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Effect of drying technologies on bioactive compounds maintenance in pumpkin by-products

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Abstract. During the pumpkin processing large amounts of waste material as a combination of pumpkin peel, seeds and the flesh between seeds has produced. Therefore it is important to investigate the possibilities for using the pumpkin residues. The aim of this research was to investigate the effect of different drying technologies on maintenance of bioactive compounds in pumpkin by-products. Two pumpkin residue products of Hubard group pumpkins were used to obtain pumpkin powder: residue products formed in the process of extracting industrial pumpkin purée by heating it in a heat exchanger and treating through a sieve of pulpier; residues resulting from pumpkin juice extraction process mechanically pressed from fresh, chopped pumpkins. In order to be able to choose the most suitable drying technology pumpkin by-products were dried in the microwave-vacuum, convective (at 40, 50, 70 and 80 °C) and freeze-drying type dryers. For all samples total carotenes, the ascorbic acid, total phenols content (TPC) and antiradical activity ($DPPH^{\cdot}$, $ABTS^{\cdot+}$) were determined by using standard methods. The highest total carotenes content was retained in freeze-dried pumpkin powders. The most suitable drying method for obtaining pumpkin powder with the highest ascorbic acid, total phenolic content and antiradical activity is drying in convective type drying at 80 °C temperature.

Key words: pumpkin residues, ascorbic acid, total phenols, carotenoids, drying technologies.

INTRODUCTION

As it is mentioned by several authors the nutritional value of pumpkin fruits is high. In the fresh pumpkin fruit total carotene content ranges from 2 to 10 mg 100 g^{-1}, vitamins C and E account for 9–10 mg 100 g^{-1} and 1.03–1.06 mg 100 g^{-1}, respectively (Terazawa et al., 2001; Nawirska et al., 2009; Ghabos et al., 2016). Pumpkin fruit is also a valuable source of other vitamins, e.g., B6, K, thiamine, and riboflavin, as well as minerals, e.g., potassium, phosphorus, magnesium, iron and selenium. Pumpkin flesh is a delicious and fully appreciated additive in a diversity of products for children and adults. Pumpkin fruits are processed to obtain juice, pomace, pickles and dried products (Nawirska et al., 2009). But one of the important problems is that pumpkin processing causes large amounts of waste which are consist of a combination of pumpkin peel, seeds and the flesh between seeds. One of the promising possibilities for reuse of pumpkin residues is drying and getting of pumpkin powder or flour.

Within the investigations of pumpkin powder scientists found that moisture, protein, fat, fiber and carbohydrate percentage of the pumpkin powder were around 6.01, 3.73, 1.32, 2.91 and 78.73%, respectively. β-carotene content of the powder was around 7.30 mg $100g^{-1}$ (Das & Banerjee, 2015).

One of the oldest methods for food preservation is drying, which consists of removing water from the product in order to provide microbiological safety (Mitra et al., 2012; Horuz & Maskan, 2015; Saengrayap et al., 2015; Ghabos et al., 2016). The most popular and traditional drying method is convective hot air drying. The method itself is a low-cost one, but has the disadvantage of entailing a time-consuming process. During contact with oxygen that is present in the air, the product becomes exposed to high temperature for a long time, and such exposure reduces the content of some valuable components which readily undergo oxidation at elevated temperature. (Lozano et al., 1983; Ghabos et al., 2016).

Drying process can cause changes in food surface characteristics which lead to color changes. Changes attributed to carotenoids and other pigments can also be caused by heat and oxidation during drying. In particular, higher drying temperatures and longer drying times were seen to facilitate greater pigment losses (Noor Aziah & Komathi, 2009; Roongruangsri & Bronlund, 2016). It is believed that drying at lower temperatures provides less nutritional loss (Galoburda & Rakčejeva, 2008). In the study of Roongruangsri & Bronlund (2016) the total carotenoid content of dried pumpkin powder produced at 70 °C (about 17.66 μg g^{-1} dry weight) was found to be significantly lower ($P \leq 0.05$) when compared to powders produced at 50 and 60 °C (about 25.99 and 16.42 μg g^{-1} dry weight, respectively). Moreover, the dried pumpkin powder produced at 70 °C showed the highest percentage of decrease in carotenoid content compared to those produced at drying temperatures of 50 and 60 °C.

Products that have been dried in microwave-vacuum dryer or freeze-dryer have biger pores, retains better structure of the plant-based product cells, while air-dried products break down the cells and form a denser structure.

Scientific research has shown that after microwave-vacuum drying, food colour, flavour, nutrients and other biologically active ingredients that are sensitive to thermal treatment and oxidation are much better preserved compared to convective drying (Scaman & Durance, 2005; Galoburda & Rakcejeva, 2008).

In the production of food, vacuum freeze-drying can be used to obtain high-quality porous products, as there is less loss of biologically active compounds and flavour compared to convective drying, the colour, shape and structure of the product are better preserved (Food Industry Technological Equipment, 2000). The products are low density and have a very good rehydration capability.

The aim of this research was to investigate the effect of different drying technologies on maintenance of bioactive compounds in pumpkin by-products.

MATERIALS AND METHODS

Two pumpkin residue products of Hubard group pumpkins were used to obtain pumpkin powder:

1) Residue products formed in the process of extracting industrial pumpkin purée by heating it in a heat exchanger at 99–100 °C temperature for 3–5 min, and treating through a sieves of pulpier (Steamed sample);

2) Residues resulting from pumpkin juice extraction process mechanically pressed from fresh, chopped pumpkins (Freshly-pressed sample).

Both types of by-products were stored in the freezer (-20 ± 2) °C before further processing for 2 mounths. In order to be able to choose the most suitable drying technology pumpkin by-products were dried in the microwave-vacuum dryer 'Musson-1' (Ingredient, Russia), convective dryer using 'Memmert' Universal Oven UF55 and UF160 (Memmert GmbH+Co.KG, Germany at 40, 50, 70 and 80 °C) and freeze-drying type using vacuum freeze-dryer FT333 (Armfield Ltd, Ringwood England).

The abbreviated terms (Table 1) were used in the part of the results for the different types of drying.

Table 1. The identification of samples

No	Description	Code
1.	Frozen untreated pumpkin residues	Fresh
2.	Died in microwave-vacuum dryer	MW
3.	Drying in vacuum-freeze-dryer	FD
4.	Dried in convective hot air dryer 40 °C	C-40
5.	Dried in convective hot air dryer 50 °C	C-50
6.	Dried in convective hot air dryer 70 °C	C-70
7.	Dried in convective hot air dryer 80 °C	C-80

For all samples total carotenes, the ascorbic acid, total phenols content (TPC) and antiradical activity ($DPPH^{\cdot}$, $ABTS^{\cdot}+$) were determined.

The ascorbic acid content (mg 100 g^{-1}) was experimentally determined using iodometric method: 5 g of the sample was added to 100 mL of 6% oxalic acid, 1 min crushed with a blender and filtered through a paper filter. Then add 2 mL of 1% starch solution to the 10 ml of filtrate and titrate with 0.05 M J_2 (Jansons, 2006).

The amount of vitamin C in each sample was determined in three replicates. The content of ascorbic acid in the sample is calculated according to formula:

$$C = 5{,}000\frac{V_{sample}}{m \cdot V_{standard}} \quad (1)$$

where 5,000 – the coefficient; V_{sample} – amount of 0.05M iodine used for titration, mL; $V_{standart}$ – Use of 0.05M iodine solution in 25 mL standard solution, titration, mL.

The carotene content (mg 100g^{-1}) was determined by weighing 1–2 g of the crushed sample on analytical scales, adding 20 mL of 96% ethanol and stirring on a magnetic stirrer (MS01). After stirring for 15 minutes, add 25 mL of petroleum ether (with boiling temperature 80–110 °C) and continue to stir for 1 hour, then the sample was placed in a dark place until a complete formation of two layers, where the upper yellow-coloured layer contains carotenes which was analysed by Jenway 6705 UV / Vis spectrophotometer at a wavelength of 440 nm, taking petroleum ether as a control solution. The carotenoids content of each sample was determined in two replications. Grading schedule was established with potassium dichromate and carotene equivalent (KE) was found. The content of carotenes was calculated according to the formula (2) (Методы биохимического ..., 1987, Ozola et al., 2017):

$$X = \frac{0.208 \times 25 \times KE}{36 \times a} \quad (2)$$

where 0.208, 25 and 36 coefficients; m – sample weight, g; KE-carotene equivalent, which is the amount of potassium dichromate at the measured absorption.

The total phenols in dried pumpkin powders determined spectrophotometrically by 'JENWAY 6705 UV' spectrophotometer at a wavelength of 765 nm using Singleton et al. (1999) method also described by Prieciņa & Kārkliņa (2014) with some modifications. Weight 3 g of pumpkin residue powder, add 20 mL of ethanol/water mixture (80 : 20), place the glass on a magnetic stirrer, and leave to stir for 2 hours. After the mixing, the sample in another conical flask was filtered through a paper filter until the sample was completely filtered. The filtered samples were collected in a 25-mL volumetric flasks and filled with solvent to the mark. In three separate flasks 0.5 mL of the extract were measured, 2.5 mL of Folin-Ciocalteu phenol reagent diluted 10 times with distilled water was added, after 5 minutes 2 mL of 7.5% Na_2CO_3 was added too, mixed and withstood 30 min Gallic acid equivalent was used to quantify the total polyphenols content. The total phenol content of the test samples was expressed as milligrams of gallic acid equivalent per 100 grams of dry sample weight (mg GAE 100 g^{-1} DW) (Singleton et al., 1999; Prieciņa & Kārkliņa, 2014).

The analyses were done in three replications.

For determination of antioxidant activity in the samples 2.2 diphenyl picyrylhydrazine (DPPH) and 2,2′-azino-bis(3-ethylbenz-thiazoline-6-sulfonic) acid ($ABTS^{\bullet+}$) radicals were used.

The determination of DPPH antiradical activity was performed on the basis of (Yu et al., 2003) with some modifications:

Place 0.5 mL of the test solution in a cuvettes;

Add 3.5 mL of freshly prepared DPPH solution (0.004 g DPPH per 100 mL of ethanol);

Leave in a dark place at room temperature 30 minutes;

The results were read on a JENWAY 6300 spectrophotometer at a wavelength of 517 nm (Prieciņa & Kārkliņa, 2014). For the quantitative expression of antiradical activity, the Trolox equivalent of 6 hydroxyl 2,5,7,8 tetramethylchromo-carboxylic acid was used. The Trolox calibration curve was created and, using the read-out absorbance, the antiradical activity in the analyzed samples was expressed in mg Trolox equivalent per 100 grams of sample dry matter (mg Trolox 100 g^{-1} DW) (Prieciņa & Kārkliņa, 2014).

The radical scavenging activity (RSA) of extracts was also measured by 2,2′-azino-bis(3-ethylbenz-thiazoline-6-sulfonic) acid ($ABTS^{\bullet+}$) radical cation assay (Re et al., 1999). For the assessment of extracts, the $ABTS^{\bullet+}$ solution was diluted with a phosphate buffer solution to obtain the absorbance of 0.800 ± 0.030 at 734 nm. The RSA was expressed as TE 100 g^{-1} DW of plant material (Kampuse et al., 2016).

RESULTS AND DISCUSSION

Total carotene content

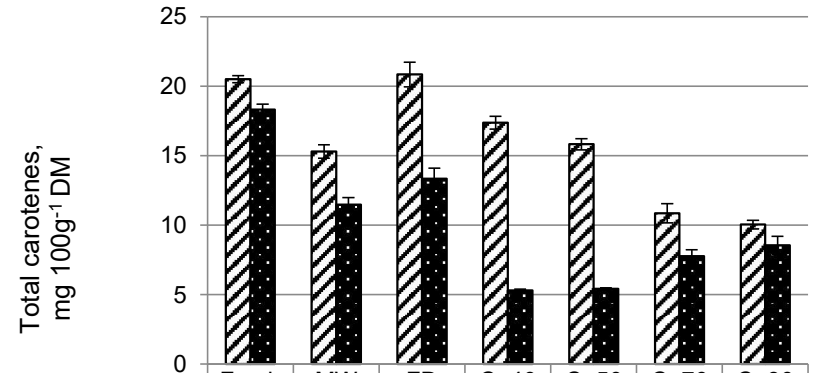
Frozen residues

The total carotene content in the raw material varied from 18.31 ± 0.4 mg 100 g^{-1} dry matter (fresh, frozen parts of pumpkin residues) up to 20.51 ± 0.25 mg 100 g^{-1} dry matter (steamed, frozen pumpkin residues), showing a significant increase ($P < 0.05$) in the initial values for steamed samples.

Pumpkin powder made from steamed, frozen pumpkin residues

There was a significant difference ($P < 0.05$) between total carotene content in pumpkin powder dried in convective, microwave-vacuum and freeze-dryer. Also, significant differences ($P < 0.05$) between the total carotene content of dried pumpkin powder in convective dryer at various temperature regimes were observed. The highest total carotene content was retained in freeze-drying system dried pumpkin powders. In total, the carotene content in pumpkin powders varied from 10.04 ± 0.31 mg per 100 g^{-1} dry matter (using convective drying at 80 °C) to 20.84 ± 0.89 mg 100 g^{-1} dry matter (using drying in a freeze-dryer) (Fig. 1).

Comparing pumpkin powder dried at different temperature regimes of convective dryer, their total carotene content significantly decreased ($P < 0.05$) with increasing temperature (comparing drying at 40 °C and 80 °C decreased by 42%).



	Fresh	MW	FD	C_40	C_50	C_70	C_80
Steamed	20.51	15.29	20.84	17.36	15.82	10.85	10.04
Freshly-pressed	18.31	11.47	13.34	5.31	5.42	7.77	8.54

Figure 1. The comparison of total carotenes content in pumpkin powder obtained in different drying regimes.

Pumpkin powder made from fresh, frozen residues

Changes in the content of carotenes in pumpkin powders made from fresh, frozen residues were similar to those observed from steamed residues. Similarly to the samples described above, there were significant differences ($P < 0.05$) between the total carotene content in samples of convective, microwave-vacuum drying and drying in vacuum freeze-dryer. Also, significant differences ($P < 0.05$) between the total carotene content of dried pumpkin powder in convective dryer at various temperature regimes were

observed but the interesting was fact that the highest total carotenes content was observed to C-80 sample, and total carotene content significantly increased ($P < 0.05$) with increasing temperature, which was a completely different tendency from the powders derived from steamed residues. This relationship can be explained by the activity of different enzymes in these two different samples: for the steamed sample enzymes activity was completely inactivated before drying, while in the freshly-pressed sample enzymes were still active at the start of the drying. It is proved also by other authors that during drying process polyphenoloxidasis activity remains still high for longer periods when the drying temperature is between 55–60 °C, whereas shorter exposure period is needed to inactivate enzymes at temperatures between 75–80 °C (Arslan et al., 1998; Sonawane & Arya, 2014).

The highest total carotene content was retained in freeze-dried samples, although the results were significantly lower compared to steamed powders. In total, the carotene content in these pumpkin powders varied from 5.31 ± 0.09 mg per 100 g^{-1} of dry matter (using convective dryer at 40 °C) to 13.34 ± 0.75 mg per 100 g^{-1} of dry matter (using drying in a freeze-dryer) (Fig. 1). A total reduction in carotene content compared to a frozen, no dried pumpkin residues ranged from 27% (using freeze-drying method) to 71% (using drying in a convective dryer 40 °C). In the study of Roongruangsri & Bronlund (2016) the carotenoid degradation was observed from 18 to 56% using convective drying at 50, 60 and 70 °C temperatures. Within the increase of temperature, the total amount of carotenoids also decreased in this investigation which coincides with our data of steamed pumpkin residues dried in convective dryer but opposite to the results of freshly-pressed by-products. There is no unanimous opinion about the influence of temperature to the degradation of carotenoids. In the study with drying of cassava roots authors (Onyenwoke et al., 2015) concluded the following statement: 'Drying at High Temperature Short Time (HTST) retained more TCC on average, than Low Temperature long Time (LTLT) as was observed during tray drying at temperature range between 80–95 °C for 1hour and 55–70 °C for 2 hours'.

Ascorbic acid content

Frozen residues

The content of ascorbic acid or vitamin C was relatively low in raw pumpkin residues. Its content ranged from 17.20 ± 0.02 mg 100 g^{-1} of dry matter (freshly-pressed pumpkin residues) to 25.43 ± 0.69 mg per 100 g^{-1} of dry matter (steamed pumpkin residues), showing a significant ($P < 0.05$) higher initial values for steamed sample. Also, all dried samples derived from steamed residues were with higher ascorbic acid content than from freshly-pressed.

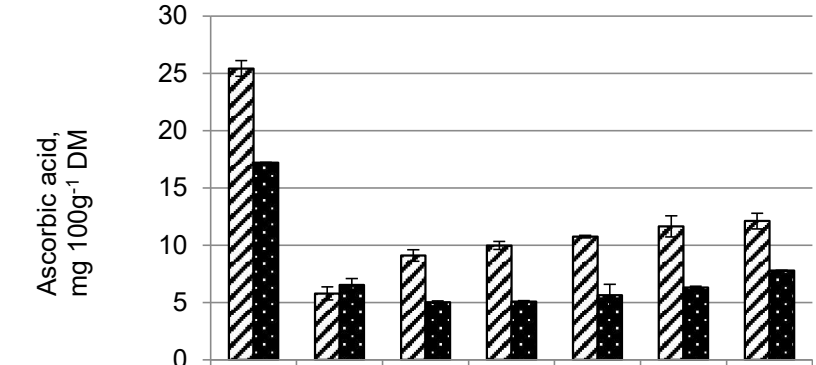
Pumpkin powder made from steamed pumpkin residues

A slight significant difference ($P < 0.05$) of pumpkin powder ascorbic acid content was observed between convective hot air, microwave vacuum drying and vacuum freeze-dying techniques. Also, the difference between the contents of ascorbic acid of convective dried samples in different temperature regimes was significant ($P < 0.05$). The highest content of vitamin C was retained in a samples dried at 80 °C temperature. In general, the content of C vitamin in pumpkin powders varied from 5.78 ± 0.57 mg of 100 g^{-1} of dry matter (using microwave-vacuum dryer) to 12.10 ± 0.69 mg of 100 g^{-1} of dry matter (using a convective dryer at 80 °C) (Fig. 2).

After drying, all pumpkin powders had a decrease in ascorbic acid content compared to raw sample ranging from 52% (using convective dryer at 80 °C) to 77% (using microwave-vacuum drying).

Pumpkin powder made from freshly-pressed residues

Comparing the changes in ascorbic acid content from freshly-pressed residue powders there were no significant differences between different drying methods and regimes. In general, the content of ascorbic acid in these pumpkin powders varied from 5.03 ± 0.04 mg of 100 g^{-1} of dry matter (using vacuum freeze-drying) to 7.77 ± 0.09 mg of 100 g^{-1} of dry matter (using drying in a convective dryer at 80 °C) (Fig. 2).



	Fresh	MW	FD	C_40	C_50	C_70	C_80
Steamed	25.43	5.78	9.09	9.97	10.75	11.64	12.10
Freshly-pressed	17.20	6.53	5.03	5.08	5.63	6.30	7.77

Figure 2. The comparison of ascorbic acid content in pumpkin powder obtained in different drying regimes.

The obtained results proved that there is no big influence of drying technology to the ascorbic acid content because of big instability of this vitamin in such crashed residue mass. Also by the observations of other authors the vitamin C is the most unstable bioactive compound because it oxidases easily during different processing operations and storage. The degradation of vitamin C is influenced by temperature, pH, the presence of metal ions, enzymes, water, light and the time of product heating (Machlin, 1991).

Total phenol content (TPC)

Frozen residues

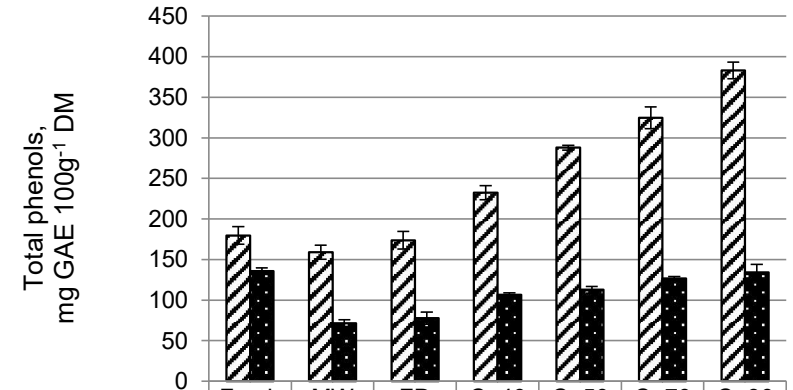
The content of total phenols in frozen residues varied from 135.59 ± 3.94 mg per Gallic acid equivalent (GAE) of 100 g^{-1} dry matter (freshly-pressed pumpkin residues) up to 179.67 ± 10.90 mg GAE 100 g^{-1} dry matter (steamed pumpkin residues), and the differences were significant ($P < 0.05$) (Fig. 3). These data are similar to the data mentioned in literature about the total phenols content in fresh pumpkins of different cultivars (Biesiada et al., 2011).

Pumpkin powder made from steamed pumpkin residues

The highest content of total phenols was in powder dried in convective dryer. Overall, the total phenol content in pumpkin powders varied from 159.14 ± 8.70 mg

GAE per 100 g^{-1} dry matter (using microwave-vacuum drying) to 383.04 ± 10.31 mg GAE per 100 g^{-1} dry matter (using drying in a convective dryer at 80 °C). The total phenol content in steamed pumpkin residues were similar or higher than in fresh samples what is similar to the findings of Yang et al. (2010) with drying of blanched sweet potatoes.

There was no significant difference between the total phenol content in microwave-vacuum dryer and freeze-dryer dried pumpkin powders ($P > 0.05$). In contrast, the difference between the total phenol content in the convective dryer in different temperature regimes dried pumpkin powder was significant ($P < 0.05$), and, with increasing drying temperature, the total content of phenols in pumpkin powders also increased (compared to a drying of 40 °C and 80 °C increase was even 65%) (Fig. 3). In case of phenolic compounds, the investigations showed that with treatment in higher temperatures and shorter time it is possible to get dried product with higher total phenol content. The release of active enzymes could cause enzymatic degradation and lose extractable phenolics (Tomsone & Kruma, 2014) what could be the main reason of lower total phenol content in dried freshly-pressed residues.



	Fresh	MW	FD	C_40	C_50	C_70	C_80
Steamed	179.67	159.14	173.80	232.20	287.89	324.66	383.04
Freshly-pressed	135.59	71.62	77.65	106.72	112.79	126.60	134.22

Figure 3. The comparison of total phenol content in pumpkin powder obtained in different drying regimes.

Pumpkin powder made from freshly-pressed residues

Comparing the total phenol content, there were significant differences ($P < 0.05$) found between dried pumpkin powders obtained with different dryers and in different temperature regimes. Similarly to powders from steamed residues, the highest content of total phenols was in convective dryer obtained pumpkin powder. Overall, the total phenol content in pumpkin powders varied from 71.62 ± 4.06 mg GAE per 100 g^{-1} dry matter (using microwave-vacuum dryer) to 134.22 ± 9.74 mg GAE per 100 g^{-1} dry matter (using drying in a convective dryer at 80 °C).

There was no significant difference between the total phenol content in microwave-vacuum dryer and vacuum freeze-dryer dried pumpkin powder ($P > 0.05$). In contrast, the total phenol content in different temperature regimes obtained samples of convective

dryer increased within increasing the drying temperatures (compared to a drying of 40 °C and 80 °C increase was 26%). Significant differences were not detected ($P > 0.05$) when dried at 40 °C and 50 °C, and dried at 70 °C and 80 °C.

Compared to frozen raw residues, the smallest reduction in total phenols was in convective dried pumpkin powder, where it decreased by 1% (80 °C) to 21% (40 °C).

As it is also reported by Aydin & Gocmen (2015) oven drying increased phenolic contents and bioaccessible phenolics (1,237.457 mg of GAE 100 g^{-1} DW, respectively) in comparison with freeze-drying. Higher total phenols content after drying and grinding of pumpkin powder comparing with fresh samples could be explained with better extraction of phenolic compounds from the flour with particles of very small size while in steamed in freshly-pressed pumpkin residues the size of particles was much bigger. Another reason of increasing phenolic compounds with increasing the temperature could be the activity of enzymes in the freshly-pressed pumpkin residues. To avoid enzymatic oxidation from polyphenol oxidases, samples may need to be heated to a temperature of more than 90 °C for a few minutes. These enzymes catalyze the oxidation of phenols to quinones with subsequent nonenzymatic rapid polymerization. These oxidases can also be inhibited by lowering the pH to below 4.0 (Murkovic, 2003). As it is reported by Rabadan-Chavez & Lugo-Cervantes (2018) in the studies with cocoa beans the roasting in high temperatures of well-fermented cocoa beans significantly affected the levels of phenolic compounds. Procyanidins (mainly procyanidin dimers B1, B2, B5, and procyanidin trimer C1) and anthocyanins showed extensive degradation due to hydrolysis, oxidation, or condensation reactions under the effect of high temperatures, elevated humidity, and enhanced exposure to oxygen. A similar trend has been observed for epicatechin, which showed intensive oxidation or degradation during the roasting process. But it has been observed also that the content of catechin increased during the roasting process. It has been attributed to the degradation of procyanidins into (+)-catechin and (−)-epicatechin, combined with the epimerization of (−)-epicatechin into (−)-catechin, due to high temperatures of roasting (Rabadan-Chavez & Lugo-Cervantes, 2018). It means that the total amount of phenolic compouns is dependent from the composition of phenolic compounds of each food product. Therefore, more studies are necessary to evaluate the composition of pumpkin residue powders.

Antiradical scavenging activity

2.2-diphenyl-1-picrylhydrazyl- (DPPH) reagent antiradical scavenging activity

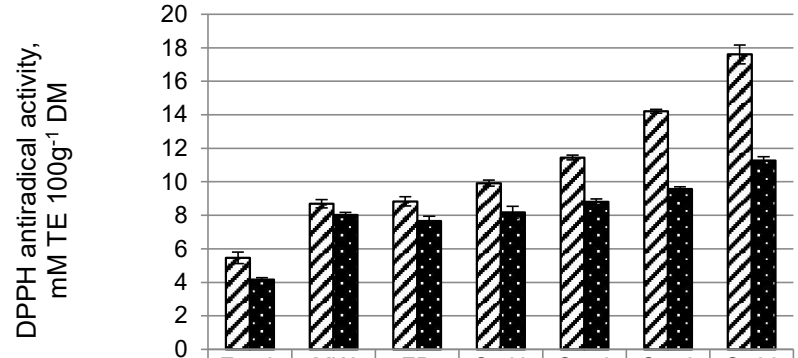
Frozen residues

The DPPH antiradical activity in the fresh samples varied from 4.16 ± 0.11 mM, converted to Trolox equivalent (TE) 100 g^{-1} dry matter (Freshly-pressed pumpkin residues) to 5.46 ± 0.35 mM TE per 100 g^{-1} dry matter (steamed pumpkin residues). Among these DPPH antiradical activity indices, significant ($P < 0.05$) differences were observed (Fig. 4).

Pumpkin powder made from steamed pumpkin residues

The highest DPPH antiradical activity was in convective dried pumpkin powder. Generally, the antiradical activity of DPPH in pumpkin powders varied from 8.69 ± 0.24 mM TE per 100 g^{-1} dry matter (using microwave-vacuum dryer) to 17.61 ± 0.56 mM TE per 100 g^{-1} dry matter (using convective drying at 80 °C) (Fig. 4),

and it was much higher than the antiradical activity of fresh samples. Similar results also were reported in Nakhon et al. (2017) comparison of fresh pumpkin and pumpkin flour. In this experiment pumpkin flour exhibited greater antioxidant activities (DPPH, ABTS and FRAP), but had lower β-carotene than fresh pumpkin (Nakhon et al., 2017).



	Fresh	MW	FD	C_40	C_50	C_70	C_80
Steamed	5.46	8.69	8.83	9.92	11.45	14.20	17.61
Freshly-pressed	4.16	8.02	7.67	8.17	8.81	9.56	11.27

Figure 4. The comparison of antiradical activity (DPPH) in pumpkin powder obtained in different drying regimes.

Comparing the DPPH antiradical activity between the microwave-vacuum dried, freeze-dried, and convective dried in different temperature regimes pumpkin powders, there were found significant ($P < 0.05$) differences. But there was no significant difference ($P < 0.05$) between DPPH antiradical activity in microwave-vacuum drying and freeze-drying methods obtained pumpkin powder. In contrast, the antiradical activity of DPPH for dry pumpkin powders dried in convective dryer in different temperature regimes was significant ($P < 0.05$), with an increase in drying temperature, DPPH antiradical activity in pumpkin powders also increased like it was also with phenols.

The DPPH antiradical activity of the microwave-vacuum dried pumpkin powder increased by 59%, of freeze-dried pumpkin powder increased by 61%, for convective dried pumpkin powder increase was even from 81% (40 °C) to 222% (80 °C). As the DPPH antiradical activity has a high correlation with total phenol content the increase of DPPH antiradical activity could be explained with the increase of phenols in dried powders compared to fresh, frozen residues. Also in in the investigations of Hossain et al. (2010) drying of herbs has been found to be a very useful technique for increasing the amount of phenolic compounds and antioxidant capacity of the extracts. Among the drying methods tested, air-drying was found to be the best method for all the samples while freeze-drying and vacuum-oven drying showed lower phenol content and antiradical activity (Hossain et al., 2010).

Pumpkin powder made from freshly-pressed residues

Comparing the DPPH antiradical activity between the microwave-vacuum dried, freeze-dried, and convective dried in different temperature regimes pumpkin powders, there were significant ($P < 0.05$) differences. The highest DPPH antiradical activity similarly as in steamed sample was in convective dried pumpkin powder. The antiradical

activity of DPPH in pumpkin powders varied from 7.67 ± 0.27 mM TE per 100 g^{-1} dry matter (using freeze-dryer) to 11.27 ± 0.24 mM TE per 100 g^{-1} dry matter (using drying in a convective dryer at 80 °C) (Fig. 4).

The antiradical activity of DPPH for dry pumpkin powders dried in convective dryer in different temperature regimes was significant ($P < 0.05$), and as the drying temperature increased, the antiradical activity of DPPH in pumpkin powders also increased (compared to a drying of 40 °C and 80 °C increase was 38%).

The lowest increase in DPPH antiradical activity was for freeze-dried pumpkin powder (increased by 84%), for microwave-vacuum dried pumpkin powder increase was 90%, but for convective dried powder increase was from 96% (40 °C) to 170% (80 °C).

Similar results in comparison of two drying methods also scientists Que et al. (2008) found. Hot air-dried pumpkin flour showed stronger antioxidant activities than freeze-dried flour. The percentage inhibition of peroxidation in linoleic acid system by 15 mg mL−1 extracts from hot air-dried and freeze-dried pumpkin flours was found to be 92.4% and 86.1% after 120 h of incubation, respectively (Que et al., 2008).

2.2-azino-bis (3-etilbenztiazolin-6-sulphonic acid) (ABTS+) reagent antiradical scavenging activity

Frozen residues

The $ABTS^+$ antiradical activity in fresh samples ranged from 11.22 ± 0.88 mM, converted to Trolox equivalent (TE) 100 g^{-1} dry matter (freshly-pressed residues) to 12.66 ± 1.04 mM TE per 100 g^{-1} dry matter (steamed, frozen pumpkin residues). There was no significant difference ($P < 0.05$) among these $ABTS^+$ antiradical activity indices.

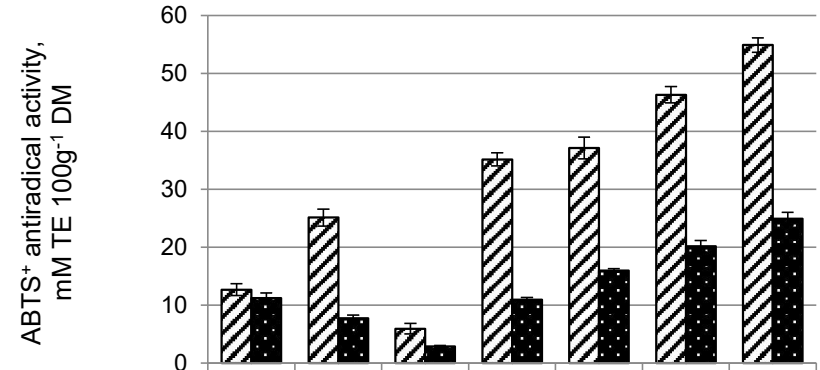
Pumpkin powder made from steamed pumpkin residues

Comparing the DPPH antiradical activity between the microwave-vacuum dried, freeze-dried, and convective dried in different temperature regimes pumpkin powders, there were found significant ($P < 0.05$) differences. The overall tendencies for changes of $ABTS^+$ antiradical activity were similar as to DPPH antiradical activity. The highest $ABTS^+$ antiradical activity was in convective dried pumpkin powder. In general, the antiradical activity of $ABTS^+$ in pumpkin powders varied from 5.93 ± 0.92 mM TE per 100 g^{-1} dry matter (using freeze-dryer) to 54.91 ± 1.23 mM TE per 100 g^{-1} dry matter (using drying in a convective dryer at 80 °C).

$ABTS^+$ Antiradical activity decreased by 53% for freeze-dried pumpkin powder. In the case of microwave vacuum drying, this activity increased by 98%, while for convective dried powder increase was from 177% (40 °C) to 333% (80 °C).

Pumpkin powder made from freshly-pressed residues

The tendences for changes of $ABTS^+$ antiradical activity for pumpkin powder made from freshly-pressed residues were similar to samples made from steamed residues, only the absolute values were much lower (Fig. 5). Overall, the antiradical activity of $ABTS^+$ reagent in pumpkin powders varied from 2.86 ± 0.17 mM TE per 100 g^{-1} dry matter (using freeze-dryer) to 24.94 ± 1.06 mM TE per 100 g^{-1} dry matter (using drying in a convective dryer at 80 °C).



	Fresh	MW	FD	C_40	C_50	C_70	C_80
Steamed	12.66	25.12	5.93	35.17	37.12	46.34	54.91
Freshly-pressed	11.22	7.72	2.86	10.91	15.98	20.17	24.94

Figure 5. The comparison of antiradical activity (DPPH) in pumpkin powder obtained in different drying regimes.

With the rissing of temperature $ABTS^+$ antiradical activity in pumpkin powders also increased.

CONCLUSIONS

The highest total carotenes content retains in freeze-dried pumpkin powders. The most suitable drying method for obtaining pumpkin powder with the highest ascorbic acid, total phenolic content and antiradical activity is drying in convective type dryer at 80 °C temperature. But it is still unclear the mechanism of formation of phenolic compounds during drying of pumpkin by-products at higher temperatures, and some more investigations are necessary for evaluation of formation and degradation processes of different phenolic compunds and antiradical activity affected by temperature.

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REFERENCES

Arslan, O., Temur, A. & Tozlu, I. 1998. Polyphenol oxidase from Malatya Apricot (*Prunus armeniaca L). Journal of Agricultural and Food Chemistry* **46**, 1239–1271.

Aydin, E. & Duygu, G. 2015. The influences of drying method and metabisulfite pre-treatment on the color, functional properties and phenolic acids contents and bioaccessibility of pumpkin flour. *LWT - Food Science and Technology* **6**(1), 385–392.

Biesiada, A., Nawirska, A., Kucharska, A. & Sokól-Letowska, A. 2011. Chemical Composition Of Pumpkin Fruit Depending On Cultivar And Storage. *Ecological Chemistry and Engineering* **18**(1), 9–18.

Das, S. & Banerjee, S. 2015. Production of pumpkin powder and its utilization in bakery products development: a review. *International Journal of Research in Engineering and Technology* **4**(5), 478–481.

Food Idustry technologycal equipment. 2000. (Pārtikas rūpniecības tehnoloģiskās iekārtas) L. Dukaļskas red. Jelgava: LLU PTF, 525 pp. (in Latvian).

Galoburda, R. & Rakčejeva, T. 2008. *The alternative processes of food processing* (Pārtikas pārstrādes alternatīvie procesi). Jelgava: LLU, 94 pp. (in Latvian).

Ghaboos, S.H.H., Ardabili, S.M.S., Kashaninejad, M., Asadi, G. & Aalami, M. 2016. Combined infrared-vacuum drying of pumpkin slices. *Journal of Food Science and Technology* **53**(5), 2380–2388.

Horuz, E. & Maskan, M. 2015. Hot air and microwave drying of pomegranate (*Punica granatum* L.) arils. *Journal of Food Science and Technology* **52**(1), 285–293.

Hossain, C., Barry-Ryan, A.B., Martin-Diana, N.P. & Brunton, M.B. 2010. Effect of drying method on the antioxidant capacity of six *Lamiaceae* herbs. *Food Chemistry* **123**, 85–91.

Jansons, E. 2006. *Theoretical background of analytical chemistry* (Analītiskās ķīmijas teorētiskie pamati), LU Akadēmiskais apgāds, 307 pp. (in Latvian).

Kampuse, S., Tomsone, L. Krūma, Z., Šabovics, M. & Skrabule, I. 2016. Effect of lovage phenolics to formation of acrylamide in French fries. *Agronomy Research* **14**(S2), 1315–1327.

Lozano, J.E., Rotstein, E. & Urbicain, M.J. 1983. Shrinkage, porosity and bulk density of foodstuffs at changing moisture contents. *Journal of Food Science* **48**, 1497–1502.

Machlin, L.J. 1991. *Handbook of Vitamins. 2nd ed.*, New York; Basel Marcel: Dekker, Inc., 595 pp.

Mitra, J., Shrivastava, S. & Rao, P. 2012. Onion dehydration: a review. *Journal of Food Science and Technology* **49**(3), 267–277.

Murkovic, M. 2003. Phenolic Compounds. In: Caballero, B., Finglas, P. & Toldra, F. (eds) *Encyclopedia of Food Sciences and Nutrition. 2nd ed.*, Academic Press, New York, pp. 4507–4514.

Nakhon, P.P.S., Jangchud, K., Jangchud, A. & Prinyawiwatkul, W. 2017. Comparisons of physicochemical properties and antioxidant activities among pumpkin (*Cucurbita moschata* L.) flour and isolated starches from fresh pumpkin or flour. *International Journal of Food Science & Technology* **52**(11), 2436–2444.

Nawirska, A., Figiel, A., Kucharska, A.Z., Sokół-Łętowska, A. & Biesiada, A. 2009. Drying kinetics and quality parameters of pumpkin slices dehydrated using different methods. *Journal of Food Engineering* **94**(1), 14–20.

Noor Aziah, A. & Komathi, C. 2009. Physicochemical and functional properties of peeled and unpeeled pumpkin flour. *Journal of Food Science* **74**(7), 328–333.

Onyenwoke, C.A., Ojo, C.C., Omodamiro, R.M., Egesi, C.N. & Simonyan, K.J. 2015. Effect of Drying Methods on Total Carotenoids Content Retention in Pro- Vitamin A High Quality Cassava Flour . *Umudike Journal of Engineering and technology* **1**(2), 1–9.

Ozola, L., Kampuse, S. & Galoburda, R. 2017. The effect of high-pressure processing on enteral food made from fresh or semi-finished ingredients. *FoodBalt 2017: 11th Baltic conference on food science and technology 'Food science and technology in a changing world': conference proceedings*, Jelgava, LLU, 80–85.

Prieciņa, L. & Kārkliņa, D. 2014. Natural Antioxidant Changes in Fresh and Dried Spiecies and Vegetables International *Journal of Biological, Biomolecular, Agricultural, Food and Bioechnical Engineering* **8**(5), 492–496.

Que, F., Mao, L., Fang, X. & Wu, T. 2008. Comparison of hot air-drying and freeze-drying on the physicochemical properties and antioxidant activities of pumpkin (*Cucurbita moschata Duch*.) flours. *International Journal of Food Science & Technology* **43**, 1195–1201.

Rabadan-Chavez, G. & Lugo-Cervantes, E. 2018. Phenolic Compounds in Cocoa and Chocolate. In: Leo, M.L., Nollet, J., Gutierrez-Uribe, A. (eds) *Phenolic Compounds in Food. Characterization and Analysis.* Taylor & Francis Group, LLC, pp. 375–389.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., Rice-Evans, C. 1999 Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine* **26**, 1231–1237.

Roongruangsri, W. & Bronlund, J.E. 2016. Effect of air-drying temperature on physico-chemical, powder properties and sorption characteristics of pumpkin powders. *International Food Research Journal* **23**(3), 962–972.

Saengrayap, R., Tansakul, A. & Mittal, G.S. 2015. Effect of far-infrared radiation assisted microwave-vacuum drying on drying characteristics and quality of red chilli. *Journal of Food Science and Technology* **52**(5), 2610–2621.

Scaman, C.H. & Durance, T.D. 2005. Combined Microwave Vacuum-drying. In: Sun. D.W. (ed) *Emerging technologies for Food Processing*. Elsevier: Academic Press, New York, pp. 507–533.

Singleton, V.L., Orthofer, R. & Lamuela-Raventos, R.M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of FolinCiocalteu reagent. *Method in Enzymology* **299**, 152–178.

Sonawane, S.K. & Arya, S.S. 2015. Effect of drying and storage on bioactive components of jambhul and wood apple. *Journal of Food Science and Technology* **52**(5), 2833–2841.

Terazawa, Y., Ito, K., Masuda, R. & Yoshida, K. 2001. Changes in carbohydrate composition in pumpkins (Cucurbita maxima) (kabocha) during fruit growth. *Journal of the Japanese Society for Horticultural Science* **70**(5), 656–658.

Tomsone, L. & Kruma, Z. 2014 Influence of freezing and drying on the phenol content and antioxidant activity of horseradish and lovage. *Proc. Conf. FoodBalt 2014*, Jelgava, Latvia, pp. 192–197.

Yang, J., Chen, J., Zhao, Y. & Mao, L. 2010. Effects of Drying Processes on the Antioxidant Properties in Sweet Potatoes. *Agricultural Sciences in China* **9**(10), 1522–1529.

Yu, L., Perret, J., Harris, M., Wilson, J. & Haley, S. 2003. Antioxidant Properties of Bran Extracts from 'Akron' Wheat Grown at Different Locations. *Journal of Agricultural and Food Chemistry* **51**, 1566–1570.

Ермаков, А.И. 1987. Methods of biochemical analysesof plants (Методы биохимического исследования растений). Под ред. А.И.Ермакова, Ленинград, ВО «Агропромиздат», pp. 112–113 (in Russian).