Changes in nutritional and sensory characteristics of canned turnips: Effect of salt

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Summary

Canned turnip greens were elaborated industrially using water without added salt and water with different levels of NaCl (0.5 %, 1 % and 2 %) as brine, and a mixture (1:1) of NaCl-KCl or NaCl-$MgCl_2$ were considered as a tool of reducing sodium. Colour, nutritional quality and consumer acceptability were analysed monthly for 3 months. Significant losses in moisture content, total soluble solids, pH, antioxidant activity, ascorbic acid, total chlorophyll as well as chlorophyll *a* and *b* were detected, but titratable acidity increased. Colour was affected by the loss of lightness and greenness, and the increase in yellowness. Consumers evaluated the overall acceptability and the intensities of 15 sensory characteristics of the six types of canned turnips. The results showed that NaCl (2 %) improved flavour, appearance, odour, colour and texture, preserving organoleptic characteristics better than when no salt was added, or when NaCl (0.5 % or 1 %) or other salts were employed. Partial replacement by KCl or $MgCl_2$ showed the worst punctuations, due to the high scores in texture parameters, such as hardness, fibrosity, astringency or adhesiveness, and in bitter and metallic tastes.

Keywords

turnip green; canning; salt; storage-time; quality

Brassica spp. are an excellent dietary source of phytochemicals, for example vitamins, phenols, minerals or glucosinolates, which reduce oxidative stress and prevent some diseases, such as cancer or cardiovascular disease. These vegetables also have an economic significance, being utilized as a source of food for either humans or animals. The most important species are *Brassica oleracea*, *B. napus* and *B. rapa* [1].

B. rapa is widely cultivated throughout the world. *B. rapa* var. *rapa* is one of the most popular crops consumed in Galicia (Northwest Spain). This vegetable is locally known as "nabiza" (turnip green, which are young leaves that were harvested in the vegetative growth period) or "grelo" (turnip top, which are fructiferous stems with the flower buds and surrounding leaves that were harvested in late winter when the flower buds are formed). Most of the production is locally consumed as fresh food, and a fraction is used for processing or canning. It is cultivated mainly in autumn and winter, and its availability may be limited during other seasons. These facts explain the necessity of applying preservation technologies, such as canning, in order to extend the shelf life of these vegetables.

Sodium chloride enhances the flavour of foods and also prevents spoilage and has a positive influence on texture, water holding capacity and shelf life of food [2]. Furthermore, sodium chloride is a suppressant of bitter flavour in the case of certain vegetables, such as *B. rapa* var. *rapa*, which are characterized by they own important bitter flavour [3]. On the other hand, according to the World Health Organization, the amount of dietary salt consumed is an important determinant of blood pressure levels and overall cardiovascular risk. Salt intake of less than 5 grams per person per day is recommended to prevent cardiovascu-

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lar diseases. Sodium chloride is the main source of sodium in food products and its total or partial replacement in industrial food manufacturing is believed to be necessary. Potassium chloride is the most frequent salt used as substitute. However, when the potassium is used in some food at blends of more than 50:50 sodium chloride/potassium chloride, the bitter flavour increases [2]. Other compounds can be used to replace or to reduce sodium chloride, but PHELPS et al. [4] pointed out that the salt replacers cannot substitute the salty flavour of sodium chloride and these cannot be used in high concentrations.

There are many studies on the influence of thermal treatment on some *Brassica* spp., but no literature is available about the combined effect of canning and salt on these vegetables. The aim of this study was to evaluate, during three months, the influence of type and concentration of different salts on some nutritional and sensory characteristics of the canned *B. rapa* var. *rapa.*

MATERIALS AND METHODS

Plant material and preparation of samples

Turnip greens of *Brassica rapa* var. *rapa* of the "Santiago" ecotype were collected in the autumn and winter seasons in different plantations of Galicia (Northwest Spain). One part of the fresh turnip greens were taken to laboratory. They were washed with deionized water, separated from inedible parts and were analysed immediately, without processing. Other part of fresh turnip greens was taken to industry, where the turnip greens were canned. The treatment consisted of blanching (at 110 °C for 7–8 s, two times), filling in the cans, addition of water or brines, hermetic sealing, sterilizing (121.1 °C, 25 min) and cooling. In the canned turnip greens production, water without salt and brines with different concentrations of salts were used: water with 5 $g\cdot l^{-1}$ (0.5 %), 10 $g\cdot l^{-1}$ (1 %) and 20 $g\cdot l^{-1}$ (2 %) NaCl. To obtain a "healthier" product for consumers, two formulations were proposed to partially replace NaCl: water with 2 % NaCl:KCl (1:1) and water with 2 % $NaCl:MgCl_2 \times 6H_2O$ (1:1).

In multiphase products, with the solids and liquid having different initial sodium concentrations, some time is necessary for sodium chloride to diffuse into the food, to be readily accessible to the taste receptors in the mouth [5]. In our study, the storage and stabilization period was six months after canned turnip greens production. Then, the samples were analysed during three consecutive months (0, 1, 2 and 3 months).

Physico-chemical analysis

Moisture content of fresh and canned turnip greens was determined by drying the sample to constant weight in an oven at 50 °C. Total soluble solids (TSS), expressed as degrees Brix, were determined with a manual digital refractometer model N-1E (Atago, Tokyo, Japan).

The pH and titratable acidity analysis were carried out according to the method AOAC 981.12 and AOAC 925.53, respectively [6].

The 2,2-diphenylpicrylhydrazyl (DPPH) radical was used to estimate the antioxidant potential. The sample (15 g) was mixed with 20 ml of methanol and centrifuged at 413 ×*g* for 40 min at 4 °C. Different concentrations were prepared in methanol (16, 25, 30, 45, 60, 68 and 75 $mg\cdot ml^{-1}$), and they were mixed with 0.5 ml of DPPH solution (0.5 $mmol\cdot l^{-1}$ in methanol). The mixtures were incubated for 15 min at room temperature in the dark. Absorbance was measured at 517 nm in a spectrophotometer UV-1800 (Shimadzu, Kyoto, Japan). A control reading was obtained using methanol (2 ml) with 0.5 ml of DPPH.

Free radical-scavenging activity was expressed as a percentage of inhibition (I) calculated according to Eq. 1:

$$I = \left[\frac{(A_c - A_s)}{A_c}\right] \times 100 \quad (1)$$

where A_c is the absorbance of the control at time 0 min, and A_s is the absorbance of the sample every 15 min during 1 h.

The concentration of the substrate that caused 50% loss of the DPPH activity (IC_{50}) was also used to interpret the results from the DPPH method.

Ascorbic acid was determined according to MARTÍNEZ et al. [7]. Sample (5 g) was homogenized with 25 ml of 2% metaphosphoric acid in a mortar and then centrifuged at 4000 ×*g* for 10 min in an Eppendorf centrifuge 5804R (Eppendorf, Hamburg, Germany). The supernatant was collected and the residue was mixed with 15 ml and 10 ml of 2% metaphosphoric acid and centrifuged again. The three obtained supernatants were combined and adjusted to 50 ml with 2% metaphosphoric acid, and then filtered through a nylon filter (pore size 0.45 mm; Millipore, Billerica, Massachusetts, USA). Ascorbic acid was determined by using a high-performance liquid chromatograph (Thermo Finnigan, San Jose, California, USA) with a Photodiode Array UV6000LP detector, reading the absorbance at 265 nm. Separation was carried out in a Phenomenex HyperClone ODS (C18) column (25 cm × 4.6 mm; particle size 5 μm). The mobile phase was distilled water acidified with sulphuric acid to pH 2.22.

Total chlorophyll, chlorophyll *a* and chlorophyll *b* contents were determined according to MARTÍNEZ et al. [7]. Samples (0.26 g) were homogenized in a mortar with 10 ml of acetone/water (80:20, v/v), and then centrifuged at 4000×*g* for 5 min in a centrifuge Eppendorf 5804R. The residue was re-extracted five times under the same conditions, and the absorbance of the mixed extracts was recorded in a Shimadzu UV 1800 spectrophotometer. The total chlorophyll, chlorophyll *a* and chlorophyll *b* concentrations, expressed in milligrams per millilitre, were calculated according to the Eq. 2–4:

$$c_a = 12.7A_{663} - 2.69A_{645} \quad (2)$$

$$c_b = 22.9A_{645} - 4.68A_{663} \quad (3)$$

$$c_T = 20.2A_{645} + 8.02A_{663} \quad (4)$$

where c_a and c_b are the concentration of chlorophyll *a* and *b*, respectively, c_T is the concentration of total chlorophyll, A_{645} and A_{663} are the absorbance values at 645 nm and 663 nm, respectively.

The colour was measured with a Chroma Meter CR-40 (Konica Minolta Sensing, Osaka, Japan) and expressed in CIE $L^*a^*b^*$ system. Coordinate L^* (from 0 to 100 units) represents lightness of colour (a lower value means a darker colour), a^* represents the balance between red (> 0) and green (< 0) and b^* between yellow (> 0) and blue (< 0). The a^* and b^* values were converted to hue angle (*H*°; 0° or 360°= red, 90° = yellow, 180° = green and 270° = blue) by Eq. 5 (when $a^* < 0$ and $b^* > 0$):

$$H° = 180° + \text{arctg}\left(\frac{b^*}{a^*}\right) \quad (5)$$

Chroma (C^*, saturation of colour starting from 0 and increasing with colour saturation) was calculated using Eq. 6 (where *a* is red-green coordinate and *b* is yellow-blue coordinate):

$$C^* = \sqrt{(a^2 + b^2)} \quad (6)$$

The total colour difference value (ΔE) was calculated as:

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2} \quad (7)$$

where the standards (L_0, a_0, b_0) were the fresh turnip greens measurements.

All determinations were performed in triplicate.

Sensory analysis

Sensory analysis was carried out using quantitative descriptive analysis by 15 untrained assessors (5 male and 10 female aged between 20 and 45) who were regular consumers of this vegetable. The panellists were selected from the students and staff of the Faculty of Sciences (Campus of Ourense, University of Vigo, Spain). About 30 g of each different canned turnip greens were placed in boiling water during 5–10 min before serving, and they were offered to the panellists in white plastic plates coded with three-digit numbers. Sensory evaluation was carried out according to a ten-point hedonic scale (0 – 'dislike extremely' or 'absent'; 10 – 'like extremely' or 'high intensity'). Descriptors were selected from ARIAS-CARMONA et al. [3] with some modifications. The sensory attributes covered aspects such as the external aspect (intensity of colour, gloss and appearance), odour (intensity), texture (hardness, fibrosity, astringency, adhesiveness to palate and gums, and mouthfeel) and taste (bitter, acid, sweet, salty, metallic and residual taste). Finally, the assessors were asked for the overall impression of quality.

Statistical analysis

The differences among the different salts or concentrations and storage-time were studied using analysis of variance (ANOVA) with a confidence interval of 95%. Means were compared by the least squares difference (*LSD*) test, using the program Statistica 7.0 (Statsoft, Tulsa, Oklahoma, USA). Principal component analysis (PCA) was performed using the mean intensities of each sensory attribute and overall impression.

RESULTS AND DISCUSSION

Physico-chemical analysis

The moisture content determined for fresh turnip greens ranged from 90.0 % to 92.5 % (Tab. 1). These values were similar to results reported for *B. rapa* var. *rapa* [7, 8] and even for other *Brassica* spp. [9].

No significant moisture changes were observed when turnip greens were canned (0 month). However, moisture content slightly decreased during storage in some cases, probably as a consequence of the incorporation of salt to the turnip, mainly with the highest salt concentrations in the brine. The salt and the heat treatment can induce an increase in solubility as well as loss of some compounds to the treatment water and modification of the moisture content. JAWORSKA et al. [10] observed a decrease in the moisture content in spinach and New Zealand spinach after blanching, though they observed an increase in the moisture content after canning. In some samples, after 8 months of storage (samples labeled as

2nd month), moisture content increased and then subsequently decreased. Finally, the percentages of moisture in the last analysis were lower than in fresh turnip greens or after canning.

TSS can be used to approximately calculate the sugar content as a quality attribute of vegetables. However, further constituents such as organic acids, amino acids and pectins also contribute to *TSS*. Fresh turnip sample presented 6.7 °Bx (Tab. 1), the mid-point of the range from 6.2 °Bx to 7.2 °Bx reported by MARTÍNEZ et al. [7] for this vegetable, and similar to 7 °Bx of *B. oleracea* var. *acephala* [11].

The losses of *TSS* during canning were statistically significant. *TSS* were lost by leaching into water or brines during blanching, sterilization and storage of the cans. Temperature and duration of treatment, heat treatment system, brine composition or pH are known to determine the losses of soluble solids [12]. Furthermore, the losses can be also due to hydrolysis of some sugars during the process. RODRÍGUEZ-SEVILLA et al. [13] also observed in turnip (*B. napus*) losses of soluble sugars during the processing. RICKMAN et al. [14] showed that the losses of soluble solids during heat treatment can be very important, and that these compounds are more stable during storage due the absence of oxygen.

The lowest *TSS* was observed in canned turnip greens with water without salt, and the values were increased with the highest NaCl concentration, probably as a consequence of the addition of salts

Tab. 1. Moisture, soluble solids, pH and titratable acidity of fresh and canned *Brassica rapa* var. *rapa*.

Brines	Storage time [months]	Parameters			
		Moisture [%]	Soluble solids [°Bx]	pH	Titratable acidity [mg·kg^{-1}]
Fresh turnips					
–	0	91.5 ± 1.5^{A}	6.7 ± 0.5^{A}	6.43 ± 0.05^{A}	0.15 ± 0.03^{A}
Canned turnips					
Water	0	89.1 ± 0.5^{aA}	2.2 ± 0.1^{aB}	5.32 ± 0.03^{aB}	0.17 ± 0.00^{aAB}
	1	86.0 ± 1.4^{aA}	2.9 ± 0.1^{bA}	5.24 ± 0.02^{bAA}	0.24 ± 0.06^{bAB}
	2	87.2 ± 1.4^{aAB}	2.7 ± 0.1^{bA}	5.26 ± 0.01^{bA}	0.20 ± 0.00^{abA}
	3	85.1 ± 0.8^{bA}	2.7 ± 0.1^{bA}	5.40 ± 0.04^{aA}	0.17 ± 0.00^{aA}
Water + 0.5% NaCl	0	90.7 ± 0.9^{aA}	2.7 ± 0.1^{aBC}	5.25 ± 0.06^{aCD}	0.16 ± 0.00^{aAB}
	1	88.8 ± 0.2^{abA}	3.1 ± 0.1^{abAB}	5.21 ± 0.04^{aA}	0.21 ± 0.00^{aAB}
	2	86.7 ± 0.3^{abAB}	2.9 ± 0.1^{aA}	5.22 ± 0.02^{aAB}	0.21 ± 0.01^{aA}
	3	86.0 ± 0.3^{bA}	3.3 ± 0.1^{bB}	5.21 ± 0.02^{aB}	0.20 ± 0.00^{aA}
Water + 1% NaCl	0	89.5 ± 0.2^{aA}	3.0 ± 0.1^{aCD}	5.28 ± 0.02^{aBD}	0.19 ± 0.01^{aBC}
	1	88.1 ± 0.4^{aA}	3.3 ± 0.1^{abAB}	5.22 ± 0.02^{bA}	0.26 ± 0.00^{bA}
	2	88.7 ± 0.1^{aA}	3.5 ± 0.1^{bB}	5.16 ± 0.04^{bB}	0.22 ± 0.00^{abA}
	3	87.1 ± 0.3^{aA}	3.5 ± 0.1^{bBC}	5.23 ± 0.02^{abB}	0.18 ± 0.03^{aA}
Water + 2% NaCl	0	91.5 ± 2.9^{aA}	3.4 ± 0.1^{aD}	5.16 ± 0.04^{aCE}	0.18 ± 0.00^{aBC}
	1	87.2 ± 1.5^{bA}	3.6 ± 0.1^{aB}	5.20 ± 0.02^{aA}	0.24 ± 0.01^{aAB}
	2	84.7 ± 1.1^{bB}	3.6 ± 0.4^{aB}	5.16 ± 0.02^{aB}	0.24 ± 0.01^{aA}
	3	85.2 ± 0.4^{bA}	3.6 ± 0.5^{aBC}	5.21 ± 0.01^{aB}	0.23 ± 0.00^{aA}
Water + 2% NaCl-KCl (1:1)	0	89.2 ± 0.6^{aA}	3.3 ± 0.2^{aD}	5.21 ± 0.02^{aCD}	0.19 ± 0.00^{aBC}
	1	85.9 ± 0.3^{abA}	3.1 ± 0.0^{aAB}	5.11 ± 0.02^{bB}	0.20 ± 0.00^{aB}
	2	87.5 ± 0.0^{abAB}	2.9 ± 0.4^{aA}	5.06 ± 0.02^{bC}	0.22 ± 0.00^{aA}
	3	83.9 ± 0.7^{bA}	3.4 ± 0.5^{aBC}	5.21 ± 0.02^{aB}	0.20 ± 0.01^{aA}
Water + 2% NaCl-$MgCl_2$ (1:1)	0	92.7 ± 0.8^{aA}	3.3 ± 0.1^{aCD}	5.09 ± 0.02^{aE}	0.22 ± 0.00^{aC}
	1	88.5 ± 0.7^{bA}	3.2 ± 0.1^{aAB}	5.06 ± 0.03^{abB}	0.23 ± 0.00^{aAB}
	2	84.3 ± 1.0^{cB}	3.7 ± 0.1^{bB}	5.01 ± 0.01^{bD}	0.22 ± 0.00^{aA}
	3	84.5 ± 0.2^{cA}	4.0 ± 0.3^{bC}	5.12 ± 0.07^{aC}	0.19 ± 0.01^{aA}

Values represent mean ± standard deviation of three determinations (fresh weight). Values with different lowercase letters (a, b) in superscript, for the same parameter and sample, in the same column were significantly different ($p < 0.05$). Values with different uppercase letters (A–E) in superscript, for the same storage time and parameter, in the same column were significantly different ($p < 0.05$).
Titratable acidity is expressed as citric acid.

into the brines. This factor may be also responsible of the increase in the soluble solids during storage in some cans during the analysed 2 and/or 3 months (i.e. 8 and/or 9 months after canning).

The use of NaCl in the cans can have a negative effect on some soluble compounds. GUERRA-VARGAS et al. [15] observed that the addition of NaCl causes losses in some soluble compounds such as carotenoids in carrots and peppers. However, in our study, the highest losses were observed in the canned turnip greens elaborated with water without added salts.

Acidity is an important factor in canned products as it determines the safety of these products. The pH value of fresh turnip greens (6.43) (Tab. 1) was consistent with the results reported for other *Brassica* spp., such as 6.48 in Chinese cabbage [16] and the range of 6.06–6.44 in *B. oleracea* [17]. However, MONDRAGÓN-PORTOCARRERO et al. [8] observed the lowest values (6.27) in turnip greens.

The decrease in pH values with the heat treatment could be due to extraction and/or degradation of certain components of the plant and the balance formed during storage between solids and liquids in canned foods. The storage caused a decrease in pH values in the canned turnip greens with water and water with NaCl-KCl or NaCl-$MgCl_2$ during the 1st and 2nd months. However, pH values increased during the 3rd month, and reached the pH values of 0 month. The increase in pH values during the last month could be due to the losses of acid compounds to water or the brine. SAPERS et al. [18] showed that canning caused an increase in pH values, however, when salt was used, pH values decreased. JAWORSKA et al. [10] observed in spinach an increase in pH values during blanching but a decrease during canning, and the pH values were constant during storage.

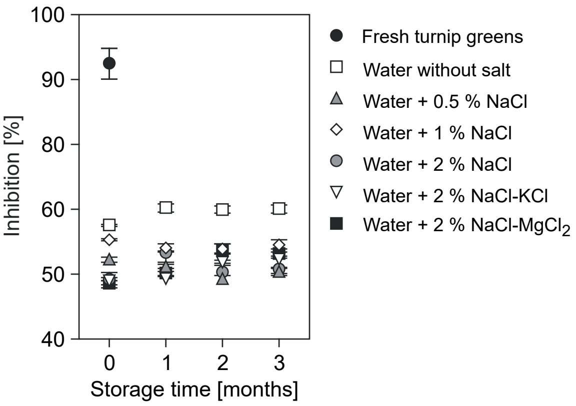

Fig. 1. Antioxidant activity of fresh and canned *Brassica rapa* var. *rapa*.

Antioxidant activity is expressed as percentage of DPPH inhibition. Extract with concentration of 60 mg·ml^{-1} was used.

Titratable acidity is an important quality parameter because it determines the taste, flavour and colour of the vegetables. Titratable acidity values determined in fresh turnip greens ranged from 0.13 g·kg^{-1} to 0.17 g·kg^{-1} (expressed as citric acid; Tab. 1), in agreement with a previous study [7]. MONDRAGÓN-PORTOCARRERO et al. [8] reported a titratable acidity value of 0.6 g·kg^{-1} (expressed as malic acid) for fresh turnip green. LO SCALZO et al. [17] observed in *B. oleracea* var. *botrytis* changes between the titratable acidity of different samples harvested in different periods and years.

Titratable acidity of canned turnip greens increased with regard to fresh samples except when water or water with 0.5% NaCl were used in the can.

The storage caused a weak increase in titratable acidity when no salt or NaCl were used in the cans. In some cases, a small increase in titratable acidity was observed in 3rd month. These changes could have been caused by extraction of acid compounds (1st and 2nd month) and their later loss to water or the brine, or their degradation (3rd month). Heat treatment can cause cell wall damage and liberation of acids to the brine in the cans, and the increase in acidity [10]. However, OCKU et al. [19] observed no significant changes in titratable acidity in blanched and canned turnip (*Brassica rapa*) after one month of storage.

Brassica spp. are characterized by a high antioxidant capacity [20]. Their beneficial properties against various diseases have been attributed to the presence of various bioactive compounds. In this study, antioxidant activity was determined in terms of percentage of inhibition of DPPH of different extracts of fresh and canned turnip greens with different brines. Fig. 1 shows the percentages of inhibition when extract with concentration of 60 mg·ml^{-1} was used. Fig. 2 shows the IC_{50} values obtained in the individual samples. The antioxidant activity of fresh turnip greens was significantly higher than that of canned samples. Fresh turnip greens exhibited percentages of inhibition higher than 90 %, and IC_{50} was 25 mg·ml^{-1}. CHU et al. [9] observed 92.3 % inhibition in Chinese cabbage, AIRES et al. [21] found between 14.1 % (turnip roots) and 91.6 % (Portuguese kale), KAUR and KAPOOR [22] reported these values for turnip between 45.8 % and 47.8 %, and OLAJIRE and AZEEZ [23] observed high IC_{50} values (49.62 mg·ml^{-1}) for *B. oleracea*.

The canning caused a decrease in antioxidant activity to between 33 % and 45 % (Tab. 2). This

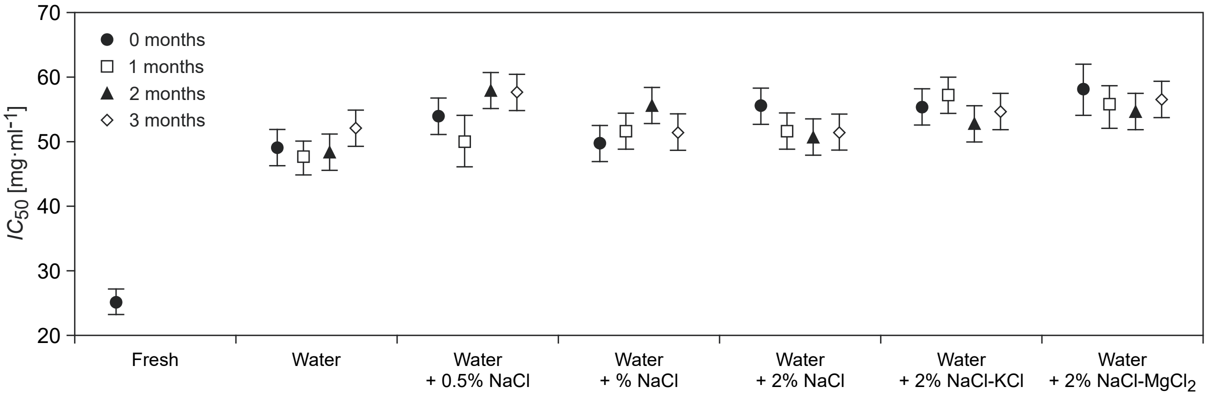

Fig. 2. IC_{50} values obtained in fresh and canned *Brassica rapa* var. *rapa.*

IC_{50} – concentration of the substrate that caused 50 % loss of the DPPH-scavenging activity.

Tab. 2. Ascorbic acid, total chlorophyll, chlorophyll *a* and chlorophyll *b* of fresh and canned *Brassica rapa* var. *rapa*.

Brines	Storage time [months]	Parameters			
		Ascorbic acid [mg·kg-1]	Total chlorophyll [g·kg-1]	Chlorophyll *a* [g·kg-1]	Chlorophyll *b* [g·kg-1]
Fresh turnips					
–	0	1036.00 ± 91.60^{A}	1.12 ± 0.03^{A}	0.81 ± 0.01^{A}	0.33 ± 0.01^{A}
Canned turnips					
Water	0	58.44 ± 1.52^{aB}	0.62 ± 0.00^{abB}	0.53 ± 0.01^{aB}	0.08 ± 0.00^{aB}
	1	62.82 ± 1.10^{abA}	0.69 ± 0.09^{bA}	0.58 ± 0.02^{abA}	0.07 ± 0.00^{aA}
	2	72.14 ± 8.64^{bA}	0.70 ± 0.06^{bA}	0.63 ± 0.05^{bA}	0.07 ± 0.01^{aA}
	3	61.20 ± 2.71^{abAB}	0.57 ± 0.00^{aA}	0.51 ± 0.00^{aA}	0.05 ± 0.00^{bA}
Water + 0.5% NaCl	0	57.50 ± 1.59^{aB}	0.52 ± 0.01^{aC}	0.41 ± 0.03^{aC}	0.06 ± 0.00^{aC}
	1	63.87 ± 3.55^{aA}	0.53 ± 0.01^{aB}	0.48 ± 0.01^{aBC}	0.05 ± 0.00^{aB}
	2	65.52 ± 10.89^{aAB}	0.58 ± 0.00^{bB}	0.49 ± 0.03^{aB}	0.06 ± 0.01^{aA}
	3	60.70 ± 3.24^{aAB}	0.68 ± 0.09^{cBC}	0.61 ± 0.07^{bB}	0.06 ± 0.01^{aAB}
Water + 1% NaCl	0	79.64 ± 7.41^{aC}	0.52 ± 0.00^{abC}	0.44 ± 0.02^{acC}	0.06 ± 0.00^{aC}
	1	64.16 ± 0.56^{bA}	0.49 ± 0.03^{aB}	0.43 ± 0.03^{acB}	0.05 ± 0.00^{aB}
	2	55.70 ± 2.16^{bB}	0.67 ± 0.00^{cAC}	0.60 ± 0.01^{bA}	0.06 ± 0.01^{aA}
	3	55.61 ± 4.63^{bB}	0.58 ± 0.02^{bA}	0.50 ± 0.01^{cA}	0.05 ± 0.01^{aA}
Water + 2% NaCl	0	83.75 ± 6.59^{aC}	0.71 ± 0.04^{aD}	0.56 ± 0.03^{aB}	0.08 ± 0.00^{aB}
	1	86.48 ± 0.73^{aB}	0.72 ± 0.03^{aA}	0.64 ± 0.02^{aA}	0.07 ± 0.01^{aA}
	2	73.42 ± 22.02^{aA}	0.71 ± 0.07^{aA}	0.63 ± 0.04^{aA}	0.06 ± 0.00^{bA}
	3	71.31 ± 15.75^{aA}	0.72 ± 0.02^{aB}	0.60 ± 0.09^{aB}	0.08 ± 0.01^{aB}
Water + 2% NaCl-KCl (1:1)	0	56.02 ± 4.34^{aB}	0.65 ± 0.02^{aBC}	0.56 ± 0.04^{abB}	0.09 ± 0.02^{aB}
	1	59.71 ± 1.96^{aA}	0.65 ± 0.01^{aA}	0.56 ± 0.03^{abA}	0.07 ± 0.01^{bA}
	2	53.16 ± 4.69^{aB}	0.68 ± 0.01^{aAC}	0.62 ± 0.02^{bA}	0.06 ± 0.01^{bA}
	3	51.24 ± 3.29^{aB}	0.60 ± 0.02^{aAC}	0.50 ± 0.00^{aA}	0.05 ± 0.00^{bA}
Water + 2% NaCl-$MgCl_2$ (1:1)	0	40.21 ± 4.31^{aD}	0.46 ± 0.05^{aC}	0.42 ± 0.00^{aC}	0.06 ± 0.01^{aC}
	1	42.66 ± 4.24^{aC}	0.52 ± 0.04^{abB}	0.47 ± 0.04^{abB}	0.06 ± 0.00^{aAB}
	2	39.76 ± 2.64^{aC}	0.61 ± 0.03^{cBC}	0.56 ± 0.03^{bAB}	0.05 ± 0.00^{aA}
	3	39.96 ± 1.69^{aC}	0.57 ± 0.03^{bcA}	0.51 ± 0.04^{bA}	0.06 ± 0.01^{aAB}

Values represent mean ± standard deviation of three determinations (fresh weight). Values with different lowercase letters (a, b) in superscript, for the same parameter and sample, in the same column were significantly different ($p < 0.05$). Values with different uppercase letters (A–E) in superscript, for the same storage time and parameter, in the same column were significantly different ($p < 0.05$).

was probably due to leaching into surrounding water of bioactive components and due to degradation by heat. The absorption of water during processing diluted the compounds and therefore the antioxidant capacity decreased [20]. Previous studies showed contradictory findings on the effects of heat treatment (blanching or cooking) on antioxidant activity of vegetables. Some authors suggested that pro-oxidant activity is due to peroxidase and its inactivation during heat treatment avoids losses of antioxidant capacity. Other studies showed that processing could induce formation of novel compounds, such as Maillard reaction products, which have antioxidant activity. The addition of salt to the canned turnip greens caused higher losses than when only water was used. The storage did not modify the antioxidant capacity except in samples without salts, because the antioxidant capacity decreased the first two months and increased in the last month.

Ascorbic acid is an indicator of quality in vegetables during preparation, processing and storage, because it is very sensitive to high temperature, oxygen, light and other factors. Fresh turnip greens are an important source of ascorbic acid (Tab. 2) with high contents (1036 $mg\cdot kg^{-1}$), in agreement with the values of 1120 $mg\cdot kg^{-1}$ found for *B. olareacea* var. *italica* [24] and 926.2 $mg\cdot kg^{-1}$ for *B. oleracea* var. *acephala* [25]. However, MONDRAGÓN-PORTOCARRERO et al. [8] found the lowest ascorbic acid content in turnip greens (680.6 $mg\cdot kg^{-1}$), the same as FRANSCISCO et al. [26] and MARTÍNEZ et al. [7], who determined values of 620 $mg\cdot kg^{-1}$ and 818.2 $mg\cdot kg^{-1}$ in turnip greens, and 460 $mg\cdot kg^{-1}$ and 899.0 $mg\cdot kg^{-1}$ in turnip top, respectively.

Heat treatment had a drastic effect on the ascorbic acid content, with a reduction of 95 % in canned turnip green with NaCl-$MgCl_2$. The losses were lower during storage than with the heat treatment. MURCIA et al. [24] found losses of 84 % for canned broccoli, and RICKMAN et al. [14] reported losses of ascorbic acid between 10 % and 90 % during canning. The degradation of ascorbic acid in the brine was the most important loss during canning [27]. In our case, the higher NaCl concentrations gave rise to lowest losses during heat treatment but highest losses during storage in canned turnip greens. The use of KCl or $MgCl_2$ increased the losses during canning.

The retention of bright green colour of vegetables during processing is very important in the canning industry. Chlorophyll is the main pigment responsible for this colour. It is degraded during heat processing and during storage. Fresh turnip greens have high chlorophyll content (Tab. 2). The mean values obtained were 1.12 $g\cdot kg^{-1}$, 0.81 $g\cdot kg^{-1}$ and 0.33 $g\cdot kg^{-1}$ of total chlorophyll, chlorophyll *a* and chlorophyll *b*, respectively, in agreement with other studies [7, 28]. The canning gave rise to important losses of chlorophyll in turnip greens, mainly in chlorophyll *b* (between 72 % and 82 %), which is in agreement with the known fact that chlorophyll *a* is more stable than chlorophyll *b*. MURCIA et al. [24] found in canned broccoli a decrease in chlorophyll *a* and *b* contents of 99.4 % and 96.7 %, respectively. KORUS [28] observed losses of 60 % in canned kale.

The losses of chlorophyll are mainly due to the conversion to pheophytin. The losses were lowest when 2 % NaCl was used. This protective effect of NaCl on chlorophyll was previously described [29].

Greenish colour of the turnips is one of the attractive quality attribute valued by consumers [3]. Tab. 3 presents the L^*, a^* and b^* values, as well as the hue angle, chroma and colour difference value. All samples showed low to medium lightness (L^*) with values from 29.59 to 44.14. The latter value was recorded for the fresh turnip sample. Canning caused a loss of lightness, which was stronger when water without added salt was used, or NaCl-$MgCl_2$ or NaCl-KCl were employed. In general, a significant increase in darkness was observed during storage. The loss of chlorophyll content also caused that greenness ($a^* < 0$) and yellowness ($b^* > 0$) of fresh turnip greens were higher than the values of the canned vegetables.

The canning, or type and concentration of salt, did not affect the hue angle, canned turnip green exhibiting values between 92.38 and 95.22. No significant differences were recorded between the different formulations, but all were different from the fresh turnip green (124.85). The canning caused a loss of chroma by about two or three folds, most markedly in samples with water, NaCl-$MgCl_2$ or NaCl-KCl. During storage, the values increased slightly but significantly, according with the increase of the coordinate b^* (yellow-colour). Consequently, the same behaviour was observed for the colour difference value (ΔE) with respect to the raw vegetable. These results are in concordance with MENSAH-BROWN et al. [30], who showed a strong significant influence of blanching time, processing time and salt concentration on the colour of the canned green peppers.

Sensory analysis

The intensity of 15 descriptors of canned turnip greens was scored from 0 to 10 by 15 untrained assessors, as well as the overall impression. The first evaluation in the sensory analysis was the external aspect. All samples elaborated with NaCl

Tab. 3. Colour parameters of fresh and canned *Brassica rapa* var. *rapa*.

Brines	Storage time [months]	Lightness L^*	Greenness a^*	Yellowness b^*	Hue angle $H°$	Chroma C^*	Total colour difference ΔE
Fresh turnips							
–	0	44.14 ± 1.76^{f}	–16.16 ± 0.54^{k}	23.24 ± 1.58^{e}	124.85 ± 1.25^{c}	28.31 ± 1.55^{g}	–^{h}
Canned turnips							
Water	0	29.59 ± 0.43^{a}	–0.51 ± 0.06^{a}	9.27 ± 0.19^{a}	93.07 ± 0.36^{ab}	9.28 ± 0.19^{a}	25.51 ± 0.38^{a}
	1	35.89 ± 063^{bc}	–0.71 ± 0.11^{abc}	16.12 ± 1.05^{bcd}	94.32 ± 0.80^{a}	16.13 ± 1.05^{bcd}	18.91 ± 0.62^{bce}
	2	34.44 ± 0.61^{bcd}	–0.61 ± 0.03^{ac}	14.54 ± 0.42^{bc}	95.22 ± 0.78^{a}	14.55 ± 0.42^{c}	20.14 ± 0.42^{c}
	3	38.22 ± 3.74^{c}	–1.37 ± 0.42^{dgi}	16.60 ± 2.76^{bcd}	94.89 ± 0.41^{a}	16.66 ± 2.73^{bcd}	17.59 ± 1.74^{bdef}
Water + 0.5% NaCl	0	37.52 ± 1.46^{cd}	–1.02 ± 0.18^{efh}	16.72 ± 1.31^{bcd}	94.93 ± 0.24^{a}	16.75 ± 1.32^{bcd}	17.79 ± 1.11^{bdf}
	1	37.49 ± 1.63^{cd}	–1.28 ± 0.45^{dei}	18.33 ± 1.32^{d}	94.11 ± 0.34^{a}	18.38 ± 1.31^{d}	17.08 ± 0.92^{deg}
	2	33.85 ± 0.56^{bde}	–0.81 ± 0.15^{af}	16.13 ± 0.72^{bcd}	93.59 ± 0.26^{ab}	16.15 ± 1.32^{bcd}	19.92 ± 0.23^{cf}
	3	37.83 ± 0.15^{cd}	–1.22 ± 0.10^{dei}	18.54 ± 0.64^{d}	94.41 ± 0.54^{a}	18.58 ± 8.59^{d}	16.83 ± 0.21^{deg}
Water + 1% NaCl	0	36.52 ± 1.07^{bc}	–1.47 ± 0.09^{dg}	17.21 ± 0.46^{bd}	93.46 ± 0.34^{ab}	17.28 ± 0.47^{bdf}	17.93 ± 0.49^{bdef}
	1	36.44 ± 0.88^{bc}	–1.12 ± 0.18^{bdefh}	15.58 ± 0.94^{bc}	93.24 ± 0.22^{ab}	15.62 ± 0.96^{bc}	18.63 ± 1.22^{bcd}
	2	35.46 ± 0.57^{bc}	–1.00 ± 0.09^{efh}	16.04 ± 0.43^{bcd}	92.89 ± 0.66^{b}	16.07 ± 0.43^{bcd}	19.07 ± 0.43^{bce}
	3	38.41 ± 2.21^{c}	–1.45 ± 0.17^{dg}	18.33 ± 1.33^{d}	93.90 ± 0.30^{ab}	18.35 ± 1.46^{de}	16.58 ± 0.80^{dg}
Water + 2% NaCl	0	34.81 ± 1.15^{bcd}	–0.85 ± 0.14^{acfh}	15.77 ± 0.74^{bc}	93.11 ± 0.35^{ab}	15.79 ± 0.74^{bce}	19.42 ± 0.94^{cf}
	1	37.77 ± 0.64^{ce}	–1.35 ± 0.27^{dgi}	17.80 ± 0.71^{bd}	92.52 ± 0.35^{b}	17.85 ± 0.72^{bd}	17.14 ± 0.59^{deg}
	2	33.96 ± 2.63^{bde}	–1.47 ± 0.10^{dg}	14.06 ± 0.82^{c}	92.38 ± 0.10^{ab}	14.14 ± 0.82^{c}	20.17 ± 1.23^{c}
	3	37.67 ± 1.10^{ce}	–1.58 ± 0.14^{g}	18.42 ± 0.46^{d}	92.57 ± 0.85^{ab}	18.49 ± 0.46^{d}	16.66 ± 0.64^{bde}
Water + 2% NaCl-KCl (1:1)	0	31.67 ± 0.79^{ad}	–0.79 ± 0.09^{af}	10.09 ± 0.61^{a}	94.47 ± 0.30^{a}	10.31 ± 0.62^{a}	23.57 ± 0.86^{ba}
	1	34.37 ± 0.95^{bcd}	–0.82 ± 0.08^{afh}	15.20 ± 0.57^{bc}	93.00 ± 0.07^{ab}	15.21 ± 0.58^{cf}	19.33 ± 0.38^{bbcg}
	2	36.11 ± 0.67^{bc}	–0.84 ± 0.08^{bcf}	16.91 ± 0.98^{bd}	92.83 ± 0.21^{b}	16.93 ± 0.98^{bcd}	18.56 ± 0.94^{bceg}
	3	34.74 ± 0.77^{bcd}	–1.37 ± 0.03^{dgi}	17.28 ± 0.91^{bd}	94.68 ± 0.20^{a}	17.34 ± 0.92^{bdf}	18.82 ± 0.20^{bce}
Water + 2% NaCl-$MgCl_2$ (1:1)	0	31.36 ± 0.49^{ad}	–0.83 ± 0.07^{bcfh}	10.11 ± 0.33^{a}	94.69 ± 0.34^{a}	10.14 ± 0.33^{a}	23.87 ± 0.46^{a}
	1	33.74 ± 0.41^{bed}	–0.87 ± 0.15^{bcfh}	14.23 ± 0.27^{c}	93.50 ± 0.67^{ab}	14.24 ± 0.47^{c}	20.60 ± 0.32^{c}
	2	35.36 ± 0.62^{bcd}	–0.92 ± 0.12^{bfh}	16.16 ± 0.34^{bcd}	93.24 ± 0.36^{ab}	16.18 ± 0.35^{bcdf}	18.95 ± 0.50^{bce}
	3	36.20 ± 0.44^{bc}	–1.14 ± 0.11^{hi}	17.86 ± 0.40^{bd}	93.65 ± 0.40^{ab}	17.90 ± 0.40^{bdf}	17.80 ± 0.29^{bdf}

Values represent mean ± standard deviation of three determinations (fresh weight). Values with different lowercase letters (a–k) in superscript, for the same parameter, in the same column were significantly different ($p < 0.05$).

were well valued, mainly the gloss attribute. The replacement with KCl allowed the best punctuation in appearance, but the worst in gloss. When the mixture NaCl-$MgCl_2$ was employed, the turnip greens presented the highest intensity of colour, but the worst appearance.

The reduction or partial replacement of NaCl in brines affected markedly most of the sensory attributes. Mouthfeel, residual taste (or after-taste) as well as bitter and acid tastes appeared to be the main sensory attributes discriminating between the different formulations, with differences of 2 points or more in the punctuation rang, followed by the other four attributes of texture and salty taste. The partial replacement of NaCl by KCl supposed the highest scores in hardness, fibrousness, astringency and adhesiveness, and less intense when NaCl (2 %) was employed. Therefore, these attributes and scores have a high impact on the quality of canned turnip greens in the overall preference.

PCA of the data from consumers' sensory analysis accounted for 86.7 % of the variability (Fig. 3). PC1 (61.7 %) showed that the partial replacement of NaCl for another salt altered the sensory profile, mainly texture and taste. Further reduction in the NaCl concentration resulted in turnips more glossy, but the intensity of colour, appearance and sweet taste decreased. The most sensitive attributes were bitter and metallic tastes, as well as the various texture attributes, which exhibited a significant increase when NaCl-KCl was employed as salt in the brine [4]. *Brassica* presents many glucosinolates and phenolic compounds, which are mainly responsible of the bitter and pungent tastes [31], and these sensory properties are negatively correlated with consumer preferences.

The total or partial replacement of NaCl affects the food quality [32] and, in fact, the overall preference of the canned turnip greens showed the following order: NaCl (2 %) > without added salt > NaCl (0.5 %) ≈ NaCl (1 %) >> NaCl-$MgCl_2$ (2 %) > NaCl-KCl (2 %). Some studies have also shown that texture characteristics and tastes are important quality food factors and the partial replacement of sodium by potassium or magnesium led to the highest scores in the undesirable attributes by the consumers, such as fibrosity, after-taste, mouthfeel, bitter and metallic tastes [33].

CONCLUSIONS

The effect of canning and the use of some salts in turnip greens on the nutritional properties, colour and consumers' acceptance were first investigated in this study. As expected, the canning affected the chemical composition and antioxidant activity of the turnip greens, which presented values lower than those of the fresh samples. Colour changed to less greenness and more yellowness. In order to obtain a safer and healthier product, brine without added salt was assayed, but this study showed that NaCl enhanced the consistency and flavour of this vegetable. The use of NaCl (2 %) was the best formulation, and only

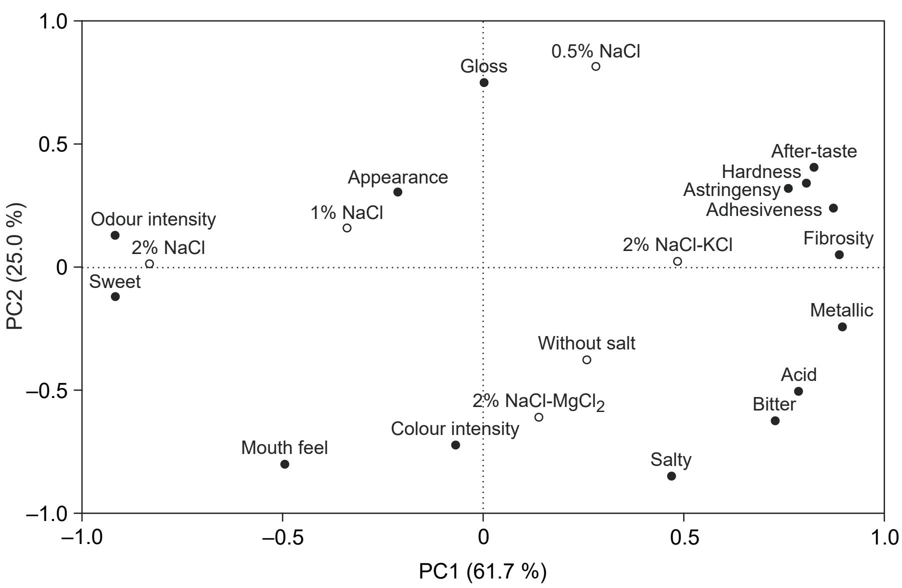

Fig. 3. Principal component analysis of the sensory attributes of canned turnip greens with different salts.

represented 2 grams of salt added in the brine of a typical portion of 100 grams per person. The partial replacement by KCl or $MgCl_2$ led to an increase in bitterness and metallic taste, as well as poor texture, which are undesirable regarding nutritional and sensory properties of these canned vegetables.

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