STUDY OF THE PUMPKIN CONVECTIVE DRYING

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Abstract: The aim of this work is to analyse the effect of convective drying on the nutritional properties of fresh and dried pumpkin (C*ucurbita máxima)*. The samples were analyzed in terms of moisture content, total and reducing sugars, acidity, proteins, lipids, crude fiber and ash. The pumpkin was cut into circular slices dried in a ventilated chamber at different temperatures, ranging between 30 ºC and 70ºC. In addition, the kinetic behaviour was also studied in this temperature band.
The results enable us to conclude that the fresh pumpkin has a low content of lipids and a high level of water, sugars, protein and crude fiber. This chemical composition, which is an excellent source of nutritive elements, associated with some components with antioxidant activity, which act as a health-protecting factor, make out of pumpkin an excellent food product, whose consumption should be further encouraged.
In addition, it is also possible to conclude that, apparently, the convective drying process has no effect on the nutritional characteristics of the pumpkin, except on sugars and acidity.
The influence of the operating condition (the temperature) on the drying kinetics was also analysed. The results show that the increase on the operating temperature strongly accelerates the drying process and a constant rate period is not observed. However, in the range of 30 to 70ºC it was observed that there is a similar kinetic behaviour for all the values of temperature tested. The experimental data for the moisture ratio content with time was fitted, using the software Sigma Plot, v8.0 (SPSS, Inc.), to eight different models, and the two that showed a better performance were the Page and modified Page.

1. INTRODUCTION

Botanically the pumpkin is a squash fruit, most commonly orange in colour when ripe and is appreciated when cooked, pureed, used in soups, breads, and many other dishes. In culinary terms, it is widely regarded as a vegetable.
It has been found that 100 g of fresh pumpkin contain 80.0-96.0g moisture content, 4.6-6.5g sugars, 0.6-1.8g protein, 0.0-0.2g lipids and 0.5-1.3g fiber[1]. This chemical composition associated with its antioxidants and vitamins allows the pumpkin to have an important health-protecting effect. In fact, the range of values of lipophilic substances as carotenoids presenting in pumpkin varieties can contribute significantly to the uptake of provitamin A and especially lutein, a carotenoid with special physiological functions[2]. The yellow to orange colour of the pumpkin flesh arises from this group of substances. Additionally, the good performance of the pumpkin-fiber products in relation to water and glucose highlights the possibility of their use as food ingredients[3].
The knowledge of the nutritive value of food, particularly the fruits and vegetables, is necessary in order to encourage the increase of their consumption and use for nutritional and technological applications.

An alternative to fresh fruits and vegetables is their dried form, that allows their use during the off-season. However, the drying process can have a strong impact on the quality of the dehydrated product, since this process involves simultaneous coupled heat and mass transfer phenomena which occur inside the product being dried. Many mathematical thin-layer models have been proposed to describe the drying process of agricultural material. Among them, the semi-theoretical models are widely used[4,5].

2. MATERIALS AND METHODS

The pumpkin used in this study is a C*ucurbita maxima* variety which is the most cultivated and consumed pumpkin in Portugal.

The fresh and dried pumpkin was analysed in respect of moisture content, acidity, total sugars, lipids, proteins, ash and crude fiber. To prepare the samples the pumpkin was peeled, and the seeds were removed. To obtain the dried samples the pumpkin was cut into circular slices (with 40 mm diameter and 4 mm thickness) and dried in a ventilated chamber. The chemical analysis of both fresh and dried pulp pumpkin were done, in triplicate, with milled samples.

The moisture content of fresh pmpkin was determined by vacuum oven method[6] and for the dried samples was used a Halogen Moisture Analyzer (Mettler Toledo HG53).

Total and reducing sugars and acidity was estimated according to previous established methodologies[6]. Protein content was estimated by the micro-Kjeldhal digestion procedure. Lipid was gravimetrically quantified after ether extraction in a Soxhlet apparatus and crude fiber by sequential hot digestion of the sample with dilute acid and alkaline solutions[6].

3. RESULTS AND DISCUSSION

3.1 Chemical characterization

The drying process was carried out at constant temperature of 30ºC, 40ºC, 50ºC, 60ºC and 70ºC until pumpkin reached a safe moisture content below 5%. However, to analyse the effect of this operational condition on the nutritive value of dried pumpkin only the samples obtained with the temperature of 30ºC and 70ºC were characterized in terms of chemical composition..

The moisture content of the fresh pumpkin was 91.9% (wet basis) and that of the dried product at 30ºC and 70 ºC was 3.1% and 2.7%, respectively.

In Table 1 the results of the evaluation of the nutritional composition of fresh pumpkin are shown, together with some data from literature, for comparison purposes. The results reveal that the pulp of fresh pumpkin has low lipids and high content of total sugar, as it is generally found in the majority of other fruits. However, it is also remarkable the high protein and crude fiber content of fresh pumpkin, which plays an important role on human health. The chemical composition of pumpkin is in accordance with other results described in the literature[1].

The results of nutritive contents of both fresh and dried pumpkin are presented in Table 2, with the values expressed in grams per 100g of dry weight, for a better comparison of the fresh to the dried products. It can be observed that the drying process at 30ºC and 70ºC allows keeping the nutritional characteristics of the dried pumpkins compared with fresh state, except the sugars and acidity contents, which diminished with drying. The decrease in the acidity of dried pumpkin can, eventually, indicate that the major part of the acidity present in the fresh

pumpkin is volatile, and therefore the temperature profile during the drying process promotes its loss by evaporation.
During the dehydration process, the pumpkin samples have been submitted to high temperatures that also promote enzymatic and non-enzymatic reactions of sugars that contribute to their decreasing during drying process.

Table 1 - Chemical composition of the fresh pumpkin, per 100 g of edible portion.

	Ref [1]	Ref [7]	Analysed
Moisture content	80.0 – 96.0 g	–	91.9 g
Protein	0.6 – 1.8 g	–	1.6 g
Lipids	0.0 – 0.2 g	–	0.2 g
Crude fibre	0.5 – 1.3 g	–	1.0 g
Ash	0.8 – 1.4 g	–	1.1 g
Carbohydrates	4.6 – 5.6 g	–	4.7 g
Total sugar	–	–	4.7 g
Reducing sugar	–	–	2.4 g
Non reducing sugar	–	–	2.3 g
Acidity	–	207 mg	20 mg*
Carotenoids	–	2 mg	–
Vitamin A	–	280 μg	–
Vitamin C	–	12 mg	–
Vitamin E	–	1 mg	–

*expressed in malic acid

Table 2 - Chemical composition of the fresh and dried pumpkin at 30 ºC and 70 ºC (expressed as a percentage of the dry mass).

	Fresh	Dried at 30 ºC	Dried at 70 ºC
Protein	17,3	15,5	16,1
Lipids	2,1	1,1	2,1
Crude fibre	11,1	8,2	9,6
Ash	12,7	17,8	18,5
Total sugar	52,8	18,6	17,0
Reducing sugar	26,3	15,8	14,6
Non reducing sugar	25,1	2,7	2,3
Acidity	0,22	0,11	0,14

The chemical composition of dried pumpkin obtained to the lowest and highest temperature showed that the nutritive values remain almost constant. This seems that although temperature had an important impact on sugars and acidity, the value of this operating condition used to dried pumpkin has a negligent effect on the nutritive values of the final product.

3.2 Kinetic model

The batch drying curves obtained for the temperatures of 30ºC, 40ºC, 50ºC, 60ºC and 70ºC reveal a similar kinetic behaviour but with a decreasing stabilization time. In fact, the samples took 8.0, 5.5, 4.0, 3.5 and 2.0 hours, respectively, to reach a final moisture content of

3.5%, 4.6%, 4.1%, 3.2% and 2.7% (wet basis). Figure 1 illustrates the dry basis moisture content of pumpkin slices during the convective air drying at the different temperatures studied.

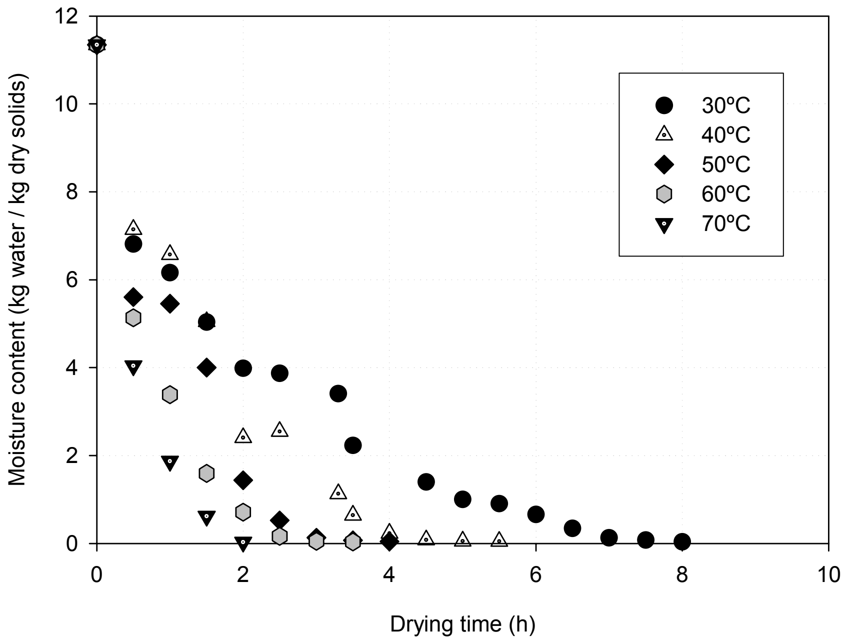

Figure 1 – Drying curves of pumpkin slices on dry basis at different temperatures.

As expected, there is an acceleration of the drying process due to the increase in the temperature of the drying air from 30º C to 70ºC. Moreover, the higher percentage of weight loss occurs during the first drying stage of the process. In fact, in the first 30 minutes of drying the loss of moisture content increased of about 40% to 64% when the temperature rises from 30ºC to 70ºC. The effect of temperature on the drying kinetic of pumpkin is consistent with others results published in the literature[8] to the same product dried at temperatures ranging between 65ºC and 75ºC.

To identify the model that has a good capacity of prediction to each drying curve, the kinetic data has to be expressed in the form of a moisture ratio (MR) versus time (t) curve. The moisture ratio is a dimensionless variable defined as:

$$MR = (W-W_e)/(W_0-W_e) \qquad (1)$$

where W is the dry basis moisture content at any time t, W_0 is the initial dry basis moisture content and W_e is the equilibrium dry basis moisture content, determined from the drying curve, taken for a higher time, assuming no more moisture was exchanged from the samples to the surrounding atmosphere.

The kinetic data obtained for the five temperatures was fitted to eight different models well documented in the literature[9,10,11]: Newton, Page, Modified Page, Henderson & Pabis, Logaritmic, Logaritmic (two terms), Wang & Singh and Diffusion approach using the software Sigma Plot, v8.0 (SPSS, Inc.).

To compare the performance of the different models two statistical parameters were determined: the standard deviation of each parameter and the corresponding model coefficient of determination (R^2). The values obtained for the coefficient of determination with the

different fittings of the models to the five temperatures varied in the range of 0.9505 – 0.9981 to Newton, 0.952 – 0.998 to Page, 0.952 – 0.998 to modified Page, 0.952 – 0.998 to Henderson & Pabis, 0.958 – 0.998 to logarithmic, 0.952 – 0.998 to logarithmic (two terms), 0.940 – 0.970 to Wang & Singh and 0.951 – 0.998 to diffusion approach model. The analysis of these results complemented the analysis of the standard variation of the equation parameters estimated for each temperature (results not shown but available from the corresponding author upon request) reveal that all the models are, in some way, applicable to the present experimental data. However, if the results were analysed in more detail it would be possible to conclude that the diffusion approach and the Wang & Singh model were, globally, the worst to reproduce the experimental results. In this later model the standard deviations of their parameters are, in some cases, higher that the estimated parameter. Combining the statistical analysis with the capacity of the models to describe the experimental results to each temperature, it is possible to conclude that Page or Modified Page are the best to represent the drying curves of pumpkin.
The semi-empirical Pages's equation is the following:

$$MR = \exp(-kt^{n}) \qquad (2)$$

where MR is the moisture ratio; t is the time in hours (h); k is the drying constant in (h^{-1}) and n is the dimensionless exponent.
Table 3 presents the value of the estimated parameters to one of the best models, the Page model, as well as the corresponding statistical information to each temperature studied.

Table 3 – Results of the fitting to the Page model, for the temperatures of 30ºC, 40ºC, 50ºC, 60ºC and 70ºC.

Temperature (ºC)	Model	Parameter		
		k	n	R^2
30	Page	0,6281 (±0,0474)	0,7812 (±0,0646)	0,973
40	Page	0,6508 (±0,0609)	1,0714 (±0,1141)	0,975
50	Page	0,9689 (±0,1173)	0,9497 (±0,1843)	0,952
60	Page	1,3929 (±0,0627)	0,9207 (±0,0815)	0,995
70	Page	1,9493 (±0,0904)	0,9390 (±0,0852)	0,998

Acording to Table 3, the drying constant (k) increased with the increasing of temperature from 30ºC to 70ºC. As a result of the important effect of temperature on the drying process this parameter triplicates in the temperature range studied. The parameter (n) has a lower dependence of this operation condition.
The experimental values of the moisture ratio for the different temperatures as well as the predictions obtained using the Page model to each case are illustrated in Figure 2. As it can be seen the Page model proved to give good fits for the diferrent drying curves along the entire range of time.

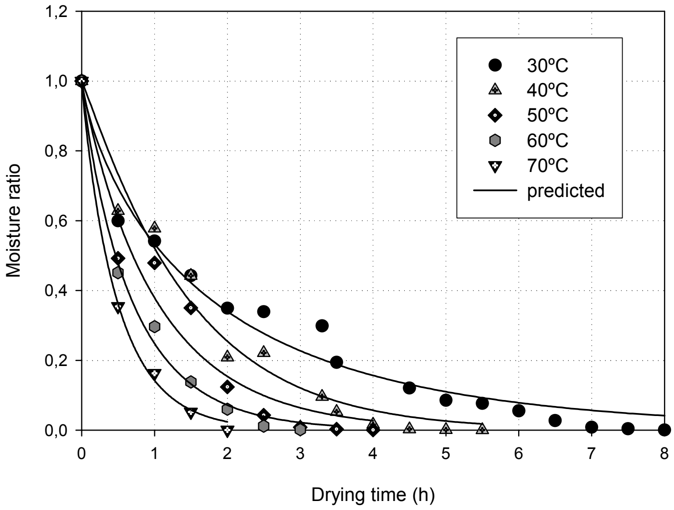

Figure 2 - Profile of experimental and predicted moisture ratio curves at different temperatures.

From the drying curves it is also possible to conclude that, despite of the similar kinetic behaviour, the increase in temperature acelarates the drying process considerably. The drying time necessary to reach a safe moisture content under 5% decreased 75% when the temperature was increased from 30ºC to 70ºC.

Moreover, the higher percentage of weight loss occurs during the first drying stage of the process.

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