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Original scientific paper

Usability of Pumpkin for Nutritional Purposes and Green Energy Production

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Abstract: A significant problem in the use of pumpkin is the fact that its total mass is not used completely, but is thrown away and becomes waste. The meat is used for the production of flour, but after its production there are leftovers. The work includes two varieties of pumpkin (seed with shell and seed without shell). The aim of this study is to determine the impact of drying and variety on the quality of meat flour and the possibility of using residues after the production of peel and seed shells with the goal of producing energy. Drying will be carried out by convection at 50, 60, and 70 °C. The obtained results showed that Variety 1 (with shell) is better for flour production and energy efficiency. LHV of peel was 14.70 MJ/kg and shell 17.80 MJ/kg and classifies pumpkin residues as a very desirable raw material for green energy production.

Keywords: drying; flour; green energy production; pumpkin; residues

1 INTRODUCTION

Pumpkin is cultivated from Mexico to Argentina and Chile and has spread to Europe, Asia, and Western America [1]. Pumpkins were traditionally grown together with corn (*Zea mays*) and beans (*Phaseolus vulgaris*) [2]. In such outlays corn served as support for bean plants providing shade for pumpkins; at the same time, beans plant fixed nitrogen in the soil while pumpkin prevented the moisture loss and weeds spreading [3]. Pumpkin was brought to Europe with the return of the first expeditions from America, but it became widespread only in the 18th century.

Pumpkin belongs to the order of *Cucurbitales*, family *Cucurbitaceae*, genus *Cucurbita* [4]. The family *Cucurbitaceae* has 118 genera and 825 species. Mexico is the most important center of diversity with as many as 34 genera (five of them are endemic) and 142 species [5]. The genus *Cucurbita* includes the species *Cucurbita argyrosperma*, *Cucurbita maxima*, *Cucurbita moschata,* and *Cucurbita pepo* which have a significant role in agricultural production [3], while the wild species of *Cucurbita okeechobeensis* is almost extinct. The decline and extinction of wild varieties of *Cucurbita* are directly connected to the extinction of megafauna as megafauna is essential for the dispersion of seeds and is responsible for loss of habitat. Wild and domesticated *Cucurbita* species have some very significant differences: most domesticated species show bigger diversity in coloration, shapes, and size than feral species. Also, domestication in the cultivated species enabled uniform germination and an increase in the size of fruit and seeds. However, the resistance to diseases and pests is reduced [6].

Of the total mass of pumpkin, it is considered that on average it has about 4% of seeds, about 6% of pulp, 83% of flesh, and 7% of peel. Depending on the structure, there are two sorts of seeds: shelled and unshelled seeds. If the seeds have a shell, the average ratio of seed-to-shell is 60:40%.

According to FAO [7], the global production of pumpkin amounted to annual 27 million tonnes per year. Although pumpkin cultivation is distributed over all the continents, Asia is the leading producer with 61% of the total, while Europe accounts for only 15% of global production. In the Republic of Croatia pumpkin is a rather common crop and is being grown today on almost every family farm, primarily for high-quality pumpkin seed oil. Different pumpkin varieties are used for oil production, some of which contain shelled seeds. It is a significant problem for the production process because seed shells must be separated and disposed off. For that purpose, peeling is applied because the shell does not contain either oil or nutrients and reduces the productive capacities of the equipment [8].

Pumpkin is often called functional food. In recent years there were numerous investigations into health-related features of pumpkin and products deriving from pumpkin [9, 10].

Pumpkin flash is a rich source of minerals, vitamins, carotene, pectin, and other bioactive substances that are beneficial to health [11] and is an excellent source of vitamins and minerals [12] as well as a source of fibers. However, the pumpkin's flash nutritive composition is changeable and depends on several factors, among which are: growing conditions, location, and variety [13-18]. It is a very valuable foodstuff such as pumpkin flour. Pumpkin flour is utilized extensively because it is used as a supplement in bakery products, sauces, for soups, spice, and instant noodle, as well as a natural coloring agent in pasta and flour mixes [19]. It has a highly desirable flavor, sweetness, and deep yellow-orange color [20]. Dried pumpkin flour can increase pumpkin consumption and has storage and transportation advantages over fresh pumpkin.

The drying process has been applied for a long time already as a method of preservation of pumpkin's nutritional features. It is the oldest preserving method of agricultural products [21] and it is one of the most common technological procedures used to prolong the lifetime of agricultural products [22-25]. Drying includes removing water from the material up to the level where microbial and enzyme activities are mainly reduced to a minimum [26]. Several factors affect the drying rate during the falling rate period such as air temperature and velocity and shape of the material to be dried. However, the temperature of the air is considered to be the most important factor affecting the drying process [27]. The drying rate increases significantly with an increase in hot air temperature which subsequently decreases the drying time [28, 29]. Convection drying is the most common drying technique and is used for most agricultural products [30] and it is suitable for drying pumpkin flash for pumpkin flour production. Also, drying as one of the preservation methods enables physico-chemical stabilization by reducing moisture content, as well as the product with new quality features of different nutritional and economic values [31-34].

A significant problem in the use of pumpkin is the fact that its total mass is not fully used. Pumpkin residues as peel and shell are making up part of the millions of tons of biomass generated annually but could find benefits for energy purposes. Biomass from agricultural production is a very acceptable fuel in terms of environmental impact, especially because it diminishes the atmospheric burden of greenhouse gases. Sustainable development of biomass resources for energy purposes requires knowledge of the biomass supply capacity as well as biomass quality [35, 36]. Pumpkin waste and other solid residues of agricultural by-products were considered raw materials for energy production [37, 38]. In general the advantage of using biomass as an energy source refers to its relatively large availability and usability potential [39].

The aim of this work was to determine the influence of drying temperature and pumpkin variety (with and without shells) on the quality of pumpkin flour from the flesh. Furthermore, the possibility of using the peel and pumpkin seeds shell will be determined, which will provide the basis for sustainable and circular bioeconomics of residues after the production of pumpkin flour.

2 MATERIALS AND METHODS

2.1 Analytical Methods

The investigations were to determine the influence of drying temperature and pumpkin variety on the nutritional properties of pumpkin flour production and energy properties of pumpkin peel and seed shell for energy production.

All the analyses were carried out after harvest. Harvest has been performed at the faculty trial in Šašinovec (45°51'02.5" N 16°10'37.3" E). When received in the laboratory of the Department of Agricultural Technology, Storage, and Transport of the Faculty of Agriculture, University of Zagreb the samples were cut into quarters, and each quarter was weighed separately on a technical scale. After weighing of whole quarters, seed, pulp, flesh, and peel were separated and weighed in order to subsequently determine their mass in relation to total pumpkin mass.

2.2 Nutritional Properties

The nutritional properties of pumpkin flesh and pumpkin flour included moisture content (HRN ISO 6540:2002) in a laboratory oven (INKO ST-40, Croatia), ash content (HRN ISO 2171:2010) in a muffle furnace (Nabertherm GmbH, Nabertherm Controller B170, Germany), starch content (HRN ISO 6493:2001) in a polarimeter (KRÜSS, P3001, Germany), by Evers polarimetric method and oil content (HRN ISO 6492:2011) in a soxhlet extractor. Total protein was calculated from the nitrogen content measured by the Kjeldahl method (HRN ISO 1871:2017). Total carbohydrate was obtained by subtracting (moisture + ash + protein + fat) from 100.

2.3 Energy Properties

The energy properties of pumpkin peel and seed shell included moisture content (HRN EN 18134-2:2015) in a laboratory oven (INKO ST-40, Croatia), ash content (HRN EN ISO 18122:2015), and coke (CEN/TS 15148:2009) in a muffle furnace (Nabertherm GmbH, Nabertherm Controller B170, Germany). The heating value was determined by method (EN 14918:2010) using a calorimeter (IKA Analysentechnik GmbH, Heitersheim, Germany). The heating value is presented in MJ/kg.

2.4 Drying

The drying treatment was carried out by using a laboratory dryer. The laboratory dryer was constructed in such a way as to be kinetically similar to a real-life industrial dryer. The air velocity in the dryer was maintained at 1.0 m/s, and the pumpkin flash was dried at three air temperatures 50 °C, 60 °C, and 70 °C. Before drying, the mass and moisture content were determined and every 5 minutes the mass loss was measured using a technical scale, i.e., the water and mass loss was calculated. All measurements were carried out in triplicates and the average moisture ratio at each value was used for the calculation of drying equations.

3 RESULTS

In order to determine the nutritive and energy properties analyses were performed, the results of which are shown in the following tables.

The results regarding the total pumpkin mass (share of flesh, pulp, peel, and seed in both varieties) are presented in Tab. 1.

Table 1 Total pumpkin mass (share)

Content	Variety 1	Variety 2
Flash	82.45 ± 0.12^B	80.97 ± 0.01^B
Pulp	4.29 ± 0.01^B	8.58 ± 0.18^A
Peel	8.12 ± 0.01^A	7.34 ± 0.02^B
Seed	3.08 ± 0.21^B	3.11 ± 0.05^A
Seed shell	2.06 ± 0.33^B	-
Total mass	100% (4.247 kg)	100% (2.315 kg)

Key: Varity 1 - seed with shell; Variety 2 - seed without shell; Capital letters - influence of variety

The contents of nutritive properties of flash for flour production: moisture, ash, protein, fat, starch and carbohydrates i.e. statistical analysis of the influence of variety on raw material are given in Tab. 2.

Table 2 Content of nutritive properties in row pumpkin flash

Variety	Moisture / %	Ash / %	Fat / %
Variety 1	88.23 ± 0.85^A	0.90 ± 0.06^A	0.70 ± 0.04^A
Variety 2	91.56 ± 1.54^B	1.10 ± 0.18^B	0.90 ± 0.06^B
	Protein / %	Starch / %	other carbonhydrates / %
Variety 1	0.83 ± 0.45^A	16.6 ± 0.85^A	9.34 ± 0.36^A
Variety 2	1.04 ± 0.12^A	19.9 ± 0.60^B	5.40 ± 0.22^B

Key: Varity 1 - seeds with shells; Variety 2 - seeds without shells; Capital letters - influence of variety

Table 3 Exponential equations of water release and coefficients of determination

Variety	Drying temperature	Moisture / %	Exponential equations	R^2
Variety 1	50 °C	88.23	$y = 85.31e^{-0.003x}$	0.93
	60 °C		$y = 92.23e^{-0.006x}$	0.98
	70 °C		$y = 113.99e^{-0.01x}$	0.97
Variety 2	50 °C	91.56	$y = 108.56e^{-0.005x}$	0.91
	60 °C		$y = 114.00e^{-0.012x}$	0.92
	70 °C		$y = 113.86e^{-0.015x}$	0.93

Key: Varity 1 - seed with shell; Variety 2 - seed without shell; y - flash moisture, x - flash water release time, R^2 - determination coefficient

For the purpose of production of pumpkin flour, the raw meat of both pumpkin varieties was thermally dried up with convection drying to the equal moisture content of 12%. Tab. 3 shows exponential equations and coefficients of determination at temperatures of 50 °C, 60 °C and 70 ºC while Tab. 4. shows the analysis of the influence of variety and drying temperature on pumpkin flour.

Table 4 Content of nutritive properties in pumpkin flour after drying

Variety	Drying temperature	Moisture / %	Ash / %	Fat / %
Variety 1	50 °C	$^{A}12.01^{b}$	$^{A}3.85^{a}$	$^{B}3.96^{b}$
	60 °C	$^{A}11.62^{ab}$	$^{A}3.94^{a}$	$^{B}3.87^{ab}$
	70 °C	$^{A}10.04^{a}$	$^{A}3.62^{a}$	$^{B}3.01^{a}$
Variety 2	50 °C	$^{B}14.83^{b}$	$^{B}4.25^{a}$	$^{A}3.19^{b}$
	60 °C	$^{B}13.28^{ab}$	$^{B}4.15^{a}$	$^{A}2.88^{ab}$
	70 °C	$^{B}12.67^{a}$	$^{B}4.14^{a}$	$^{A}2.17^{a}$
	Drying temperature	Protein / %	Starch / %	Carbonhidrates / %
Variety 1	50 °C	$^{B}1.46^{b}$	$^{B}2.70^{a}$	$^{B}78.82^{b}$
	60 °C	$^{B}1.61^{a}$	$^{B}2.06^{b}$	$^{B}78.96^{a}$
	70 °C	$^{B}1.09^{a}$	$^{B}1.82^{a}$	$^{B}81.88^{a}$
Variety 2	50 °C	$^{A}2.53^{b}$	$^{A}1.81^{ab}$	$^{A}75.20^{a}$
	60 °C	$^{A}2.31^{ab}$	$^{A}1.21^{a}$	$^{A}77.38^{a}$
	70 °C	$^{A}2.24^{a}$	$^{A}1.34^{a}$	$^{A}78.34^{a}$

Key: Varity 1 - seed with shell; Variety 2 - seed without shell; Capital letters - influence of variety; small letters - influence of drying temperature

Table 5 Content of nutritive properties in pumpkin flour after drying

Variety	Biomass	Moisture / %	Ash / %	Coke / %
Variety 1	Peel	83.74 ± 1.48^{A}	9.05 ± 0.55^{A}	2.92 ± 0.31^{B}
	Seed shell	28.81 ± 0.32^{A}	5.41 ± 1.49^{A}	8.35 ± 0.49^{B}
Variety 2	Peel	90.23 ± 1.20^{B}	11.01 ± 0.16^{B}	1.30 ± 0.24^{A}
	Biomass	HHV / MJ/kg	LHV / MJ/kg	Ratio / kg
Variety 1	Peel	18.59 ± 0.90^{A}	14.87 ± 0.22^{A}	1:2.82
	Seed shell	22.32 ± 0.45^{B}	17.86 ± 0.15^{A}	1:2.35
Variety 2	Peel	18.34 ± 0.31^{A}	14.67 ± 1.01^{B}	1:2.86

Key: Varity 1 - seed with shell; Variety 2 - seed without shell; Capital letters - influence of variety; HHV - higher heating value; LHV - lower heating value; Ratio - ratio of crude oil:biomass (kg)

4 DISCUSSION

Before the analyses for the purpose of production of pumpkin flour from flash, the total pumpkin mass was determined by weighing as well as a total share of flash, pulp, peel, and seed (seed shell) in the investigated varieties (Tab. 1). The share of flash is significantly higher in Variety 1 (seed with shell) and is 82.45% of the total mass of pumpkin. Although the Variety 2 (seed without shell) has a higher content of pulp 8.58% of the total mass and a lower share of meat 80.97% of the total mass. The share of peel is in Variety 1 8.12%, while in Variety 2 it is 7.34% of the total mass. The share of seeds in both varieties was approximately identical, but Variety 1 had also shells on the seed which is 2.06% of the total mass. It turned out that for the quantitative needs of the production of pumpkin flour it is important to choose a variety with a higher share of meat which in this case is Variety 1. The same Variety is also better for energy production with higher content of peel and seedshell.

From Tab. 2 it can be concluded that all investigated nutritive parameters in row pumpkin meat are statistically higher in Variety 1 except for carbohydrates. The moisture content, which in this investigation is 88.23 and 91.56% depending on variety, is in conformity to the results of Kim et al. [40], who found the pumpkin flash moisture content between 87.60% and 92.30% and with results of Escobar and Buesa [41]; Almeida [42]; Barroso et al. [43] and Monteiro [44] who range moisture content between 88% and 92%. The ash content was as high as 1.10% in Variety 2 while in Variety 1 it was 0.90%. Guiné et al. [45] found in their investigation the ash content in row sample of pumpkin meat between 0.8 to 1.4%, which is in accordance with this investigation. Determination of ash content in foodstuffs is an important measure of their biological values but is also a measure of quality and sanitary safety of food. From the aspect of flour quality, the variety has an aspect on it. The fat content in the Variety 1 variety is 0.70%, and in Variety 2 it is 0.90%. The results for the content of fat are somewhat higher than the results obtained by Guiné and Barrocab [46], who report the share of fat in row samples of pumpkin flesh of 0.2%. Kim et al. [47], in their investigation, found the ash content of 3.44%, and fat content of 0.55%, and these values do not conform to the results obtained in this investigation, which corroborates the assertion that conditions of cultivation do affect the nutritive composition of pumpkin flesh. Content of protein 1.04% and starch 19.9% was higher in Variety 2 while the content of very important carbohydrates was significantly higher in Variety 1 - 9.34% in regard to Variety 2 - 5.40%. According to the literature, raw pumpkin flash contains 1.29% protein and 10.51% carbohydrates [48]. It can be concluded that different nutritive properties of flash for flour production are significantly affected by variety and cultivation and are better in Variety 1 because of the lower content of water and higher content of carbohydrates.

For the purpose of pumpkin flour production, the raw flash of both pumpkin varieties was thermally dried up with convection drying to the equilibrium moisture content of 12%. Based on the exponential equation for drying presented in Tab. 3 it can be seen that Variety 2 has the fastest water release. The analysis of the data found high coefficients of determination in both varieties, between 0.91 and 0.98, which proves that the investigations of pumpkin meat water release were done with precision. Similar results for pumpkin flash drying are also reported by Hii et al. [49] where the coefficient of determination was 0.99, while Lech et al. [50] found the coefficients of determination between 0.96 and 0.99.

According to results from Tab. 4, all results are significantly different. The moisture, ash, and protein contents were higher in Variety 2 while the fat, starch, and carbohydrates contents were higher in Variety 1. It is evident that the moisture content decreases after drying as well as the starch content, while the ash, fats, protein, and other carbohydrates contents grow at all temperatures. All investigated nutritional parameters obtained the best results at the lowest temperature of 50 °C due to the lowest energy consumption during drying and the obtained results that meet the standards. Dorantes-Jiménez et al. [51], in their investigation of dried pumpkin flour, obtained the results which are in accordance with this investigation.

The analysis of the results of the investigated biomass of pumpkin peel and seed shell is presented in Tab. 5. According to the data, there is a significant difference between the investigated parameters of biomass after flour production. Moisture is an undesirable, incombustible ingredient in fuels and has a direct effect on the heating value of biomass because of the amount of heat consumed for water evaporation [52]. The moisture content in pumpkin peel in both varieties is significantly higher in relation to the seed shell. The higher water content in peel (90.23%) is found in Variety 2. The ash content was higher in the peel of both varieties and it was about 10%. According to Vassilev et al. [53], the ash content commonly ranges between 0.5 and 3% which depends on the type of biomass and parts of biomass from agricultural crops, although in biomass of all sources ash content may vary from 0.1 up to as much as 46%. Coke content as a desirable feature in biomass is significantly higher in Variety 1. Observing the HHV - higher heating value, it can be noticed that the values are about 18.40 MJ/kg in the peel and 22.30 MJ/kg in the shell, while the values of the LHV - lower heating value - are about 14.70 MJ/kg in the peel and 17.80 MJ/kg in the shell, depending on the investigated variety. Compared to the HHV and LHV of other lignocellulosic biomasses: wheat straw (19 MJ/kg), olive husk (16 MJ/kg), cornstraw (19.2 MJ/kg) pumpkin peel wastes are suitable feedstock energy production [54-60]. Pumpkin biomass has very good heating values, which makes it a usable biomass material and Variety 1 has better energy properties. If the obtained energy values of the peel or seed shell are compared with the value of fossil fuel - crude oil, it is obtained that for 1 kilogram of crude oil you need 1.28 kg of peel and 1.23 kg of a pumpkin shell.

5 CONCLUSION

Following the analyzed data, it can be determined that Variety 1 showed better results in the production of pumpkin flour because it has a significantly higher amount of meat and better nutritional properties. The best nutritional characteristics of pumpkin flesh are achieved by drying at an air temperature of 50 °C. According to the exponential equations at temperatures of 50 °C, 60 °C, and 70 °C, it can be concluded that Variety 2 releases water faster than Variety 1. Both varieties showed similar energy properties of biomass (peel and shell). The high calorific value of the peel and the even higher calorific value of the seed shell place pumpkin biomass among the desirable reserves for energy production. Such full use of pumpkin could ensure greater cost-effectiveness of flour production and help remove large amounts of unused residues. Precisely because of sustainable and circular bioeconomics of residues, quality biofuel can be obtained and at the same time the residue which is a major environmental problem would be rehabilitated.

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