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THE EFFECT OF DRYING METHODS ON THE CONTENT OF SELECTED BIOACTIVE COMPOUNDS AND FIBRE IN CARROT POMACE

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K e y w o r d s: carrot pomace, drying, carotenoids, polyphenols, DPPH radical, fibre.

A b s t r a c t

The aim of the study was to analyse the content and profile of carotenoids, polyphenols content, the capacity to scavenge DPPH radical, the content of neutral detergent fibre, acid detergent fibre and hemicellulose, cellulose and lignin fractions in carrot pomace dried with different methods. Fresh carrot pomace obtained as a by-product during the extraction of juice from Nantejska carrot was used in tests. Portions of pomace were frozen, dried by convection or lyophilized. The study demonstrated a significant loss of total carotenoids in convective dried (CPC) and lyophilized (CPL) carrot pomace. The greatest decrease was found for β-carotene. The content of phenolics increased by ca. 2.5% for CPC and by ca. 20% for CPL. The capacity to scavenge DPPH radicals was also higher in dry pomace. Significantly higher content of neutral detergent fibre, including hemicellulose fraction, was found in CPC. The analysis did not clearly indicate the optimal drying method. The choice of drying method should depend on the type of final product in which carrot pomace will be used.

WPŁYW SPOSOBU SUSZENIA WYTŁOKÓW Z MARCHWI NA WYBRANE SKŁADNIKI BIOAKTYWNE I BŁONNIK

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S ł o w a k l u c z o w e: wytłoki marchwiowe, suszenie, karotenoidy, polifenole, DPPH, błonnik.

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Abstrakt

Celem badań była ocena wpływu metody suszenia wytłoków z marchwi na zawartość i profil karotenoidów, zawartość polifenoli, aktywność przeciwutleniającą oznaczoną jako zdolność wiązania rodnika DPPH, zawartość błonnika pokarmowego (NDF), błonnika kwaśnego detergentowego (ADF) oraz frakcji hemiceluloz, celulozy i lignin. Materiał badawczy stanowiły wytłoki uzyskane jako produkt uboczny przy tłoczeniu soku z marchwi odmiany Nantejska. Część wytłoków świeżych zamrożono, a część poddano suszeniu konwekcyjnemu i liofilizacji.

Wykazano, iż zarówno proces suszenia konwekcyjnego, jak i liofilizacji spowodował duże obniżenie zawartości karotenoidów ogółem w wytłokach, odpowiednio o 31,8% i 34,5%. Największy spadek, na poziomie 41%, odnotowano dla β-karotenu. Stwierdzono także większą zawartość polifenoli ogółem w wytłokach suszonych niż w świeżych. Wzrost zawartości polifenoli wynosił ok. 2% w przypadku konwekcji i ok. 20% dla liofilizacji. Oznaczona wyższa zawartość polifenoli może wynikać m.in. z lepszej dostępności analitycznej tych związków z materiału suszonego. Aktywność wiązania rodnika DPPH była również większa dla wytłoków suszonych. Badane wytłoki są dobrym źródłem błonnika. Pod względem zawartości błonnika pokarmowego (NDF), w tym frakcji hemiceluloz, wyróżniały się wytłoki suszone konwekcyjnie. Analizując uzyskane wyniki, trudno jednoznacznie wskazać wariant optymalny. Wybór w znaczącym stopniu zależał będzie od rodzaju produktu końcowego, do którego wytłoki będą aplikowane.

Introduction

Fruit and vegetable processing generates a significant amount of waste and by-products, which sometimes account for 10–35% of processed raw material (TARKO et al. 2012). Pomace is a particularly important by-product, and is obtained during the industrial production of wine, juice and beverages (CYBULSKA et al. 2013, HERNÁNDEZ-ORTEGA et al. 2013). In Poland, which is a major producer of fruit and vegetable juices, ca. 260,000 t of fruit pomace and ca. 100,000 t of vegetable pomace is created each year. Pomace consists mainly of cell wall polysaccharides, which constitute dietary fibre (pectin, cellulose and hemicellulose) (NAWIRSKA and KWAŚNIEWSKA 2004, BORYCKA 2012, GAZALLI et al. 2013, HERNÁNDEZ-ORTEGA et al. 2013). Studies have indicated that pomace is also a rich source of bioactive compounds with health-related benefits, such as vitamins, minerals and polyphenols (SHARMA et al. 2012, TARKO et al. 2012, HERNÁNDEZ-ORTEGA et al. 2013). Dry pomace can be a valuable additive in many food products, including beverages, breads, biscuits, extruded products, etc. (STOLL et al. 2003, GULLÓN et al. 2007, UPADHYAY et al. 2010, KUMAR and KUMAR 2011, GAYAS et al. 2012, KOHAJDOVÁ et al. 2012, CYBULSKA et al. 2013).

Carrot pomace is a particularly valuable residue. To date, it has mainly been utilised through composting and processing into animal feed. Because of its high water content (ca. 70%) fresh pomace is susceptible to a rapid increase in microbial contamination (TARKO et al. 2012). Drying is one of the major methods to prevent this process. The removal of a significant amount of water from pomace reduces its weight by several times, which also reduces the cost of transport and storage. Major factors determining the quality of dry pomace include pre-treatment, drying method and drying parameters. Convective drying is the most popular method. Other, rarely used methods, mainly because of greater costs, are lyophilisation and microwave drying (MARMO 2007, AL-HARAHSHEH et al. 2009, KUMAR et al. 2012, HERNÁNDEZ-ORTEGA et al. 2013, JANISZEWSKA et al. 2013). High temperatures can cause darkening of pomace, and the degradation of carotenoids, polyphenols, aromatic compounds, etc. (GAWAŁEK 2005). Because pomace is mainly used in the food industry, an increasing number of studies are being carried out to design drying conditions that could produce dry pomace characterised by good sensory, nutritional and physical parameters (CIURZYŃSKA et al. 2011).

The study attempts to determine the influence of the applied drying method of carrot pomace – the convection and freeze drying – on changes of biologically active substances and fiber. The aim of the study was to identify more favorable method of drying carrot pomace.

Material and Methods

Preparation of pomace

Analyses were carried out on fresh carrot pomace (CPF), convective dried carrot pomace (CPC), and lyophilized carrot pomace (CPL). Fresh carrot pomace was obtained as a by-product during the extraction of juice from Nantejska carrot in a laboratory hydraulic press (Biowin, Poznań, Poland). Carrot used in the study was harvested in 2014 near Olsztyn, Poland. Fresh carrot pomace was divided into three portions. The first portion was frozen at -25°C, and two other portions were dried either by convection in a oven (KBC 200, Warszawa, Poland) (for 5 hours at 40°C), or freeze-dried in a lyophilizer (Heto CD 13-2, Danmark) (for 48 hours, condenser temp. -60°C, pressure 1 mbar). Fresh pomace before freezing and dry pomace were closed in plastic bags after evacuation of air from inside the package under vacuum. Fresh carrot pomace for chemical analysis was blended in a homogenizer (BRAUN 2096, KRONBERG, Germany), and dry pomace was blended in a laboratory mill (IKA M-20, Germany).

Chemical reagents

2,2-Diphenyl-1-picrylhydrazyl (DPPH), catechin, $AlCl_3$, Folin-Ciocalteau's reagent, alpha-amylase, tert butyl methyl ether, acetone, ethanol, hexane, sulphuric acid, hydrochloric acid, methanol, toluene, sodium carbonate and sodium hydroxide were purchased from Sigma-Aldrich (St. Louis, Missouri, USA). 6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) was purchased from Acros Organics (Morris Plains, New Jersey, USA). All other reagents were of analytical purity and supplied by POCh (Gliwice, Poland).

Determination of total phenolics

The total phenols content of fresh pomace and dry pomace were determined by the Folin-Ciocalteu method (AOAC 1974). The extraction of phenols was performed a mixture of methanol : water 80:20 (v/v) solution in an ultrasonic bath for 30 minutes. The extraction process was repeated 3 times, each time separating the supernatant by centrifuging (Eppendorf 5810R, Germany). An aliquot of the extract (1 ml) was mixed with 0.5 ml of Folin-Ciocalteu's reagent and 2 ml of sodium carbonate (20%). After incubation at room temperature for 30 minutes, the absorbance of the reaction mixture was measured at 750 nm (FLUOstar Omega, BMG LABTECH GmbH, Germany). Gallic acid (GA) was chosen as a reference standard. The data were expressed as mg of gallic acid equivalents (GAE) per 100 g of dry matter (d.m.) pomace.

Determination of antioxidant activity using DPPH (2,2-Diphenyl-1-picrylhydrazyl)

The DPPH radical-scavenging activity of methanol extracts (prepared according to the above procedure) from fresh and dry carrot pomace was determined by using the method described by MOURE et al. (2001). Extracts from pomace samples were mixed with a methanol solution of DPPH. Absorbance was measured at the beginning of the test and after 16 minutes of reaction against the blank at 515 nm (FLUOstar Omega, BMG LABTECH GmbH, Germany). Results were expressed in μM DPPH scavenged by 1 mg of phenolics.

Determination of carotenoids

Carotenoids were determined using high-performance liquid chromatography (HPLC). Extracts were prepared according to the procedure proposed by CHEN and YANG (1992), using 30 mL a mixture of hexane : acetone : absolute ethyl alcohol : toluene in a ratio of 10:7:6:7 (v/v/v/v) to which an internal reference standard (β-Apo-8'-carotenal) was added. Saponification, 40% methanol solution of potassium hydroxide was added to the extract and left to stand for 16 hours. The released carotenoids were extracted 3 times with hexane. After the evaporation of hexane using nitrogen, samples were dissolved in 1 mL of mixture containing methanol: dichloromethane (45:55, v/v) and the supernatant was separated by centrifuging (Eppendorf model 5417R Hamburg, Germany), and then analysed chromatographically. Compounds were separated using HPLC and a procedure proposed by EMENHISER et al. (1995) modified by CZAPLICKI (2006). Modification involved the use of methanol-MTBE (methyl tert-butyl ether) gradient and simultaneous different flow rates of the mobile phase. This ensured high resolution of the process and minimised the time of analysis. Samples were analysed using a high-performance liquid chromatography (HPLC) apparatus, series 1200 from Agilent Technologies (Santa Clara, CA, USA), with a fitted diode array detector (DAD) from the same supplier. Compounds were separated at 30°C on a YMC C_{30}, 3 μm, 150 mm × 4.6 mm column from YMC Europe GmbH (Germany). Carotenoids were detected at 450 nm. The content of carotenoids was expressed as mg per 100 g of dry matter.

Determination of fibre

The content of neutral detergent fibre (NDF) and acid detergent fibre (ADF) in the obtained material was determined by the VAN SOEST procedure (1963, 1967) as modified by MCQUEEN (1979). This method consists in the hot extraction of samples using acidic or inert detergent solutions. The content of hemicellulose was calculated from the difference between NDF and ADF; the content of cellulose was calculated from the difference between ADF and lignin content. Results concerning the contents of the fibre were expressed as g per 100 g of dry matter. The content of fibre was measured using a Fibertec System I (Tecator, Sweden).

Determination of dry matter

Dry matter in fresh and dry carrot pomace was determined by the weighing method according to the Polish standard *Przetwory owocowe...* PN–A-75 101-03:1990).

Statistical analysis

The results of all analysis (performed in triplicate) were statistically analyzed using Statistica 12.0 PL software (StatSoft, Kraków, Poland). The differences between the means were determined using analysis of variance (ANOVA) with Duncan test at $P < 0.05$ significance level.

Results and Discussion

Bioactive compounds and antioxidant activity

The analysed fresh (CPF), convective dried (CPC) and lyophilized carrot pomace (CPL) differed for the content of bioactive compounds and antioxidant activity (Table 1). Differences between most samples were statistically significant ($P < 0.05$). The drying process caused qualitative and quantitative changes in the level of carotenoids. The total content of carotenoids in fresh, convective dried and lyophilized carrot pomace was 120.14 mg/100 g d.m., 81.93 mg/100 g d.m. and 78.66 mg/100 g d.m., respectively (Table 1). The loss of carotenoids was 31.8% for convective drying and 34.5% for lyophilisation. Smaller changes in carotenoid content during drying were reported by HERNÁNDEZ-ORTEGA et al. (2013) (a 29% decrease for convective dried and a 20% decrease for microwave dried carrot pomace). In plant tissues, carotenoids exist in cis and trans forms and during thermal processing some of the trans forms are either lost or converted to cis and their derivatives (SHARMA et al. 2012).

All analysed samples, regardless of the drying method, contained the highest amount of β-carotene, followed by α-carotene (Table 1). Considering total carotenoid content, β-carotene accounted for 62.3% (CPF), 53.5% (CPC) and 55.3% (CPL). The predominant share of β-carotene has been reported in studies by SHARMA et al. (2012) and LEONG and OEY (2012). The content of β-carotene in both types of dry carrot pomace was similar, and about 41% lower than in fresh pomace (Table 1). The lowest loss of β-carotene, not exceeding 14%, was reported by LEONG and OEY (2012) for freeze-dried carrot. The loss of α-carotene in our study was lower than that for β-carotene and did not exceed 22%. The analysis also demonstrated the presence of small amounts of β-cryptoxanthin and lutein, as well as traces of carotene isomers, with slightly greater levels detected in dry pomace.

The content of phenolics also changed after drying (Table 1). The highest level of total phenolics (1188.04 mg/100 g d.m.) was found in CPL, and the lowest (987.88 mg/100 g d.m.) in CPF. To summarize, the total phenolics content in the analysed pomace was ca. 20% higher in lyophilized samples

Table 1
Carotenoids, total phenols, dry matter contents, and DPPH scavenging activity of carrot pomace

Component	Fresh pomace	Convective dried pomace	Lyophilized pomace
Carotenoids [mg/100 g d.m.]:	–	–	–
Lutein	0.54 ± 0.05[a]	0.15 ± 0.04[b]	0.19 ± 0.03[b]
β-cryptoxanthin	1.72 ± 0.06[c]	1.06 ± 0.13[a]	1.40 ± 0.02[b]
α-carotene	42.97 ± 1.64[c]	36.91 ± 1.76[b]	33.57 ± 2.24[a]
β-carotene	74.91 ± 1.31[b]	43.80 ± 2.86[a]	43.50 ± 2.13[a]
Isomers of carotenoids	–	traces	traces
Total	120.14 ± 2.72[b]	81.93 ± 2.47[a]	78.66 ± 1.84[a]
Total phenols [mg/100 g d.m.]	987.88 ± 45.03[a]	1013.02 ± 28.14[a]	1188.04 ± 57.26[b]
DPPH scavenging activity [μmol DPPH/mg phenolics]	5.75 ± 0.55[a]	6.80 ± 0.78[a]	13.74 ± 1.56[b]
Dry matter [%]	16.54 ± 0.33[a]	94.43 ± 0.14[b]	98.43 ± 0.27[c]

d.m. – dry matter
Values are expressed as mean ± standard deviation, $n = 3$
Means in the same row with different letters differ significantly ($P < 0.05$)

and ca. 2% higher in convective dried samples as compared to fresh pomace. It is possible that the extractability of phenolics from dry material is greater than from fresh material under the conditions of the method used in our study for the determination of phenolics (AOAC 1974). Studies by HERNÁNDEZ-ORTEGA et al. (2013) revealed a greater content of phenolics in fresh, convective dried and microwave dried carrot pomace, which may be attributed to the specific variety of polyphenol-rich carrot used for analyses, or different parameters of juice extraction and then pomace drying. As with the phenolic content HERNÁNDEZ-ORTEGA et al. (2013) reported 1841 mg gallic acid equivalents/100 g d.m. for fresh carrot pomace vs 1505 mg gallic acid equivalents/100 g d.m. for convective dried pomace and 1412 mg gallic acid equivalents/100 g d.m. for microwave dried pomace.

The antioxidant activity of carrot is associated with the presence of phenolics and carotenoids in the plant (SHARMA et al. 2012). In our study the antioxidant activity expressed in μM DPPH scavenged by 1 mg of phenolics was in the range of 6.8–13.74 and was the highest for CPL and the lowest for CPF (Table 1). There may be many reasons explaining such a significant difference in antioxidant activity. One potential reason for the increased antioxidant activity of dry pomace is the formation of compounds during the drying of fresh pomace. Maillard's reaction, facilitated by high temperature, may also contribute to this increase in the case of convective drying (TAMANNA and MAHMOOD 2015). Another reason may be the different stability of phenolics characterised by different capacity to scavenge DPPH radicals during the used drying processes. Antioxidant activity was determined in methanol extracts of pomace, and thus a diversified selective extractability of antioxidants from individual samples cannot be ruled out, either.

Fibre

As with carotenoids and phenolics, the study demonstrated differences between the analysed samples in the content of different forms of fibre depending on the drying method (Figure 1). Statistically significant differences were found for most of the samples (P < 0.05). Interestingly, high fibre content was found for fresh carrot pomace and dry carrot pomace. The highest content of neutral detergent fibre (NDF) (28.23 g/100 g d.m.) was found in CPC, and the lowest (19.86 g/100 g d.m.) in CPL (Figure 1). The content of acid detergent fibre (ADF) also varied, and was from 16.93 g/100 g d.m. for CPL to 24.67 g/100 g d.m. for CPC. Cellulose fraction was dominant in all analysed samples, with the highest content also found in CPC. The content of lignin was lower, especially in lyophilized pomace. The content of hemicellulose was the lowest (from 1.39 g/100 g d.m. for CPF to 3.57 g/100 g d.m. for CPC). The study demonstrated an increase in hemicellulose after drying. Other authors (D'ARCHIVIO et al. 2010, PALAFOX-CARLOS et al. 2011) reported that the increased content of NDF after heat treatment may result from the formation

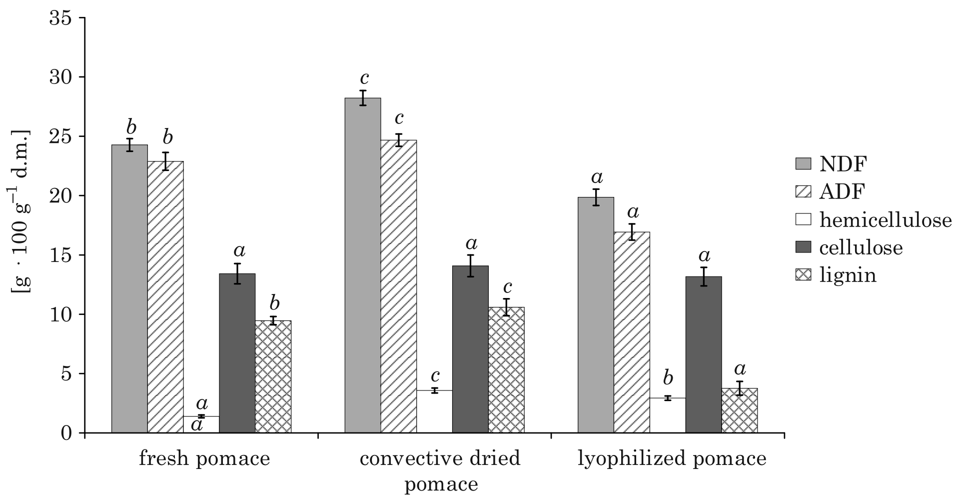

Fig. 1. Content of different fractions of fibre in carrot pomace
Values are expressed as mean ± standard deviation, n = 3; *a–c* – bars with different letters for different fractions differ significantly (P < 0.05)
NDF – Neutral Detergent Fibre, ADF – Acid Detergent Fibre

of polysaccharide complexes with other compounds, e.g. phenolics. This was confirmed, for example, in a study by KOMOLKA et al. (2012), who found a significant 58–59% increase in NDF content after boiling Brassicaceae vegetables in water. The reported increase in ADF content was even greater (78–112%). Studies by KOMOLKA et al. (2012) revealed that changes in the components of fibre fraction depend on the heat treatment method, and also vegetable species.

The lower levels of individual fibre fractions in CPL found in our study may result from the degradation of fibre structure, promoted by rapid freezing in liquid nitrogen (at -195.8°C), followed by exposure to vacuum. A significant effect of the drying method on changes in the content of fibre in carrot pomace was also demonstrated by ALAM et al. (2013), who found the highest fibre content in samples after convective drying (at 65°C) compared to sun drying and solar drying.

Conclusions

Carrot pomace obtained as a by-product during juice extraction is a rich source of important nutrients, such as carotenoids, polyphenols and fibre. It also has good antioxidant properties. Drying used for the preservation of fresh (moist) pomace caused qualitative and quantitative changes in the content of the analysed components, and the differences were statistically significant in most cases ($P < 0.05$). The study demonstrated significant changes determined by the drying method. A relatively low stability was found for carotenoids, especially β-carotene, and the greater loss in the content of this substance was caused by lyophilisation. It is worth noting that the used analytical method indicated a greater content of total phenolics and higher capacity to scavenge DPPH radicals for dry carrot pomace compared to fresh pomace. Particular differences were found for lyophilized pomace. Potential reasons explaining the significant differences are presented in the discussion. Interestingly, the drying process, particularly convective, had a positive effect on the increased content of neutral detergent fibre, including hemicellulose fraction. However, the analysis of results did not clearly identify the optimal drying method. It can be assumed that the choice of method should depend on the type of final product in which carrot pomace will be used.

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References

ALAM S., GUPTA K., KHAIRA H., JAVED M. 2013. *Quality of dried carrot pomace powder as affected by pretreatments and methods of drying*. Agricultural Engineering International: CIGR Journal, 15: 236–243.

AL-HARAHSHEH M., AL-MUHTASEB A.H., MAGEE T.R.A. 2009. *Microwave drying kinetics of tomato pomace: effect of osmotic dehydration.* Chemical Engineering and Processing: Process Intensification, 48: 524–531.

AOAC (Association of the Official Analytical Chemists). 1974. *Official Methods and Analysis*. Washington DC, 9: 110.

BORYCKA B. 2012. *Fractions of dietary fibre from aronia pomace in relation to Pb, Cd, and Mg ions.* Food. Science. Technology. Quality, 85: 31–40.

CHEN B.H., YANG S.H. 1992. *An improved analytical method for the determination of carotenoids and xanthophylls in dried plant materials and mixed feeds*. Food Chemistry, 44: 61–66.

CIURZYŃSKA A., PIOTROWSKI D., JANOWICZ M., SITKIEWICZ I., LENART A. 2011. *The influence of temperature and pressue in vacum-dryer chamber on rehydration of dried strawberries*. Acta Agrophysica, 17: 289–300.

CYBULSKA J., ZDUNEK A., SITKIEWICZ I., GALUS S., JANISZEWSKA E., ŁABA S., NOWACKA M. 2013. *Możliwości zagospodarowywania wytłoków i innych odpadów przemysłu owocowo-warzywnego*. Przemysł Fermentacyjny i Owocowo-Warzywny, 9: 27.

CZAPLICKI S. 2006. *Nasiona żmijowca jako źródło bioolejów roślinnych stabilizowanych olejem rokitnikowym*. UWM w Olsztynie (praca doktorska).

D'ARCHIVIO M., FILESI C., VARÍ R., SCAZZOCCHIO B., MASELLA R. 2010. *Bioavailability of the polyphenols: status and controversies.* International Journal of Molecular Sciences, 11: 1321–1342.

EMENHISER C., SANDER L.C., SCHWARTZ S.J. 1995. *Capability of apolimeric C30* stationary phase to resolve cis-trans carotenoid isomers in reverse-phase liquid chromatography. Journal of Chromatography A, 707: 205–216.

GAWAŁEK J. 2005. *Wpływ warunków konwekcyjnego i sublimacyjnego suszenia korzeni marchwi na jakość suszu*. Inżynieria Rolnicza, 11: 119–127.

GAYAS B., SHUKLA R.N., KHAN B.M. 2012. *Physico-chemical and sensory characteristics of carrot pomace powder enriched defatted soyflour fortified biscuits.* International Journal of Scientific and Research Publications, 2: 1–5.

GAZALLI H., MALIK A.H., JALAL H., AFSHAN S., MIr A. 2013. *Proximate composition of carrot powder and apple pomace powder. International Journal of Food* Nutrition and Safety, 3: 25–28.

GULLÓN B., FALQUÉ E., ALONSO J.L., PARAJÓ J.C. 2007. *Evaluation of apple pomace as a raw material for alternative applications in food industries*. Food Technology and Biotechnology, 45: 426–433.

HERNÁNDEZ-ORTEGA M., KISSANGOU G., NECOECHEA-MONDRAGÓN H., SÁNCHEZ-PARDO M.E, ORTIZ--MORENO A. 2013. *Microwave dried carrot pomace as a source of fiber and carotenoids*. Food and Nutrition Sciences, 4: 1037–1046.

JANISZEWSKA E., WITROWA-RAJCHERT D., KIDOŃ M., CZAPSKI J. 2013. *Effect of the applied drying method on the physical properties of purple carrot pomace.* International Agrophysics, 27: 143–149.

KOHAJDOVÁ Z., KAROVIČOVÁ J., JURASOVÁ M. 2012. *Influence of carrot pomace powder on the rheological characteristics of wheat flour dough and on wheat rolls quality.* Acta Scientiarum Polonorum, Technologia Alimentaria, 11: 381–387.

KOMOLKA P., GÓRECKA D., DZIEDZIC K. 2012. *The effect of thermal processing of cruciferous vegetables on their content of dietary fiber and its fractions. Acta Scientiarum* Polonorum, Technologia Alimentaria, 11: 347–354.

KUMAR N., KUMAR K. 2011. *Development of carrot pomace and wheat flour based cookies.* Journal of Pure and Applied Science and Technology, 1: 5–11.

KUMAR N., SARKAR B.C., SHARMA H.K. 2012. *Mathematical modelling of thin layer hot air drying of carrot pomace.* Journal of Food Science and Technology, 49: 33–41.

LEONG S.Y., OEY I. 2012. *Effects of processing on anthocyanins, carotenoids and vitamin C in summer fruits and vegetables*. Food Chemistry, 133: 1577–1587.

MARMO L. 2007. *Low temperature drying of pomace in spout and spout-fluid beds.* Journal of Food Engineering, 79: 1179–1190.

McQueen R.E., Nicholson J.W.G. 1979. *Modification of the neutral detergent fiber procedure for cereal and vegetables by using* α-amylase. Journal of Association of Official Analytical Chemists, 62: 676–680.

Moure A., Franco D., Sineiro J., Domínguez H., Núñez M.J., Lema J.M. 2001. *Antioxidant activity of extracts from Gevuina avellana and Rosa rubiginosa defatted seeds*. Food Research International, 34: 103–109.

Nawirska A., Kwaśniewska M. 2004. *Dietary fibre fractions from fruit processing waste.* Acta Scientiarum Polonorum, Technologia Alimentaria, 3:13–20.

Palafox-Carlos H., Ayala-Zavala J.F., González-Aguilar G.A. 2011. *The role of dietary fiber in the bioaccessibility and bioavailability of fruit and vegetable antioxidants*. Journal of Food Science, 76: R6-R15.

Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie zawartości suchej masy metodą wagową. PN-A-75101-03: 1990.

Sharma K.D., Karki S., Thakur N.S., Attri S. 2012. *Chemical composition, functional properties and processing of carrot – a review*. Journal of Food Science and Technology, 49: 22–32.

Stoll T., Schweiggert U., Schieber A., Carle R. 2003. *Application of hydrolyzed carrot pomace as a functional food ingredient to beverages.* Journal of Food Agriculture and Environment, 1: 88–92.

Tamanna N., Mahmood N. 2015. *Food processing and Maillard reaction products: effect on human health and nutrition.* International Journal of Food Science, article ID 526762.

Tarko T., Duda-Chodak A., Bebak A. 2012. *Biological activity of selected fruit and vegetable pomaces.* Food. Science. Technology. Quality, 83: 55–65.

Upadhyay A., Sharma H.K., Sarkar B.C. 2010. *Optimization of carrot pomace powder incorporation on extruded product quality by response surface methodology*. Journal of Food Quality, 33: 350–369.

Van Soest P.J. 1963. *Use of detergents in the analysis fibrous feeds.* I. *Preparation of fiber residues of low nitrogen content.* Journal of Association of Official Analytical Chemists, 46: 825–835.

Van Soest P.J. 1967. *Use of detergents in the analysis fibrous feeds.* IV. *Determination of plant cell wall constituents*. Journal of Association of Official Analytical Chemists, 50: 50–55.