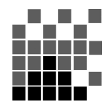

ORIGINAL SCIENTIFIC PAPER

Chemical Properties of Pumpkin Dried by Different Methods

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Summary

The present work evaluates the effect of drying treatments such as convective air drying and freeze-drying on the chemical properties (moisture contents, fibre, ash, vitamin C and sugars), antioxidant activity and phenolic compounds of pumpkin (Cucurbita maxima L.). The trials in the convective chamber were done at 40 ºC and 60 ºC, in the drying tunnel were done at 60 ºC and in the freeze dryer were done at -50 ºC.

From the results obtained it was possible to verify that all drying treatments affected the chemical composition of pumpkin in terms of fibre, ash, vitamin C and sugars. Furthermore, the freeze drying originated products with less reduction in sugars, but with a higher degree of degradation of fibre and vitamin C. With respect to antioxidant activity and phenolic compounds it is possible to conclude that the different dried products are quite similar and do not reveal important differences when compared to the fresh product.

Key words: Pumpkin, Drying, Fibre, Ash, Vitamin C, Sugars, Antioxidant Activity, Phenolic Compounds.

1. INTRODUCTION

Cucurbitaceae (Cucurbits) family includes around 825 species, derived from tropical and subtropical regions, including 26 species that are cultivated as vegetables. In tropical regions the consumption of cucurbits is very high and it has an important role in human consumption (Almeida, 2006). The main crops are pumpkins, watermelon, cucumbers and melons. Pumpkins are rich in water, vitamins, antioxidants and carotene (provitamin A) that protects the body and prevents the premature aging (Caniço et al, 2005), although this is particularly true if it comes from orange fruit pulp. Pumpkins are also poor in total solids (Alibas, 2007) and in calories, which means that they are adequate for low calories regimes, and they are often recommended in diets. This vegetable is also known for the properties of its seeds, that are rich in fat, protein, thiamin, niacin and various minerals (Almeida, 2006), and when crushed provide a pulp with medicinal power which acts as anti-inflammatory, diuretic and emulsifier that helps in fever treatment, ear pain, inflammation of the urinary and prostate disorders (Cunha, 2003).

Pumpkin, like most vegetables, is a perishable food whose characteristics are changed with time. Therefore it becomes necessary to use conservation methods that allow preserving its properties. One of the most commonly used methods for conservation is drying, which is considered the oldest and the most important method of food preservation (Sacilik, 2007). This process consists of removing water from the product in order to reduce the water activity and as a consequence minimize the microbiological changes (Krokida et al, 2003) or enzymatic reactions (Harbour et al, 2009). Furthermore, it originates a considerable reduction in weight and volume, minimizing packing, storage and transportation, as well as allowing storage of the product without refrigeration (Guiné, 2008). During drying many changes occur in the food, such as structural and chemical modifications, that affect the final product quality. Furthermore, it can cause significant loss of some compounds which have importance at the functional level (Maskan, 2001).

The two most commonly employed methods for drying are conventional hot air drying and freeze drying (Vashisth et al, 2011). Nowadays, to dry agricultural products such as vegetables, the most used process is hot air drying (Sacilik, 2007). Air drying is generally favoured due to its low operating costs, and also because less drying time is required in comparison to freeze drying (Vashisth et al, 2011). In conventional air drying, high temperatures are employed that adversely affect the texture, colour, flavour, and nutritional value of the products in question (Vashisth et al, 2011). However, this method allows obtaining a uniform, hygienic and attractive dried product (Doymaz, 2004).

Another preservation method is freeze drying (Peñarrieta et al, 2011). This conservation technique has been increasing in the past decades, and is often used for the processing of seafood, fruits, vegetables and meats (Lindon and Silvestre, 2008). This process involves two steps: first the product is frozen and then is submitted to extreme conditions, namely very low pressure and temperature, so as to provide sublimation of frozen water in the vacuum. This sublimation results from the application of a vapour pressure gradient between the surrounding atmosphere and the ice inside of the product. The freeze dryer is equipped with a heating and condensation system which eliminates the water vapour formed. The elimination of most of the water by sublimation leads to the formation of a product with a highly porous structure keeping the same size and shape of the original product (Hui, 2006). However, an important loss in tissue firmness occurs, as a result from the high porosity (Dermesonlouoglou et al, 2008). On the other hand, freeze drying does not expose the product to high temperatures and helps preserve some product quality parameters such as colour, flavour, nutrients, phenolics, and antioxidant activity when compared to hot air drying (Vashisth et al, 2011). Still, and since this processing involves freezing, some slight degradation of textural properties, colour alteration and nutritional loss also occur (Dermesonlouoglou et al, 2008), both as a consequence of the freezing treatment (Shahidi and Naczk, 1995)

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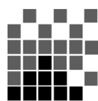


and exposure to very low pressure (Nawirska et al, 2009). The main disadvantage of freeze drying is its high operating cost and long drying time (Vashisth et al, 2011).

Oxidation reactions are of major significance in human physiology as well as the food industry. With respect to human health, oxidative stress has been associated with diseases such as atherosclerosis, cancer and tissue damage in rheumatoid arthritis while the food industry has long been concerned with problems such as rancidity and oxidative spoilage of fruits, vegetables and beverages (McDonald et al, 2004). The idea that the prejudicial effects of oxidative metabolism can be minimized through a diet rich in antioxidants has gained credibility in the past decades (McDonald et al, 2004).

Polyphenols are naturally occurring substances essential in all plant materials, and particularly present in fruits, vegetables, seeds and herbs, but also in plant products such as beverages, wines or cocoa (Aouidi et al, 2011). Phenolic compounds from natural sources have attracted great attention during the last decade, because they are potent antioxidants that play an important role in human nutrition as preventative agents against several diseases, protecting the body tissues against oxidative stress, and thus contributing to human health (Chiou et al, 2007; Aouidi et al, 2011). Antioxidants neutralise free radical reactive oxygen species that are generated endogenously through aerobic metabolism (Bennett et al, 2011).

Antioxidants are compounds that inhibit or delay the oxidation of other molecules by inhibiting the initiation or propagation of oxidizing chain reactions. They can be synthetic or natural, being the synthetic used as antioxidants since the beginning of the XXth century. However, some important restrictions on the use of these compounds are being imposed due to their potential carcinogenicity. Therefore, the interest in natural antioxidants has increased considerably (Velioglu et al, 1998).

Many of the natural antioxidants, especially flavonoids, are widely regarded as some of the major bioactive compounds which have been identified to exhibit antioxidant activity (Mattila and Hellström, 2007; Thoo et al, 2010). They possess various therapeutic a wide range of biological effects, including antibacterial, antiviral, anti-inflammatory, antiallergic, antihepatotoxic, antithrombotic, antiatherogenic, anticarcinogenic, as well as vasodilatory actions and cardioprotective effects (Velioglu et al, 1998; Luthria, 2008; Peinado et al, 2009; Bennett et al, 2011). Furthermore, polyphenols seem to have a protective effect on brain degenerative processes (Bennett et al, 2011). Many of the biological functions, such as antimutagenicity, anticarcinogenicity, and antiaging, among others, originate from the antioxidant capacity (Velioglu et al, 1998).

Phenolic compounds are considered to be metabolically inert and stable (Baitha and Pandey, 2003). They exist in a phenolic acid form as hydroxybenzoic acid or hydroxycinnamic acid derivatives, and are usually covalently bound to insoluble polymers. This limits the activity of bound phenolic compounds as natural anti-oxidative agents and there have been attempts to liberate bound phenolic acids, for example, through heat treatment, thereby increasing the anti-oxidant activity (Choi et al, 2011).

The present work aims to compare the chemical properties such as fibre, ash, vitamin C and sugars, antioxidant activity and phenolic compounds of pumpkin in fresh and after drying, specifically freeze-drying, convective air drying in tunnel and convective air drying in a chamber at different temperatures.

2. MATERIALS AND METHODS

Sample preparation

The pumpkin used in this work is *Cucurbita maxima* Duchesne ex Lam., var. Menina. The pumpkin was peeled and washed, and the skin and seeds were removed. The samples for drying were cut into circles with approximately 4 cm diameter and 1 cm thick.

Drying

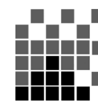
Three different drying equipments were used: a convective chamber, a drying tunnel and a freeze drier. For the convective air drying in the chamber, a chamber BINDER WTB (Germany) with ventilation was used. The experiments were done at constant temperatures of 40 ºC and 60 ºC. For these two trials the drying time was approximately 9 and 6 hours, respectively. The convective drying in the tunnel was done in a Tray Drier UOP-8 (Armfield, UK). The temperature was kept approximately constant at about 60 ºC and for this trial the drying time was 4 hours. For the freeze drying experiment a Freeze Dryer TDF 5505 (Uniequip, Germany) was used. The samples were previously frozen in a conventional kitchen freezer, and then left in the freeze-drier for 96 hours at a temperature approximately -50 ºC and a pressure of 0.7 Pa.

Analysis of chemical composition

Some chemical properties of the fresh and dried samples were evaluated, namely moisture content, fibre, ashes, vitamin C and sugars (reducing, total and non reducing sugars). The moisture content was determined with a Halogen Moisture Analyser HG53 (Mettler Toledo, USA), with operating temperature set to 120 ºC and speed 3 (in a scale of 1 to 5, in which 1 is very fast and 5 is very slow). For the determinations of moisture content, the samples had a mass between 0.2 g and 0.5 g. A total of 18 measurements were made: 6 pumpkin samples were used and three determinations were performed to each sample.

For fibre, ashes, vitamin C and sugars the samples were obtained from triturated pumpkin. Three different samples were used and in each one three analyses were made, in a total of 9 analyses per state: fresh and different dryings. Dosi Fibre method was used to determine crude fibre. 1 g of each sample (crushed) was treated with 150 mL of an acidic solution (H_2SO_4 1.25 %) and then washed trice with 150 mL of distilled water. Next, the process was repeated with a basic solution (NaOH 1.25 %), and washed with 5 mL of acetone, for 3 times. Finally, samples went to muffle and were weighed (AOAC, 2000). For ashes, the Weende method was used, and the samples (1 g) were calcinated at 550 ºC (AOAC, 2000). Vitamin C was determined by titration. 10 mL of an acidic solution (H_2SO_4 20 %) were added to 5 g of sample (crushed) followed by filtration, adding again 10 mL of H_2SO_4 20 % , 1 mL of potassium iodide 10 % and 1 mL of starch solution 1 %. The titration was done with potassium iodate 0.01 N.

For the determination of sugars the Portuguese standard 1420 (NP-1420, 1987) was used, allowing the quantifcation of reducing sugars, non reducing sugars and total sugars, using the technique of Luff-Schoorl. In the case of the fresh product a sample of 10 g was used, and in the case of the dried products 5 g were used. Then, 12.5 mL of carrez I and 12.5 mL of carrez II solutions were added to the sample with distilled water, originating the precipitation (base solution). This solution was then used to the various determinations. For reduction sugars, 25 mL of Luff-Schrool solution, 10 mL of base solution and



water were used in a total volume of 50 mL, which was boiled for 8 minutes with a condenser to avoid evaporation. Later, it was added 9 mL of potassium iodide (1 M), 20 m of H_2SO_4 (1 part acid + 6 parts water), 2 mL of starch paste solution and titrated with sodium thiosulfate solution (0.1 N). For total sugars it was used 50 mL of base solution and 3.5 mL of HCl (37 %) left on a bath at around 70 ºC for 5 minutes. After cooling the solution was neutralized with NaOH (40 g/100). The titration was like in the reducing sugars, but instead of using 10 mL of the base solution it was used 10 mL of the solution that was obtained from the determination of total sugars. The blank trial was done with the same procedure but just with 25 mL of Luff-Schrool solution and 25 mL of distilled water.

Except for the moisture content, which was expressed in fresh weight, all other results were expressed in terms of dry matter, in order to allow a direct comparison of the values for the different dried samples.

Determination of antioxidant activity and quantification of phenolic compounds

The antioxidant activity and total phenolic compounds of the fresh and dried samples were assessed using a spectrophotometer UV Mini-1240 (Shimadzu, Japan) at different absorbencies: for antioxidant activity the absorbance was 734 nm and for phenolic compounds was 760 nm. All samples, for fresh and dried pumpkin, were obtained by crushing the product, having taken a mass of 5 grams. Subsequently, 6 extractions were performed for each sample (three with methanol and three with acetone), lasting one hour each, done with the aid of a magnetic stirrer.

The antioxidant activity was determined using the method base on the capacities of different substances to neutralize the radical $ABTS^+$ in comparison with a standard antioxidant (Trolox) in a dose-response curve. 200 µL of the extract solution were taken and 2 mL of ABTS solution were added (this last was prepared the day before and left to stand all night). After 15 minutes the samples were used to read the corresponding absorbance, at 734 nm. The calibration lines were obtained with Trolox solutions at different concentrations (200 µL, 175 µL, 150 µL, 125 µL, 100 µL, 50 µL, 25 µL), and for each concentration 3 readings were made. The values of the antioxidant capacity were expressed in µmol equivalents of Trolox (TEAC) per gram.

The method used to quantify the total phenolic compounds used the Folin Ciocalteu reagent (Shahidi and Naczk, 1995). For this, 125 µL of the sample solution were used and 750 µL of distilled water plus 125 µL of Folin Ciocalteu reagent were added. After a 6 minutes pause 2 mL of sodium carbonate solution were added and, after 90 minutes in the dark, the samples absorbencies were read at 760 nm. The calibration curve was prepared using 50 mg/L, 100 mg/L, 150 mg/L, 250 mg/L, 350 mg/L, 500 mg/L solutions of gallic acid, and for each concentration 3 readings were performed. Total phenolic compounds were expressed in mg gallic acid equivalents (GAE) per gram.

3. STATISTICS

With the aim to evaluate if the differences between the medium values of the properties analyzed in this study were significant, a statistical analysis was performed by the Tukey HSD test with a level of significance of 5 % ($P < 0.05$). The Tukey's HSD (Honestly Significant Difference) test is a statistical test to find out which means are significantly different from each other, and consists in a single-step multiple comparison procedure, coupled to an Analysis of Variance (ANOVA). The test identifies if the difference between two means is greater than the standard error allowed. The software Statistica V6.1 from Satsoft was used to perform the statistical analysis.

4. RESULTS AND DISCUSSION

Table 1 presents the mean values for moisture content, crude fibre, ash and vitamin C for pumpkin in fresh and after the different drying treatments. The mean value obtained for fresh pumpkin moisture content was 90.81 %, being in the range of other values reported in literature, between 88 % and 92 % (Escobar and Buesa, 1999; Senser and Schertz, 1999; Almeida, 2006; Barroso et al, 2007; Monteiro, 2009). As to the dried samples, those dried in the chamber were dried to a further extent (around 7 %) than those in the freeze drier (11 %) and drying tunnel (15 %). The value for the fibre of the fresh pumpkin was found to be 15.13 % (dry basis), corresponding to 1.49 % (wet basis), which is a value a little higher than that reported by Monteiro (2009), 0.76 %. However, the value stays close to the upper value of the range of values found in literature, between 0.5 % and 1.3 % (wet basis) (Fennema et al, 2004; Almeida, 2006; Barroso et al, 2007). As to the effect of the different drying treatments on the fibre contents, it was observed that freeze drying induce the highest degree of loss, corresponding to a disintegration of the polymeric fibres. The convective air dryings induced intermediate changes in the fibre contents, varying with temperature and operating conditions (Femenia et al, 2009; Borchani et al, 2011). The mean value for the ash contents of the fresh pumpkin was 12.34 % (dry basis), corresponding to 1.13 % (wet basis), being in the range found in the literature for ash content in pumpkins: 0.3 % to 1.4 % (Ferreira and Graça, 1977; Senser and Scherz, 1999; Fennema et al, 2004; Guiné et al, 2011).

Table 1. *Moisture, Fibre, Ash and Vitamin C contents of fresh and dried pumpkin.*

	MOISTURE (g/100g fresh weight)	FIBRE[(1)] (g/100g dry matter)	ASH[(1)] (g/100g dry matter)	VITAMIN C[(1)] (mg/100g dry matter)
Fresh product	90.81 (±0.43)	15.13^a (±2.02)	12.34^d (±1.16)	127.04^a (±3.68)
Drying chamber (40ºC)	7.19 (±1.98)	5.95^d (±0.45)	17.90^b (±0.55)	16.52^b (±2.77)
Drying chamber (60ºC)	7.49 (±2.04)	9.69^b (±0.23)	19.41^a (±0.58)	12.79^c (±0.01)
Tunnel drying (60ºC)	14.77 (±3.66)	8.06^c (±0.57)	19.27^{ab} (±1.40)	14.57^{bc} (±0.28)
Freeze drying	10.93 (±1.83)	1.15^e (±0.13)	16.05^c (±1.32)	13.74^{bc} (±0.03)

[(1)]Mean values in the same column with different superscripts are statistically different ($P<0.05$).

The value encountered for the vitamin C content in the fresh pumpkin was 127.04 mg/100 g dry matter, corresponding to 12 mg/100 g wet product. This value is similar to other reported in literature (Maroto, 1995; Senser and Scherz, 1999). In all drying treatments, the vitamin C contents decreased drastically, what would be expected, taking in consideration that this chemical compound is very much affected by temperature (Mclaughlin and Magee, 1998; Gliguem and Birlouez-Aragon, 2005; Vikram et al, 2005; Cruz et al, 2008).

Table 2. *Sugar contents of fresh and dried pumpkin.*

	REDUCING SUGARS(1) (g/100g dry matter)	TOTAL SUGARS(1) (g/100g dry matter)	NON REDUCING SUGARS(1) (g/100g dry matter)
Fresh product	24.61[a] (±2.94)	43.78[a] (±4.43)	19.47[a] (±4.27)
Drying chamber (40ºC)	14.74[b] (±0.639)	19.55[c] (±1.33)	4.57[c] (±1.68)
Drying chamber (60ºC)	15.31[b] (±0.74)	17.62[c] (±0.99)	1.97[c] (±0.57)
Tunnel drying (60ºC)	15.40[b] (±0.58)	17.46[c] (±1.53)	2.72[c] (±0.597)
Freeze drying	16.46[b] (±0.88)	28.02[b] (±1.30)	10.99[b] (±1.45)

(1)Mean values in the same column with different superscripts are statistically different ($P<0.05$).

Table 2 shows the mean values obtained for sugar contents (reducing, total and non reducing) for pumpkin in fresh, after air drying in the chamber and in the tunnel and after freeze-drying, expressed in dry basis. The total sugars of the fresh pumpkin were 43.78 g/100g dry matter, corresponding to 4.02 % wet basis. This value is similar to those reposted by Senser and Scherz (1999) and by Monteiro (2009) for carbohydrates, 4.60 % and 4.30 % respectively. All drying treatments produced a significant reduction in the sugar contents, varying from 36 % for the freeze drying to 60 % for the drying in the chamber at 60 ºC. In fact, the higher losses correspond to those treatments where the temperature was higher (60 ºC) and where the thermal degradation was more intense (Ameur et al, 2007; Forbes et al, 2010; Lan et al, 2010). Similarly, the reducing and non reducing sugars also suffered important losses in all drying treatments. The reducing sugars content for the fresh pumpkin was 24.61 g/100 g dry matter, while the non reducing sugars was 19.47 g/100 g dry matter. In literature were found values for reducing sugars, non reducing sugars and total sugars of 26.35 g/100g dry matter, 25.12 g/100 g dry matter and 52.84 g/100g dry matter, respectively. In literature were also found values for reducing and non reducing sugars, expressed in wet basis, of 2.4 % and 2.3 %, respectively (Guiné et al, 2011), which are similar to those found in the present work: 2.2 % and 1.9 % respectively for reducing and non reducing sugars.

Table 3. *Percentage of extraction of compounds with antioxidant activity in the fresh and dried pumpkin.*

Extraction	% Extraction of compounds with antioxidant activity				
	Fresh	Chamber 40ºC	Chamber 60ºC	Tunnel (60ºC)	Freeze drying
1ª Extr. Methanol	54	52	52	55	53
2ª Extr. Methanol	30	30	30	28	30
3ª Extr. Methanol	15	18	18	17	18
1ª Extr. Acetone	40	44	50	46	41
2ª Extr. Acetone	34	33	32	32	35
3ª Extr. Acetone	26	22	18	22	24

Table 3 shows the percentages of extraction of compounds with antioxidant activity obtained with extracts of methanol and acetone. Two solvents were used in order to extract a larger amount of compounds with antioxidant activity. It is possible to verify that for the methanol extractions, the efficiency of the successive extractions is practically equal regardless of the state of the samples (fresh or dried), meaning that the procedure if efficient in all cases. The percentage of extraction in the first extraction was about 52-54 % while the third extraction varied from 15 % to 18 %. With respect to the extractions with acetone, also the different samples present similar extraction results, but in this case the extraction is less efficient, considering that in the third extraction the percentages of antioxidant compounds recovered are higher, varying from 18 to 26 %.

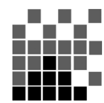
Equations 1 and 2 express the calibration lines that have been made to quantify the antioxidant activity in different samples of pumpkin. It was necessary to have two calibration lines because measurements were made on different days. Equation 1 was used for fresh pumpkin, pumpkin dried in tunnel and freeze dried, while Equation 2 was used for the pumpkin dried in the chamber at both temperatures (40 ºC and 60 ºC):

% Inhibition = 347.0735 * Concentration (mmol/L) + 9.4071 ($R^2 = 0.9906$) /1/

% Inhibition = 362.0314 * Concentration (mmol/L) + 5.0206 ($R^2 = 0.9958$) /2/

Both calibration lines are quite similar and have relatively high R^2 values, meaning that the fit was good.

Figure 1 presents the mean values and their deviations to the values of antioxidant activity measured in extracts of methanol and acetone obtained for fresh pumpkin, pumpkin dried at 40 ºC, dried at 60 ºC, dried in the tunnel and freeze dried. The results show that, except for the fresh and freeze dried samples, which showed equal values of antioxidant activity in both extraction solvents; in the other cases the antioxidant activity was observed to be higher in the methanol extracts. However, the results indicate that both extracts are equally rich in compounds with antioxidant capacity.



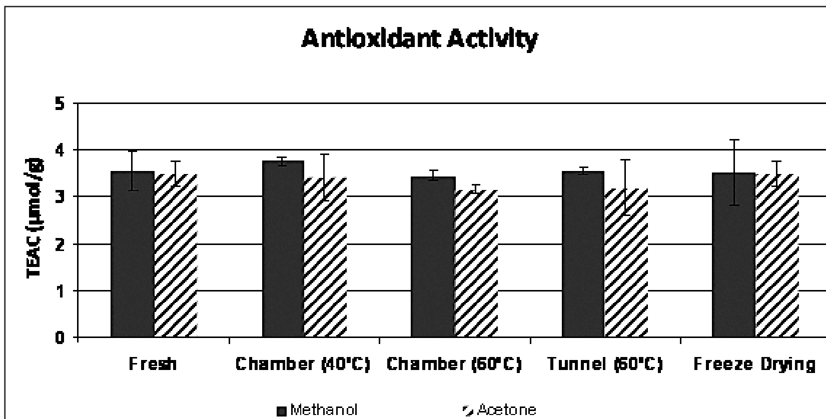


Figure 1. *Antioxidant activity for fresh and dried pumpkin, with methanol and acetone extractions.*

As to the effect of drying on the antioxidant activity, it could be observed that drying practically does not influence the antioxidant capacity, at least for the methods and conditions tested in the present work. Nonetheless, the product originated from air drying in the chamber at the higher temperature (60 ºC) showed the lowest antioxidant activity.

Bennett et al. (2011) studied the effect of drying conditions on total polyphenols and antioxidant activity of different dried fruits and they observed that for sultanas the drying conditions could affect both sensory and helth-related quality attributes of grapes, whereas for all other fruits, the drying conditions did not induce significant changes in total phenols or antioxidant activity. Peñarrieta et al. (2011) evaluated the changes in phenolic antioxidants for freeze and sun dried potato by two methodologies: ferric reduction antioxidant power and ABTS. The results showed that the antioxidant capacity appeared reduced after freeze drying if the ferric method was used, but remained the same if with the ABTS method. Peinado et al. (2009) showed that during the drying of grapes compounds of high molecular weight are formed and are partially responsible for the antioxidant activity. Catechins and procyanidins as well as polymeric procyanidins were greatly enhanced during drying. Furthermore, antioxidant activity did not vary during drying although a reduction in total phenolics was observed. Choi et al. (2011) studied the effect of storage and heat treatment on phenolic compounds of citrus peels, and concluded that both, long term storing and heat treatment, originated an increase in total phenols and bioactivity.

Table 4 shows the percentages of recovery of phenolic compounds obtained with different extractions, using methanol and acetone as extraction solvents. Again two solvents were used, since there are some molecules that are more soluble in one solvent and less in another, and the use of two solvents allows extracting a higher amount of phenolic compounds. It is possible to verify that the different samples of pumpkin (fresh and dried) presented the same patterns of extraction, corresponding to similar percentages of recovery in all three extractions, and for both solvents. In this case, the efficiency of extraction is similar for both solvents.

Equation 3 presents the calibration line used for the quantification of phenolic compounds, which has a high regression coefficient, indicator of a good fitting:

Absorbance = 2.5405 * Concentration (g/L) + 0.1193 ($R^2 = 0.9750$) /3/

In Figure 2 it is possible to observe the mean values and standard deviations for the phenolic compounds quantified in the extracts of methanol and acetone obtained for fresh and various dried states of pumpkin. It may be noted that the values of phenolic compounds are always higher in the extracts of methanol than in acetone, but otherwise confirms the utility of using two extraction solvents, because even slightly lower; the values of total phenols extracted with acetone represent a significant part of the phenolic compounds quantified in the different samples. Furthermore, it is possible to verify that the drying process, regardless of the method used does not affect the amounts of phenolic compounds, being this an aspect of major importance, since it is intended that the processing will not affect the nutritional and functional properties of the product.

Table 4. *Percentage of extraction of phenolic compounds in the fresh and dried pumpkin.*

Extraction	% Extraction of phenolic compounds				
	Fresh	Chamber 40ºC	Chamber 60ºC	Tunnel (60ºC)	Freeze drying
1ª Extr. Methanol	42	42	42	42	41
2ª Extr. Methanol	34	34	34	34	34
3ª Extr. Methanol	25	24	24	24	24
1ª Extr. Acetone	46	46	45	46	46
2ª Extr. Acetone	28	28	28	28	28
3ª Extr. Acetone	26	26	27	26	26

Vashisth et al. (2011) reported that freeze drying induced a high retention rate of the phenolic compounds relatively to

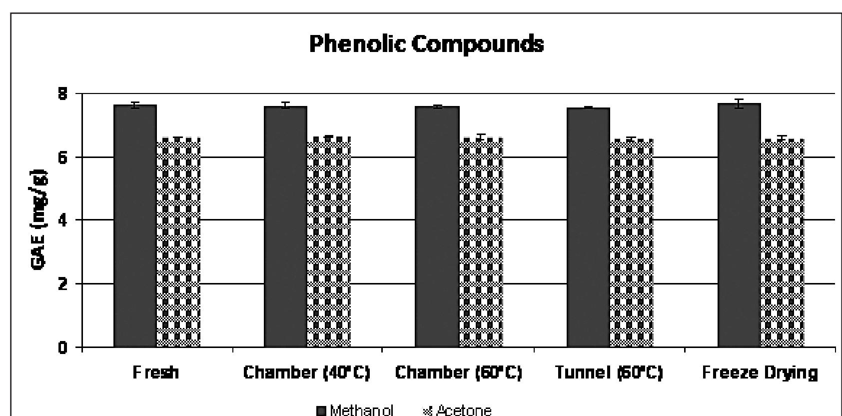


Figure 2. *Phenolic compounds for fresh and dried pumpkin, with methanol and acetone extractions.*

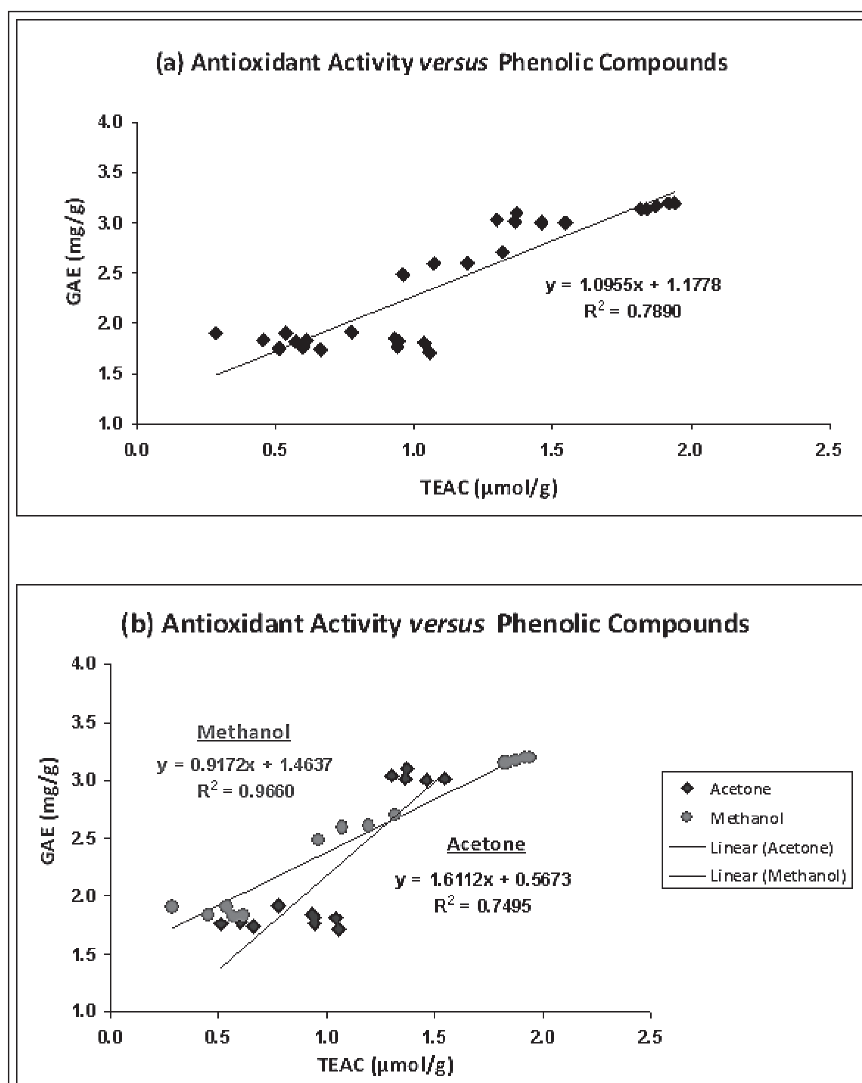


Figure 3. *Correlations between phenolic compounds and antioxidant activity: (a) with both types of extracts; (b) with methanol and acetone extracts separately.*

the fresh state, when compared to hot air drying, for muscadine pomace. Some researchers suggested that polyphenols are heat labile and that prolonged heat treatment and high temperatures cause irreversible chemical changes to such compounds. Furthermore, some destruction of flavanoids and tannins may also occur. Harbourne et al. (2009) studied the effect of drying methods on the phenolic constituents of herbs and freeze drying and oven or tray drying at 30 ºC did not affect the phenolic compounds, while if the temperature was raised to 70 ºC some reduction was observed. Rózek et al. (2010) evaluated the phenolic stability during air drying of grapes submitted to a pre-treatment of osmotic dehydration, and found that this pre-treatment effectively protected against degradation during air drying.

Figure 3 shows the correlations between the antioxidant activity and the amount of phenolic compounds obtained for all samples analyzed. The graph in Figure 5(a) shows all the points, considering both solvents, whereas the graph in Figure 5(b) shows the regressions applied separately to the points obtained from the two solvents tested. From the graph (a), and attending the values of the regression coefficient (0.789), it can be observed that there is some correlation between these two variables (Equation 4), meaning that the antioxidant activity is somehow directly related to the amount of phenolic compounds present, as expected.

TEAC (μmol/g) = 1.0955 * GAE (mg/g) + 1.1778 ($R^2 = 0.7890$) /4/

However, when analysing the lines in graph (b), it becomes evident that the points resulting from the methanol extracts fit much better a stright line (Equation 5) than those from the acetone extracts (Equation 6), with the value of the regression coefficient being respectively 0.9660 and 0.7495.

TEAC (μmol/g) = 0.9172 * GAE (mg/g) + 1.4637 ($R^2 = 0.9660$) /5/

TEAC (μmol/g) = 1.6112 * GAE (mg/g) + 0.5673 ($R^2 = 0.7495$) /6/

5. CONCLUSIONS

The present work evaluates the effect of different drying treatments on the chemical properties, antioxidant activity and phenolic compounds of pumpkin, which were dried using three different methods: convective air drying in chamber, convective air drying in tunnel and freeze-drying.

In general, the drying process induced a reduction in fibre, ashes, sugars and vitamin C, being this component much affected by drying, with losses of up to 90 %. Freeze drying was the process that allowed obtaining the most similar values sugar contents as compared to the fresh pumpkin, but induced a higher degree of degradation of fibres and vitamin C.

The results also showed that in terms of antioxidant activity and amount of phenolic compounds, the differences between the fresh pumpkin and all the other states of drying are practically negligible, which means that even though some of the chemical components of pumpkin have changed with drying at different conditions, the compounds of functional importance within it do not change or get lost. This allows us to conclude that it is possible to preserve the functional characteristics of pumpkin even after drying.

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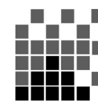

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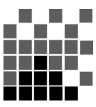

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