higher than that verified in B3 and B4 treatments. Three and four minutes of blanching induced a decrease in maximum force of 80% and 86%, respectively.

When comparing to literature data, Canet et al. (1991) found out that a blanching in stages (water at 70 °C, 10 min, followed by cooling + immersion in water at 97 °C, 2 min) induced minor texture loss than conventional blanching (97 °C, 10 min), while no differences were found between a combined blanching (5 min in microwaves and 2 min in water at 97 °C) and the conventional processing. These authors also indicated that measurements of shear resistance showed lower values for samples blanched in boiling water than for samples blanched with microwaves, for the same treatment time.

3.3. Surface colour

Brussels sprouts heads colour. Colour corresponding to fresh sprouts was characterized by the following parameter values: hue (h) = 126.5°, Chroma (or brightness) = 43.1 and $L^* = 63.7$. Taking the CIE scale as reference, an angle of 90° represents the yellow hue. Objects with higher hue angles are more green (Gnanasekharan, Shewfelt, & Chinnan, 1992), as in this case.

In Fig. 3a, variation of L^* as affected by different treatments is represented. It can be seen that all of them induced significant decreases of L^* with respect to the control. A decrease in L^* is related to product lightness loss.

Both types of pre-processing (PB and MW), as well as the lower blanching (B1) time, produced a decrease of L^* parameter between 22% and 25%, existing no significant differences between both values. Values of L^* given by B3 and B4 treatments were 29.6% and 28.8% lower than that corresponding to the control, respectively.

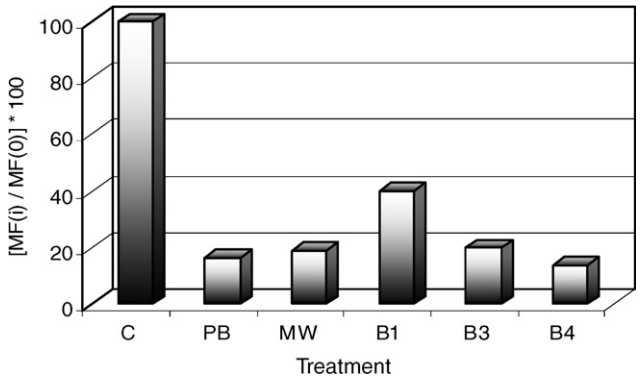

Fig. 2. Texture changes in blanched Brussels sprouts, referred to fresh product (controls) and expressed as percentage (%). MF: maximum force (N) for treated samples (i) or for controls (0). $LSD_{0.05} = 11.4$.

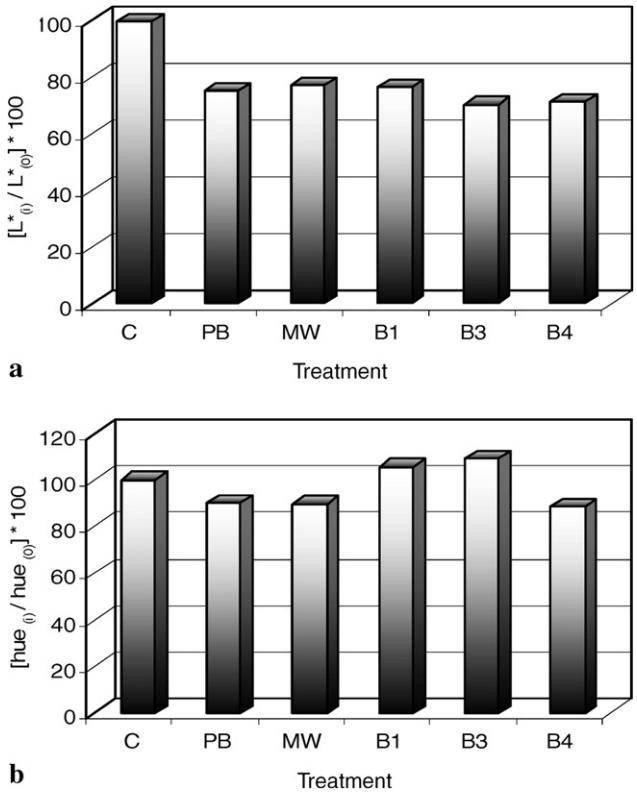

Fig. 3. Colour changes in blanched (i) Brussels sprouts heads, referred to fresh product (controls, 0) and expressed as percentage (%). (a) L^* (lightness); $LSD_{0.05} = 3.75$; (b) hue angle (basic tint); $LSD_{0.05} = 2.00$.

Changes of hue angle can be observed in Fig. 3b. Both pre-blanching methods (PB and MW) and blanching for 4 min induced the major hue angle variations respect to untreated sprouts (C) ($p < 0.05$), indicating a slight decrease of basic green tint. The values of co-ordinate a^* (green parameter) changed according to hue angle (data not shown).

Proportion of grey component characterizing colour is given by values of Chroma. As Chroma decreases, colour becomes less intense (Lancaster, Lister, Reay, & Triggs, 1997) changing – in our case – from a vivid to a dull green. Lower values of Chroma corresponded in our tests to the direct blanching treatments of minor duration (88.4% and 75.9% with respect to the control for B1 and B3, respectively) (data not shown).

Additionally to objective measurements of superficial colour, samples were visually inspected, making transversal cuts of them with the aim of evaluating the internal tissues state. Thus, it was detected that sprouts blanched for 1 and 3 min had suffered different degrees of browning, while those subjected to the rest of treatments had not. This agrees with determinations made by Canet et al. (1991), who indicated that Brussels sprouts blanched in boiling water (97 °C) for 1 and 3 min did not reach temperatures at thermal centre high enough to inactivate peroxidase enzyme.

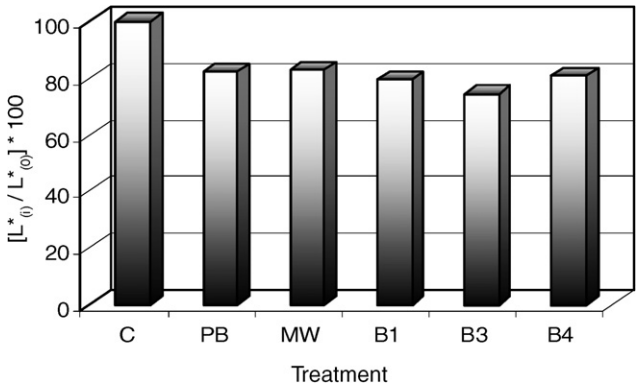

Fig. 4. Colour changes (L^*) in blanched (i) Brussels sprouts cut zones, referred to fresh product (controls, 0) and expressed as percentage (%). $LSD_{0.05} = 1.40$.

Brussels sprouts bases colour. Respect to the bases, initial value of L^* was 83.9. Fig. 4 shows changes in parameter L^* of Brussels sprouts bases, according to blanching method. PB and MW pre-blanching and direct blanching B4 were the treatments that showed the minor decrease of L^* value with respect to the control, phenomena that could be related to a lesser incidence of surface browning in the cut zones for these treatments. Differences between them were not significant. Otherwise, methods B1 and B3 induced the major diminutions observed in parameter L^*. This would indirectly show that 1 and 3 min of direct blanching were not enough to inactivate enzymes involved in enzymatic browning reactions, at the level of tissues corresponding to buds insertions in the stems. Note that those tissues present a high proportion of conduction elements (phloem, xylem).

3.4. Chlorophyll (Chl) content

Chlorophyll determinations are shown in Fig. 5. Initial total Chl content was equal to 33.3 μg/g fresh tissue and the ratio Chl *a*/Chl *b* corresponded, in average, to 2.55. Of the applied treatments, pre-blanching by water immersion at 50 °C was the method which produced the major lowering in the total chlorophyll content (27% respect to the control). Reductions of lower magnitude ($p < 0.05$) were recorded for MW and B4 treatments (8% and 11% respectively).

Likewise, Fig. 5 shows that blanching for 1 and 3 min did not affect significantly the initial chlorophyll content of samples. In that way, Lisiewska, Kmiecik, and Slupski (2004) observed that blanching dill (*Anethum graveolens* L.) leaves for 30 s and petioles and stems for 3 min, both in water at 94–96 °C, did not affect significantly the content of Chl *a* or Chl *b*. Respect to this, several authors have stated that the thermal inactivation of enzymes achieved by blanching limits the degradation of both chlorophylls and carotenoids (Brewer, Begum, & Bozeman, 1995; Heaton, Yada, & Marangoni, 1996; Lisiewska et al., 2004). The deaeration of plant tissues induced by blanching and the consequent reduction in oxygen content could also contribute to a better preservation of pigments (Lisiewska et al., 2004; Toivonen, 1997; Yamauchi, Yoshimura, Shono, & Kozukue, 1995). Results obtained in our tests indicate that there were comparably higher chlorophyll losses in treatments involving longer total periods of immersion in water, even when in PB method the blanching temperature was considerably lower than in conventional blanching.

Likewise, when comparing colour and chlorophyll changes after blanching treatments, a good correlation was observed between hue angle values and total chlorophyll content ($r = 0.84$; $p = 0.037$).

3.5. Radical scavenging activity

For control samples, mean radical scavenging activity was 730.7 μmol DPPH·/100 g fresh tissue. Both pre-blanching methods (PB and MW) induced the greatest increases in radical scavenging activity values (Fig. 6). With respect to direct blanching treatments, a rise ($p < 0.05$) in radical scavenging activity was observed as the blanching time increased.

Turkmen, Sari, and Velioglu (2005) have studied the effect of cooking methods on antioxidant activity of

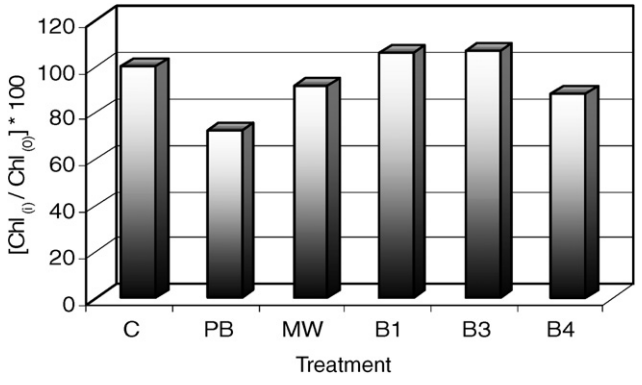

Fig. 5. Total chlorophyll content (Chl) changes in blanched (i) Brussels sprouts, referred to fresh product (controls, 0) and expressed as percentage (%). $LSD_{0.05} = 11.7$.

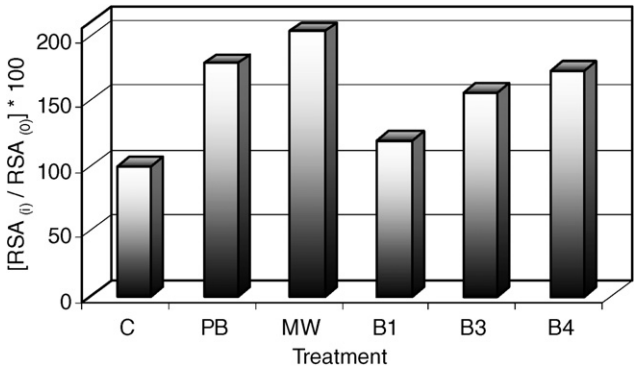

Fig. 6. Radical scavenging activity (RSA) changes in blanched Brussels sprouts (i), referred to fresh product (controls, 0) and expressed as percentage (%). $LSD_{0.05} = 8.05$.

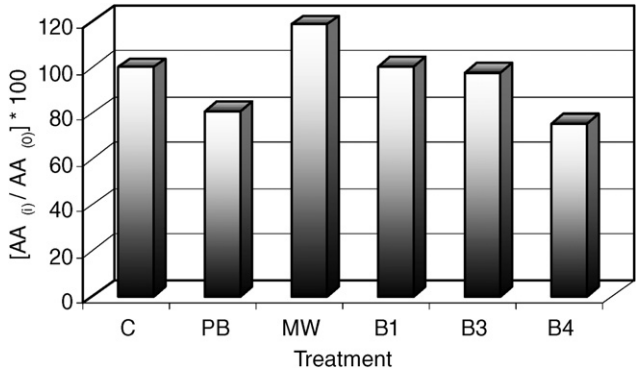

Fig. 7. Ascorbic acid (AA) content changes in blanched (i) Brussels sprouts, referred to fresh product (controls, 0) and expressed as percentage (%). $LSD_{0.05} = 4.47$.

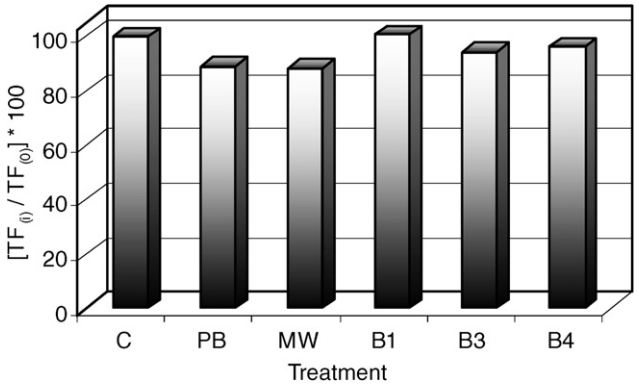

Fig. 8. Total flavonoids (TF) content changes in blanched (i) Brussels sprouts, referred to fresh product (controls, 0) and expressed as percentage (%). $LSD_{0.05} = 18.86$.

selected green vegetables, such as pepper, green beans, broccoli and spinach. These authors found that boiling (5 min), microwave cooking (1000 W for 1–1.5 min) and steaming over boiling water (7.5 min) induced significant increases in total antioxidant activity as determined by the DPPH radical scavenging method and expressed on a dry basis.

3.6. Ascorbic acid content

Ascorbic acid content of recently harvested Brussels sprouts was, in average, 96.4 mg/100 g fresh tissue. Blanching for 1 and 3 min did not cause variations in ascorbic acid content ($p > 0.05$) with respect to the controls (Fig. 7). However, PB and B4 treatments affected significantly ($p < 0.05$) initial ascorbic acid content, since they produced diminutions of 19% and 24% in comparison with fresh product, respectively.

Conversely, MW treatment induced a slight increase in the measured ascorbic acid content. Some authors have reported the increase of certain organic compounds content such as glucosinolates (Oerlemans, Barrett, Suades, Verkerk, & Dekker, 2006; Verkerk & Dekker, 2004) and vitamin E (Chun, Lee, Ye, Exler, & Eitenmiller, 2006) in microwaved vegetables tissues. For example, Verkerk and Dekker (2004) found a 78% higher total extractable glucosinolates levels in red cabbage after microwaving. The authors explained this phenomenon by an increase in chemical extractability from the plant tissue after heating.

3.7. Total flavonoids concentration

In fresh sprouts, mean level of flavonoids was 15.1 mg catechin/100 g fresh tissue. Pre-blanching treatments (PB and MW) showed tendency to generate losses in total flavonoids content of samples, with respect to the control (Fig. 8). Nevertheless, the differences observed in both cases did not become significant ($p > 0.05$). Direct blanching methods, independently on applying time, did not affect significantly total flavonoids content either.

4. Conclusions

Blanching for 1 min (B1) produced the minor firmness loss, did not negatively affect surface colour of the heads (hue angle) and did not induce variations in total chlorophyll content, ascorbic acid concentration nor radical scavenging activity, with respect to fresh product (control). However, treatment extent resulted insufficient to control the internal browning of tissues and cut zones. Increasing exposition time up to 3 min (B3), was not enough to prevent bases browning, measured through L^* parameter, as well as texture loss raised in such way that no advantages were found with respect to other performed methods. When 4 min of direct blanching were applied, although browning of internal tissues was avoided, the greater decrease in firmness was produced. Also, significant losses in total chlorophyll and ascorbic acid content were registered, in a similar way to that verified for the water immersion pre-blanching treatment (PB).

Microwaves pre-blanching (MW) affected texture in an equivalent degree as PB, B3 and B4 methods did, but its great advantages were the lower decrease of L^* in the heads as well as at the cut zones, the conservation of initial chlorophyll content, the higher increase in radical scavenging activity with respect to the control and an elevated level of ascorbic acid content.

This study would indicate that the microwave blanching treatment had no deleterious effects on total antioxidant activity and ascorbic acid content of Brussels sprouts and, according to Turkmen et al. (2005), the moderate heat treatment induced by this method may be considered to be a useful tool to improve health properties of Brussels sprouts. Thus, the assayed microwave pre-treatment could be recommended for blanching this vegetable.

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cia Nacional de Promoción Científica y Tecnológica (ANPCyT).

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