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ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 07, Issue, 08, pp.3439-3446, August, 2016

RESEARCH ARTICLE

OBTAINING A DIETARY SUPPLEMENT FROM DISPOSABLE CABBAGE LEAVES

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ARTICLE INFO

Article History:
Received 28th May, 2016
Received in revised form
29th June, 2016
Accepted 13th July, 2016
Published online 30th August, 2016

Key words:
Cabbage,
Dietary fiber,
Antioxidant activity,
Phenolic content,
Drying, Microwave.

ABSTRACT

The present study aims at determining the most convenient operating conditions for obtaining a dietary complement of high quality, in terms of nutrient content and rehydration capacity, from disposable leaves of the white cabbage. Different thermal treatments were used for dehydration. Previously, some samples were applied blanching and freezing. These technological treatments and pretreatments, applied at different stages of the productive process, were conducted in order to evaluate and compare their effect on the content of nutrients and substances to be preserved, which were present in the fresh leaves. Then, the dietary complements obtained were analyzed. Proximal composition, vitamin C content, phenols and antioxidant activity were determined. Results indicate that a microwave drying process at 200 W following a 2 min blanching at 96±2 ºC resulted in an antioxidant dietary complement with an energy value of 1415.76±25.84 kJ, showing interesting amounts of proteins, carbohydrates, crude fiber, lipids and ashes.

INTRODUCTION

Over the last years, a new type of food has been introduced, the functional foods, which has been specifically developed to improve our health and reduce chances of contracting diseases. Several traditional food products, such as fruits, vegetables, soya, whole grains and milk have been found to contain components which are beneficial for our health. These are precisely the components of a normal diet and they contain biologically active components which offer important benefits to our health and reduce chances of contracting diseases. Some examples of functional foods include those which contain specific minerals, vitamins, fat acids, dietary fiber, antioxidants (Chu *et al.,* 2002), as well as those foods which are biologically active substances, such as phytochemicals and probiotics containing live cultures of beneficial microorganisms. The white cabbage (*Brassica oleracea var. capitata*) is known to contain bioactive compounds with antioxidant activity, and to present considerable amounts of dietary fiber and carbohydrates (Wennberg *et al.,* 2003). Some of the compounds with antioxidant activity include bioactive phenols and polyphenols which protect the human body from oxidative stress (Lixiang *et al.,* 2009) which may cause several diseases such as cancer, aging (Robards *et al.,* 1999) , heart conditions (Adams *et al.,* 1999; Maxwell *et al.,* 1997; Singh *et al.,* 1995) and high cholesterol (Teissedre *et al.,* 2000; Vinson *et al.,* 1995), among others. Cabbage also presents an interesting content of ascorbic acid, or vitamin C. The ascorbic acid found in many fruits and vegetables (Block *et al.,* 2001) is an essential nutrient for human beings. Some of its functions include its antioxidant activity, by fixing oxygen, capturing free radicals and controlling browning (Roig *et al.,* 1993). Moreover, a daily intake of dietary fiber is known to produce numerous beneficial effects for health. A significant intake of this fiber reduces risks of contracting numerous diseases, such as heart disease, stroke, hypertension, diabetes, obesity, and gastrointestinal disorder (Butt *et al.,* 2007; Petruzziello *et al.,* 2006; Lairon *et al.,* 2005; Montonen *et al.,* 2003). At a global level, most people consume less than half of the recommended daily intake of dietary fiber; this is why the incorporation of a dietary supplement is recommended. These dietary fiber supplements have a potential complementary role in the variety of health benefits offered by high-fiber foods (Anderson *et al.,* 2009). Some authors (Jongaroontaprangsee *et al.,* 2007) have reported that the external leaves of cabbage,

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which are discarded, and sometimes used as animal feed, present large quantities of the nutrients mentioned above. It is known that the characteristics and content of a plant depend upon endogenous factors: variety, part of the plant in which it is found, as well as exogenous factors, such as plant age, area of cultivation, and weather, among others. Furthermore, different technological treatments modify the initial contents of a fresh plant in various ways. The objective of the present study is to determine the most convenient operating conditions for obtaining a high-quality dietary complement, in terms of nutrient content and rehydration capacity, from the outer disposable leaves of white cabbage cultivated in the central-west region of Argentina. This would allow for the reuse of waste and the use of raw matter which lacks commercial value to obtain a low-cost product with important nutritional value. To achieve this purpose, the outer leaves of white cabbage were subjected to different drying processes: forced air convection, natural air convection and microwave. The effect of pretreatments such as blanching and freezing of the leaves which were then subjected to drying was also analyzed. In all cases, the corresponding curves were plotted. Afterwards, the results obtained in the different cases were compared in terms of cost, time and final nutrient content. The energy value of the complements obtained was calculated as well.

MATERIALS AND METHODS

The outer disposable white cabbage leaves obtained from greengroceries from the city of San Luis, central Argentina, were used. The selected leaves were in good condition, without browning or damage caused by pests or transportation, so as to obtain a complement with excellent nutrient content and antioxidant substances. They were washed in abundant water and shredded into 4 cm long by 1 cm wide strips. A third of the total sample was blanched in hot water at 96±2°C during 90s (B), and then immediately cooled in a cold water bath at 4±1°C. Another third was frozen at -18±2°C for 2 days (F) and the rest was reserved as sample without pretreatment prior to drying (WP).

Drying treatments

The samples, with or without previous treatment, were subjected to different drying methods at laboratory scale. For every experiment, approximately 1 kg of leaves shredded and exposed to drying on a stainless steel tray was used to allow for dehydration above and below the sample mass. During the drying treatment, approximately 10g of sample were taken at different time intervals to determine moisture content, until a constant weight was reached. After complete dehydration of the samples, drying curves were obtained for the different treatments applied, which were:

a. **Drying by forced air convection:** The leaves placed on a drying tray were exposed to dehydration using a hot air convection oven (Dalvo instruments, Argentine; mod. EHR/F/I; 220 V, 2500 W) at a temperature of 50±2°C with an air speed of approximately 2 m/s.
b. **Drying by natural air convection:** A drying oven (San Jor mod. SE70SD; 7.2 A, 50/60 Hz, 220 V, from Argentina) was used and the samples were subjected to temperatures of 50±2°C and 90±2°C.
c. **Drying by microwave:** A microwave oven (BGH Quick Chef, Argentine with 30 l of capacity and maximum power of 1000 W, 7-115 V) was used. The sample was placed on a sheet of silicone paper, suitable for microwave cooking, and it was dried at 200 W and 400 W.

Powder preparation

Following dehydration, the dry samples were ground up using a cutting mill (Marshall, USA, mod. TF-B224, 220 V, 50 Hz, 350 W) and sieved to obtain a powder with a particle range of 150-450 μm. The powder obtained was stored in hermetic containers which were kept away from light and moisture until their later use.

Proximal Analysis

The proximal composition comprises, according to AOAC (Association of Official Agricultural Chemist, 2000) specifications, the analytic determination of moisture content, proteins, lipids, crude fiber and ashes. The extract free from Nitrogen, that represents carbohydrate content such as sugars and starches, was calculated on the basis of the difference. Moisture content was determined by using a gravimetric method at 103±2°C (Association of Official Agricultural Chemist, 2000) .To determine the total protein content, the Kjeldahl-Gunning-Arnold method was used. Crude fiber content was determined by acid and basic digestion. Total fats were estimated by the Soxhlet method and ashes by incineration at 500-550°C. All the samples were assayed in duplicate, in agreement with the AOAC standard.

Ascorbic acid content determination

The ascorbic acid content present in the samples was determined by high-performance liquid chromatography (HPLC) using a Gilson 322 series pump from France with a Therma Sphere TS-130 column temperature controller from Phenomenex, USA, Rheodyne 7725i injector and Gilson 152 UV-Vis (France). The data were obtained using UniPoint v2.10 (Gilson) software and a Phenomenex Luna C18 (250 mm x 4.6 mm, 5 μm) reversed-phase column. The mobile phase used was a NaH_2PO_4 solution (Mallincrodt Chemical Works, USA, 99.5% purity) at 1% (pH=2.7) with a 0.7 ml/min flow. An ascorbic acid calibration curve was constructed (Riedel-deHaën AG, Germany) at a wavelength of maximal absorbance (λ=247nm) making dilutions from a stock solution of 0.1 g of ascorbic acid/50 ml phosphoric acid 0.05 N (Sigma-Aldrich Inc., USA).Sample analysis extraction was performed from a sample of 1 mg of dry sample (or 3g of fresh matter) using phosphoric acid 0.05 N, agitating at ambient temperature for 30 min. Then the supernatant was filtered using a 45 μm nylon sieve. The filtered solution was injected in the HPLC equipment. Water was purified using a Super Q Millipore System S.A., USA, with conductivity lower than1.8 μS/cm. Before being used as mobile phase, the solutions and the water were degassed and filtered with Minisart RC (0.5μm) filters. All determinations were performed in triplicate.

Total phenol content determination

This determination was performed through the Folin-Ciocalteu (F-C) method (L. Lixiang *et al.,* 2009; R. Kaur *et al.,* 2008) based on the capacity of phenols to react with oxidizing agents. Initially, a calibration curve was estimated using

different volumes of a pattern solution of gallic acid (Sigma-Aldrich Inc.) 0.1g/l added with 1.5ml of the F-C 2N reactant (MerckKGaA, Germany), 15 ml of Na_2CO_3 (MerckKGaA) at 20% and distilled water to a final volume of 25 ml. To allow for the reaction development, they were left to rest in the dark for 2 h. Absorbance for every solution were measured at 760 nm in a spectrophotometer UV-Vis Cary 50 (Varian Inc., Italy), using a solution prepared in the same way as blank, without the addition of gallic acid. For the sample preparation, 2.5 g of powder were added to 25ml of acetone-water solution (1:1 v/v). It was left to rest for 15 h at ambient temperature (~30°C). The extract was then filtered and kept at the same temperature in the dark. Later, 5ml of filtered extract were taken and the same procedure was followed. Every sample was assayed in duplicate and the total phenol content for each extract was expressed as mg of gallic acid/100 g of dry matter (DM).

Determination of total antioxidant activity

The free radical method 2,2-difenil-1-picrilhidrazil (DPPH) (P. Molyneux, 2004) was used. The method is based on the reduction of DPPH alcoholic solution in the presence of an antioxidant hydrogen donor resulting from the formation of the non-radical DPPH-H or DPPH-R through reaction, which leads to a change in color, from purple to yellow. The results obtained were expressed as percentages of antioxidant activity and mg of ascorbic acid/100g DM. The calibration curve was calculated using dilutions (1.25-6.25 mg/l) prepared from an ascorbic acid stock solution of 375 mg/l. A quartz cell for UV-Vis was used for placing 3 ml of ethanol solution at 90% de DPPH (Sigma-Aldrich Inc., USA) 0.15 mM and convenient volumes were added to each of the dilutions. It was left protected from light and oxygen for 30 min and absorbance was read at 517 nm. Each one of the dilutions was used as a blank; an ethanolic solution at 90% of DPPH was used as control. For the sample reading, 100 ml of ethanol 90% (MerckKGaA, spectroscopic grade) were added to 10 g of dry sample and this solution was agitated permanently at 25°C for 6 h.It was then filtered and the residue was extracted twice with 50 ml of ethanol. The solvent was evaporated using a rotary evaporator (Buchi, Switzerland). The solid residue was kept in the dark and it was then dissolved in 100 ml of ethanolic solution at 90% and its absorbance was measured at 517 nm (sample blank).A quartz cell was used for UV-Vis; 3 ml of ethanolic solution of DPPH and a convenient volume of ethanolic solution of extract or sample were left to incubate for 30 min in the dark. After incubation time, absorbance was recorded. Absorbance of the DPPH solution was used as control. The total antioxidant content was expressed as a percentage of antioxidant activity (%AA) using the following equation:

$$\%AA = \left[\left(Abs_{control} \quad Abs_{sample}\right)/Abs_{control}\right] \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The values obtained were expressed as mg of ascorbic acid in 100 g of dry matter using the calibration curve.

Energetic value calculation

In order to determine the energetic value provided by the dietary complements, a calculation of physiological combustion heat corresponding to the nutrient energetic or food value in physiological conditions (in vivo) was performed, bearing in mind that a part of the combustion energy is dissipated. To estimate these combustion heat values, Atwater factors, reference values for the main nutrient combustion of the food, were used to obtain an approximate value of the energy that these complements may provide, i.e. 17kJ/g for glucids and proteins and 37kJ/g for fats. The energetic value for the complement in kJ/100 g DM was calculated directly from these factors, using the following formula:

$$EV\ (kJ) = \%\ Protein \times 17 + \%\ Carbohydrates \times 17 + \%\ Fats \times 37 \ldots\ldots (2)$$

Statistical analysis

Data were presented as means ± confidence intervals ($x \pm ts/\sqrt{n}$) (confidence level 95%, n = 3). Statistical analysis was performed using MINITAB Release 14.1computer software (1972-2003, Minitab Inc., USA). One way ANOVA was used to test whether there was a significant difference in total phenolic content, antioxidant activity, acid ascorbic, protein, lipid, ash, carbohydrates, crude fiber and remaining humidity between the treatment and pretreatment. A significant difference was considered at a level of $p < 0.05$. All the experiments were performed in triplicate. Furthermore, the data were presented in tables and graphics.

RESULTS AND DISCUSSION

Drying treatment

During the application of each dehydration operation, the respective drying curves were constructed. Figure 1 shows the curves obtained by applying a microwave oven at 400 W. It may be observed that water loss follows the same dynamics in the three curves, showing a small difference in behavior between samples with treatment and those which underwent blanching or freezing. It may also be observed that for a 400 W power, a constant weight is obtained 10 min after the drying process is started. For the other drying methods applied, which were less energic, the necessary time for sample dehydration was considerably longer: forced convection at 50±2 ºC: 7 h; natural convection at 50±2 ºC: approximately 9 h; natural convection at 90±2 ºC: 5-7 h and microwave drying at 200 W: 23 min. All the moisture loss curves obtained show similar behavior to each other, as displayed for the three curves in Figure 1. From the analysis of the results obtained in the drying procedures applied, it is possible to conclude that blanching and freezing prior to drying of the samples do not affect the kinetics of water loss.

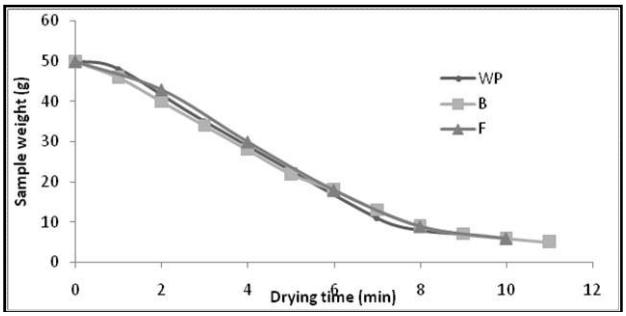

Figure 1. Drying curves obtained by applying a microwave oven at 400 W

Percentage of remaining moisture

At the end of the process of powder preparation, after the application of the different treatments, the samples showed the remaining water content reported in Table 1. It may be noted that for the samples without previous treatment, the remaining water content ranged from 6.00 to 11.30%; while for the blanched samples, it ranged between 7.60 and 9.90, showing more even moisture levels, whereas for the previously frozen samples, moisture content level presented a variation between 6.55 and 10.30% after the treatments. A further aspect related to the remaining moisture in the powder is its rehydration capacity, which constitutes a quality that has been apparently unaffected by the aggressiveness of the thermal treatments applied, as may be observed in Figure 2. The data presented in Table 1 indicates that none of the complements goes beyond 14.5% of moisture, which means that the dietary complements obtained are semi-stable and stable foods (Heldman *et al.,* 2006), presenting a high intermediate durability, or a longer useful life when compared to the fresh vegetable.

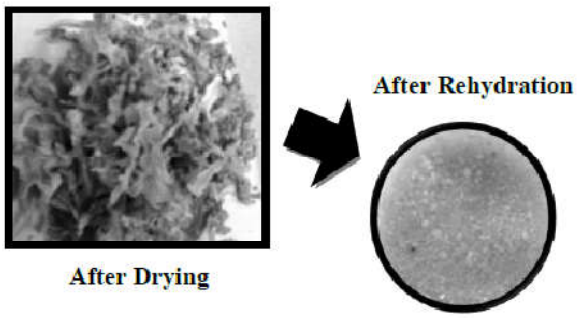

Figure 2. Rehydration capacity of powder

Characteristics and nutritional composition of the powder samples

Proximal Analysis

The data for carbohydrate content, total lipids, proteins, ashes and crude fiber found in the powders subjected to the different drying treatments with their pretreatments are also reported in Table 1. According to the literature (G. D. Hayes, 1987), the water content in the inner and outer cabbage leaves is approximately 90-92% of its weight. This indicates that 8-10% of the remaining weight is divided among nutrients, such as proteins, carbohydrates and lipids. This may be observed in Figure 3 which demonstrates that the largest quantity in this percentage corresponds to carbohydrates, while small but significant amounts of proteins, lipids and crude fiber are also present.

Ascorbic acid determination

Fresh Brassica vegetables (cauliflower, broccoli, cabbage and brussels sprouts) have been reported to contain large amounts of vitamin C by numerous authors (Korus, 2011; Podsędek, 2007; Singh *et al.,* 2007). Table 2 shows the results obtained in the dietary powders, i.e., after being submitted to different treatments. Most complements presented great losses of this antioxidant. This tendency to lose vitamin C was even observed in fresh samples with a prior blanching, resulting in 120.08 mg/100 g DM for fresh outer leaves, and 29.58 mg/100 g DM for these leaves after blanching. This loss represents about 75% of vitamin in only one pretreatment, and if a drying treatment is added, losses are even greater, as may be seen from the table. Some interesting values are shown in the microwave dehydration at 400 W in leaves with and without previous blanching, which maintained an ascorbic acid content of 92.94% and 62.16% respectively, in other words, losses of 7.06% and 37.84% of vitamin C were produced. It is also worth noting that freezing helps the preservation of this component in drying processes at 90±2 ºC, showing a loss of only 41% in reference to the fresh leaves.

Total phenol content

The results obtained for these compounds, which have been widely studied in several foods (A. Korus, 2011; A. Podsędek, (2007; P. Stratil *et al.,* 2007) are shown in Table 2.

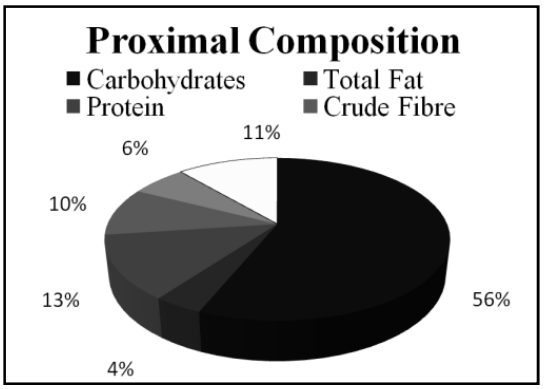

Figure 3. Proximal analysis of the samples without pretreatment dried at 90±2°C NC

Cabbage itself contains an important amount of phenolic compounds. In their study on the outer leaves of cabbage cultivated in Turkey reported an amount of 571.50 mg of gallic acid (GA)/100 g DM (Nilnakara *et al.,* 2009). The values obtained in this study for the vegetable under analysis (original from Argentina) presented a value of 982 mg GA/100 g DM, which may result from different weather conditions, sawing and harvesting, as mentioned above. Like vitamin C, phenolic compounds are very sensitive to temperature changes. Therefore, exposing these foods to cooking produces, in most cases, a significant decrease in their content, though in some exceptions, an increase may be produced, which is attributed by some authors to reactions described as resulting from modifications in other substances. In the experiences reported here, they showed a strong tendency to decrease in the range of 13-73% of the total phenol content initially present in the fresh samples after the application of the different treatments. In general terms, it may be observed that the least aggressive treatment for these compounds is dehydration at 400W. This may be due to the fact that, in spite of being a more aggressive treatment than the conventional ones, the exposition time of the matter (treated or untreated) is reduced to a few minutes as compared to several hours in oven, where the development of all the effects mentioned above is favored. It is worth highlighting that when the only available drying possibility is the use of conventional processes, prior freezing better preserves phenol content.

Table 1. Composition of dried outer leaves of cabbage at various conditions. The data are presented as mean value with confidence limits (x ± t.s/√n) (confidence level 95 %, n = 4)

Treatment	PT	Protein (mg/100 g DM)	Lipid (mg/100 g DM)	Ash (mg/100 g DM)	Carbohydrates (mg/100 g DM)	Crude Fiber (mg/100 g DM)	Remaining Humidity (mg/100 g DM)
	WP	18.42 ±3.17	0.38 ± 0.19	3.81 ± 0.55	65.20 ± 11.46	8.03 ± 0.25	9.48 ± 4.44
Dried 50±2 °C CN	B	14.21 ± 1.52	0.44 ± 0.05	4.92 ± 1.30	68.16 ± 10.46	7.27±21.15	9.85 ± 1.71
	F	11.89 ± 1.01	0.40 ± 0.02	4.97 ± 0.33	72.28 ± 10.43	7.22±15.12	8.05 ± 1.93
	WP	13.05 ± 0.82	0.37 ± 0.39	5.86 ± 1.41	74.08 ± 7.74	4.05 ± 4.89	6.19 ± 3.14
Dried 50±2 °C CF	B	11.34 ± 1.01	0.24 ± 0.03	4,93 ± 1,62	71.33 ± 9.86	6.80 ± 6.73	9.90 ± 0.69
	F	13.65±1.27	0.30 ± 0.14	8,42 ± 0.80	68.00 ± 21. 08	10.20 ± 51.77	8.42 ±2.85
	WP	12.72±3.17	0.39 ± 0.04	6.25 ± 1.38	70.39 ± 12.91	9.63±5.33	6.62 ± 2.97
Dried 90±2 °C CN	B	13.65±1.46	0.50 ± 0.09	5.83 ± 1.33	69.09 ± 13.19	9.46±16.07	7.58 ± 1.29
	F	19.67±1.27	0.45 ± 0.09	5.30 ± 3.94	62.62 ± 28.28	13.15±27.38	10.25 ± 4.32
	WP	15.65±0.69	0.35 ± 0.21	4.95 ± 0.68	69.48 ± 3.50	2.58 ± 9.15	8 61 ± 3.82
Dried 200 W M	B	20.65±3.11	0.34 ± 0.09	4.95 ±1.39	63.64 ± 20.77	11.46 ± 1.59	8.31 ± 4.32
	F	14.25±2.92	0.49 ± 0.04	4.35 ± 0.81	67.49 ±13.03	9.11±0.31	10.36 ± 3.44
	WP	17.01±6.67	0.79 ± 0.08	6.26 ± 3.11	61.69 ± 18.45	13.55 ± 48.79	8.90 ± 4.02
Dried 400 W M	B	19.51±3.87	0.68 ± 0.05	4.73 ± 2.16	64.35 ± 13.29	9.27±8.25	7.63 ± 1.55
	F	10.75±0.69	0.89 ± 0.28	4.84 ± 2.92	71.49 ± 11.04	6.99±7.36	9.71 ± 3.60

PT: Pretreatment; NC: natural convection; FC: forced convection ; M: microwave; WP: without pretreatment; B: blanching; F:freezing

Table 2. Composition of fresh and dried outer leaves of cabbage at various conditions. Data are presented as mean value with confidence limits (x ± t.s/√n) (confidence level 95 %, n = 4)

Treatment	PT	Phenols (mg AG/100 g DM)	Antioxidant activity (%)	A. Ascorbic (mg AA/100g DM)
	WP	975.23 ± 6.71	66.86 ± 2.28	120.20 ± 9.69*
Fresh	B	1169.64 ± 34.42*	66.95 ± 0.09	29.4 ± 1.94*
	WP	321.01 ± 3.13	84.54 ± 18.06	4.20 ± 0.90
Dried 50±2 °C CN	B	268.75 ± 6.36*	87.38 ± 11.40*	4.32 ± 3.95
	F	229.27 ± 40.72	59.72 ± 4.08	4.05 ± 0.88
	WP	243.96 ± 7.56	57.12 ± 4.96	113.74 ± 9.57
Dried 50±2 °C CF	B	245.25 ± 19,24	68.40 ± 3.93	3.84 ± 1.96
	F	289.85 ± 9.05	32.53 ± 3.25	8.27 ± 0.11
	WP	260.33 ± 22.56	51.63 ± 11.12	1.46 ± 0.80
Dried 90°±2 °C CN	B	290.69 ± 11,01	45.43 ± 10.78	12.43 ± 5.63
	F	323.36 ± 9.06	56.78 ± 8.01	70.78 ± 2.91
	WP	259.42 ± 54.00	84.00 ± 3.33	19.83 ± 3.48
Dried 200 W M	B	494.10 ± 36.56	56.48 ± 16.51	12.8 ± 0.60
	F	246.20 ± 4.09	58.94 ± 17.30	5.13 ± 3.60
	WP	278.00 ± 24.99	78.95 ± 6.78	111.61 ± 9.22
Dried 400 W M	B	554.95 ± 34.90	67.97 ± 15.22	74.64 ± 16.70*
	F	458.04 ± 23.47	83.75 ± 12.69	4.2 ± 0.19

*in the same column indicate that values are significant (α 0.05) according to ANOVA test
PT: Pretreatment; NC: natural convection; FC: forced convection ; M: microwave; WP: without pretreatment; B: blanching; F:freezing

Total antioxidant activity determination

The results obtained, which are shown in Figure 4, suggest that when a fresh sample is subjected to the same pretreatment, only those dried by microwave cause an increase in antioxidant activity. As proposed by some authors (Cabello-Hurtado *et al.,* 2112) , this could be due to the modification and/or molecular breakdown of some antioxidant compounds of large size into other smaller ones, without losing their quality.

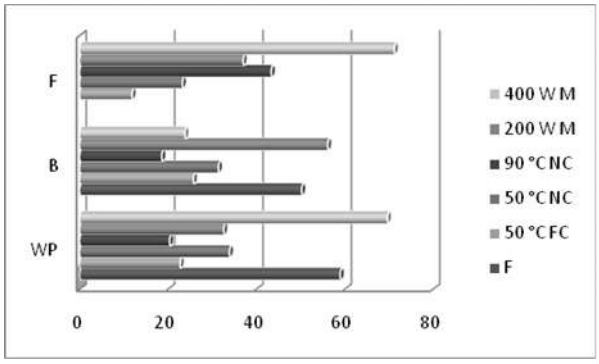

Figure 4. Total antioxidant activity of samples after different treatments and pretreatments

In the previous figure, it may be noted that, even though the %AA is affected by the drying process, the loss is smaller when the leaves are exposed to drying in a conventional oven at 50±2 ºC (23-33% of AA) with or without previous treatment .It may also be observed that an increase of these substances is produced when the leaves are dehydrated at 200 W. The data may also be expressed by making use of a calibration curve using ascorbic acid, in mg equivalent of ascorbic acid for every 100 g DM. For example, 1g of the complement obtained from leaves dried at 50±2 ºC with an air flow would produce the same antioxidant effect than 170.96 mg of ascorbic acid/100 g DM.

Energetic Value calculation: The calculation the Energetic Value (EV) was performed using formula (2), from the percentages of protein, carbohydrate and fats contents multiplied by the Atwater factors. Table 3 shows the EV values obtained for the different treatments.

Effect of treatments and pre-treatments on nutrients

Thermal treatments: As expected, it may be said that the more aggressive the thermal treatment, the shorter the drying time, i.e., when drying oven or microwave are applied. Hence, remaining moisture comparable to that of flours is obtained.

Table 3. Energetic values of complements (kJ/100 g DM)

Pretreatment	WP	B	F
Dried 50°C FC	1507.76±65.79	1432.69±33.32	1329.55±115.94
Dried 50±2 °C NC	1415.79±26.52	1425.55±62.22	1470.65±90.27
Dried 90°C NC	1320.25±133.28	1408.89±54.57	1301.33±105.06
Dried 200 W M	1582.91±33.66	1415.76±25.84	1470.41±25.84
Dried 400 W M	1405.43±165.58	1468.29±49.30	1510.02±57.12

FC: forced convection; NC: natural convection; M: microwave; WP: without pretreatment; B: blanching; F: freezing

Table 4. Effect of different treatments on white cabbage outer leaves

	Forced air convection	Natural air convection	Microwave
Drying time	Drying at 50°C, less than 12 hours	Drying at 50°C, about 24 hours	Drying at 200W (lowest power), about 30 minutes
Total lipid content	It retains lipid values close to those of the fresh sample	It retains lipid values close to those of the fresh sample	It increases lipid values (unwanted, trans fats)
Other nutrients and effects	It retains more protein, but there are losses of antioxidant activity	Keeping of some compounds as crude fibre with the help of a pretreatment prior	Great overall nutrient conservation

Table 5. Nutritional information and operational conditions to obtain the best complement

Operational Conditions to obtain the best dietary complement		Nutritional Information of complement obtained (Values in 100 g product)	
Pretreatment Conditions: Blanching at 96ºC ± 2ºC, 90 s	Drying Conditions: Drying at 200 W in microwave oven until constant weight	Energy Value (kJ)	1415.76±25.84
		Protein (g)	20.64±0.35
		Carbohydrates (g)	47.84±1.17
		Total Fat (g)	6.80
		Ash (g)	4.95±0.16
		Crude Fibre (g)	11.46±0.18
		Vitamin C (mg)	12.80±0.24

In consequence, powders are stable, or present a longer useful life. Moreover, none of the dehydration processes used damaged the dietary complement rehydration. The effects caused by the thermal processes may be summarized in Table 4. This table shows a comparative description of the drying and conservation time for the different nutrients in three out of the five drying treatments applied, which allowed us to obtain more satisfactory results.

Effect of pre-treatments

As to the pre-treatments, blanching was observed to facilitate water loss during drying; lower moisture levels are obtained (greater product stability), though small protein losses are produced when the leaves are dehydrated trough methods with and without convection, and the protein content increases when microwave is used. It is also worth highlighting that microwave drying favors an increase in lipid content, which is undesirable, since it preserves crude fiber content in more aggressive treatments (90±2 ºC, 200 W and 400 W) and it maintains ash values within a medium range regardless of the following drying treatment. It is also necessary to mention that this pretreatment causes great losses of vitamin C content, though it is slightly maintained when microwave drying at 400 W is applied. This causes important losses at the level of total phenols in fresh leaves, maintaining their content in dry samples with conventional methods and increasing phenol values in microwave treatments. In relation to the influence of the different drying methods on antioxidant activity, it may be said that a decrease is produced when compared to the untreated leaves, except for those dried at 200 W, in which case an important activity is recorded, which is higher than 40% of its original value. Regarding the carbohydrate contents obtained, they indicate that, in general, this pretreatment does no lead to great losses of this nutrient.

Freezing, the other pretreatment applied, facilitates water extraction after drying. The remaining moisture is similar to that reached using a previous blanching, also leading to a stable product from the perspective of its moisture content. Freezing was observed to produce small losses of proteins in general, except for dehydration at 90±2 ºC, when an increase in the nutrient is recorded. A considerable increase in fats content is also produced, which is a very negative aspect for the product, since it might be causing oxidation of unsaturated acid fats and/or their isomerization in their trans phase. The application of this pre-treatment largely increases crude fiber values in dietary complements. With the exception of forced convection drying, all other treatments allow for the preservation of ash levels close to their original values, and they cause an increase or minimal decrease if compared to the untreated samples. As in the case of blanching, previous freezing causes great losses of ascorbic acid, with the exception of drying at 90±2 ºC, when it is preserved well above the values of the untreated sample. According to this, we may claim that, in general, an increase is produced in phenol content. In contrast, when a previous freezing was applied, a decrease in antioxidant activity was observed in treatments at 50±2 ºC with and without air flow and in the drying at 200 W, while in the others, it increased over 100% in contrast to the untreated leaves.

Conclusions

Taking into consideration the high nutritional importance of protein content and crude fiber, the selection of a process to obtain a dietary complement from the processing of the disposable outer leaves of white cabbage should consider the treatments displayed in Table 5. In this study the crude fiber values (>11 g/100 g DM) and the protein values (20 g/100 g DM approximately) were high if compared to complements

that were obtained using other methods. The permitted values of ashes, lipids and carbohydrates could be kept. Antioxidant activity was higher than in the case of the samples without blanching. Likewise, phenol content was high, and vitamin C loss was lower than in the fresh samples. An important variable for selecting the procedure should also be the short time demanded by microwave drying. Another alternative might be to obtain the complement without any form of previous treatment, and applying a drying at 400 W, which might provide a powder with high crude fiber content but with the drawback of a high amount of lipids with undesirable modifications (trans fats). The choice of a treatment to apply depends upon the nutrient to be reinforced in a diet, i.e., on the deficiencies suffered by the potential consumers. It may be concluded that the complement here proposed from disposable white cabbage leaves presents amounts of nutrients and substances of interest and benefit to human health equivalent to those shown by edible leaves. Therefore, this complement may be considered a good functional food from the nutritional perspective.

Acknowledgment

This work was supported by grants from National University of San Luis (Argentine Republic).

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