Content of saccharides, antioxidant and sensory properties of pear cultivar "Abate Fetel" affected by ultrasound pre-treatment and air drying duration

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Summary

The effect of ultrasound pre-treatment on quality attributes of air-dried pears was investigated, with the aim of shortening the overall processing time, maximizing the production yield and maintaining the optimum contents of saccharides and bioactive compounds. The contents of saccharides, total phenols and flavonoids, as well as the antioxidant capacity were determined spectrophotometrically. Consumer evaluation of sensory properties was conducted using hedonic scale preference analysis. Under the same air-drying conditions, prolonged ultrasound pre-treatment led to a decrease in the contents of total saccharides, phenols and flavonoids, as well as to a decrease in antioxidant capacity and sensory quality (appearance of brown spots, grainy mouth feel, hard texture) of dried pears. The highest contents of fructose, glucose and saccharose amounted to 381.95 mg·kg^{-1}, 279.81 mg·kg^{-1} and 28.52 mg·kg^{-1} of dry matter of sample, respectively, while non-treated pears dried for 720 min exhibited the highest total phenol content of 4.33 g·kg^{-1} of dry matter (expressed as gallic acid equivalent). According to the performed experiments, the combination of a shorter ultrasound pre-treatment (up to 10 min) and 360 min of air drying is the most efficient for obtaining a product with the best nutritive composition, in terms of saccharide and polyphenol contents, as well as the best sensory properties.

Keywords

air drying, pears, polyphenols, saccharides, ultrasound pre-treatment

Pear (*Pyrus communis* L.) is traditionally one of the most consumed fruits in the temperate climate regions, representing an important share of the fruit-growing market, due to very fertile and high yielding cultivars [1]. Pears are an excellent source of saccharides (of total saccharide content, on average 54% is fructose, 18% sorbitol, and only 15% saccharose and 13% glucose) and dietary fibre (15–28 g·kg^{-1} fresh weight) [2], as well as bioactive compounds such as naturally occuring antioxidants, polyphenols. The presence of chlorogenic acid, cryptochlorogenic acid and neochlorogenic acid in pear has been confirmed in the first studies on the subject [3], while subsequent research revealed other polyphenolic compounds in pear such as cyanidin glycosides, catechin, epicatechin, chlorogenic acid, quercitrin and arbutin [4,5]. Recently, some other polyphenolic compounds, such as coumaroylquinic acid [6], hydroxycinnamic acid esters and eight flavonol glucosides, were also identified in pear fruits [7, 8]. Owing to these nutritional features, pears are a recommendable food for diabetics and the obese; moreover, dietary fibre together with phenolics help to reduce the risk of cardiovascular diseases [8].

Surplus of the fruit crop that could not be consumed or exported, represents an appropriate raw material for drying, which provides an extension of shelf-life and minimizes packaging and storage requirements, as well as transport costs. However, recent advances in food technology have lead to higher consumer expectations, which include mini-

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mized effects of processing methods on nutritional value and colour changes [9]. Although many fruit species are presumed to be consumed fresh or minimaly processed, dried fruits posess a characteristic flavour [10], which makes it appropriate for direct consuption as well as for use in the confectionery industry [11].

The production of pears in Croatia in the last decade has not only stagnated but also decreased, and is estimated to constitute only 1% of the total fruit production in Croatia. In order to increase and popularize pear production, a need arises for production of pear cultivars with good characteristics and high yields, available to consumers during cold periods of the year. Apart from "Williams" cultivar, "Abate Fetel" is becoming the most important cultivar in terms of production and exported tonnage of pear in Europe, in particular Italy. The success of "Abate Fetel" can be attributed to the distinctive elongated shape, the strong recognition by consumers and maintaining excellent eating quality through long-term cold storage [12].

Conventional air drying is a process with high energy consumption, which involves simultaneous heat and mass transfer, accompanied by phase change. Hot air drying results in extremely shrunken products with tough texture, severe browning, low rehydration rate and low nutritive value [13, 14]. In order to reduce the initial water content or to modify the fruit tissue structure to reduce the total drying processing time, various pre-treatment procedures are applied [15–17]. Ultrasound has several applications in food processing, while the use of ultrasonic treatment has aroused a great interest of food scientists, due to its significant potential of product modification and process improvement. The effect of ultrasound on fruit tissue depends on its structure and composition, providing an improved air drying efficiency, with consequent reduction in process costs. The major advantage of ultrasound pre-treatment is enabling of food processing at ambient temperature as no heating is required, reducing the potential of thermal degradation [18]. Ultrasound treatments also induce the disruption of cell walls to facilitate the release of contents, which enhances the mass transfer [19–21]. According to the findings of previous studies [22, 23], ultrasonic treatment of fruit leads to a significant saccharides loss, showing a potential for production of low saccharides content dried fruits, aimed for use in low-calorie products and products for diabetics.

In this paper, the use of ultrasound as a pre-treatment to air drying of pears was investigated, in order to evaluate the influence of ultrasound pre-treatment duration and air drying on the contents of saccharides, polyphenols as representatives of bioactive compounds, as well as their antioxidant capacity and sensory properties. Correlation analysis was also conducted in order to confirm the relationship between the determined parameters as affected by ultrasound and air drying, searching for the operating condition that minimizes the total processing time and preserves the highest content of bioactive compounds.

MATERIALS AND METHODS

Chemicals

Folin-Ciocalteu, potassium peroxodisulphate, sodium carbonate, sodium acetate trihydrate, acetic acid, hydrochloric acid, ferric chloride hexahydrate and ferric sulphate heptahydrate were of analytical grade and supplied by Kemika (Zagreb, Croatia). Formaldehyde was obtained from Alkaloid (Skopje, Macedonia). Trolox (6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid), TPTZ (2,4,6-tripyridyl-S-triazine) and ABTS (2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) diammonium salt) were obtained from Aldrich (Sigma-Aldrich Chemie, Steinheim, Germany). K-SUFRG enzymatic assay kit for the determination of saccharides content was supplied by Megazyme (Wicklow, Ireland).

Sample preparation

Pears (*Pyrus communis* L., cultivar "Abate Fetel") were obtained from a local market in Zagreb, Croatia. The pears were washed and cut into radially shaped, 8 mm thick slices. A sample of 5 pears was used for determination of average saccharide and phenolic content, as well as the antioxidant capacity of fresh and treated pears for all pre-treatment conditions. Moisture content was determined according to official AOAC method 934.06 [24], and expressed as a percentage of the initial sample weight.

Ultrasound pre-treatments

Pear slices were immersed in distilled water and submitted to ultrasound pre-treatments for 0, 10, 22, 35 and 45 min. The experiments were carried out under ambient water temperature (21 °C), in an ultrasonic bath Elmasonic S 120 (Elma, Singen, Germany), nominal power 200 W and frequency 37 kHz. After 45 min of ultrasonic pre-treatment, the temperature in the bath increased for 16.5 °C. The power input into the fluid bulk was determined by calorimetric method described by Löning et al. [25], and the resulting intensity was 0.035 $W\cdot cm^{-3}$.

Air drying

At the end of the pre-treatment, the samples were drained to remove the excess water and transferred to an air-drying oven (Alaska FD 1250; Oriental Universe Industries, Hong Kong, China), nominal power 250 W, with vertical air flow and the average air temperature of 70 °C. Room temperature was kept at 25 °C with relative humidity of air at 26.2%. After 360, 540 and 720 min of drying, weight loss of samples was calculated.

Saccharides content

The contents of saccharose, glucose and fructose were determined enzymatically using the assay kit K-SUFRG, based on the methods developed by OUTLAW and MITCHELL [26], BEUTLER [27] and KUNST et al. [28]. All reagents were prepared according to the manufacturer's instructions. The procedures suggested by the manufacturer were strictly followed, and the content of individual saccharides calculated and expressed as milligrams per kilogram of dry matter.

Total phenol and flavonoid contents

For the detemination of total phenols and flavonoids and the antioxidant capacity of pears, sample extracts were prepared according to a procedure described by SCALZO et al. [29]. Total phenol content (TPC) was determined spectrophotometrically according to a modified method of LACHMAN et al. [30]. In order to determine the flavonoid content (TFC) of fresh and treated pears, formaldehyde precipitation was used and the content of flavonoids calculated as the difference between total phenol content (TPC) and non-flavonoid content (TNC). All determinations were carried out in triplicates and the results were expressed as grams of gallic acid equivalents (GAE) per kilogram of dry matter.

Determination of antioxidant capacity

Ferric reducing/antioxidant power

The ferric reducing/antioxidant power (FRAP) assay was carried out according to a standard procedure by BENZIE and STRAIN [31]. All measurements were performed in triplicate. Aqueous solutions of $FeSO_4.7\ H_2O$ (0.1–1 $mmol{\cdot}l^{-1}$) were used to construct the calibration curve and the results were expressed as millimoles of Fe(II) per kilogram of dry matter.

Free radical-scavenging assay

The Trolox equivalent antioxidant capacity (TEAC) of fresh and treated pears was estimated by the ABTS radical cation-decolorization assay [32]. The results, obtained from triplicate analyses, were expressed as Trolox equivalents (millimoles of Trolox per kilogram of dry matter), and derived from a calibration curve determined for Trolox (0.1–1 $mmol{\cdot}l^{-1}$).

Sensory evaluation of dried pears

Consumer analysis of fresh and pre-treated and dried pears was conducted. The panellists (n = 40) were students and staff members of the Faculty of Food Technology and Biotechnology (University of Zagreb, Zagreb, Croatia), that had no or little previous experience in the assessment of dried pears. All panellists were selected according to the following criteria: a) absence of aversions, allergies or intolerance against pears, b) non-smokers, c) age of 22–65, d) normal perception abilities, e) availability for all sessions and f) interest in participating. The panellists were first given a brief introduction in the methodology, followed by discussing and clarifying particular attribute definitions.

For the experimental samples, 2 sessions in a period of one week were held. During each session, fresh pear and four different dried pear samples in random order were evaluated. All samples were evaluated in partitioned booths of sensory laboratory under white light illumination at room temperature. For the evaluation, three pieces of each dried pear per evaluator, which had been randomly selected from each treatment, were served at 20 °C in transparent vessels with lids (coded with random numbers) to avoid any loss of aroma or cross-contamination, and to protect the samples from humidification. Warm water was provided for rinsing between samples. A 9-point hedonic scale ranging from 1 = dislike extremely to 9 = like extremely was used to evaluate taste, colour, flavour, chewiness, crispness and overall acceptability of dried pears.

Statistical analysis

All measurements and analyses were carried out in triplicate. The results were analysed statistically using Statistica 7.0 computer programme (StatSoft, Tulsa, Oklahoma, USA) to determine the average value and standard deviation, and to perform correlation analysis. Variance analysis, with a significance level of α = 0.05%, was performed using Statistica 7.0 programme to determine the differences in the saccharide and phenolic contents due to different processing conditions. The significance was established using the Dunnett and Tukey post-hoc test, the probability level of $p < 0.05$ was considered significant.

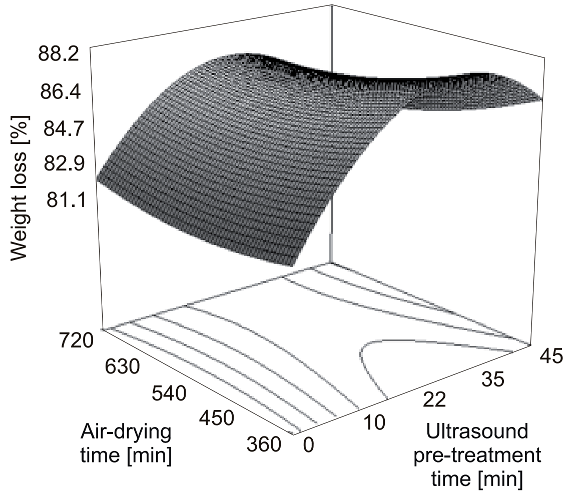

Fig. 1. Response surface plots of weight loss of fresh and dried pears affected by ultrasound pre-treatment and duration of air drying.

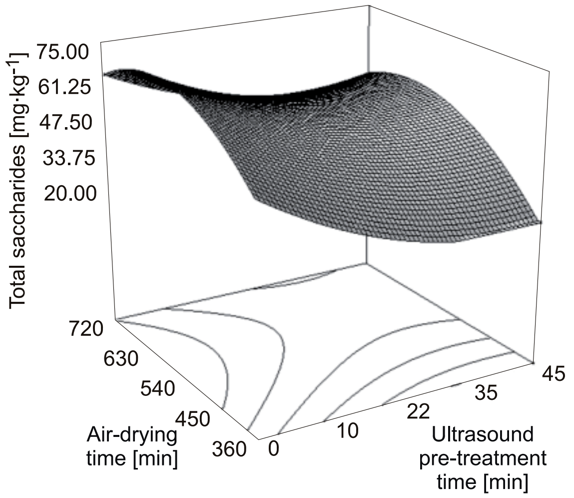

Fig. 2. Response surface plots of total saccharides content of fresh and dried pears affected by the ultrasound pre-treatment and duration of air drying.

Total saccharides are expressed as miligrams per kilogram of dry matter.

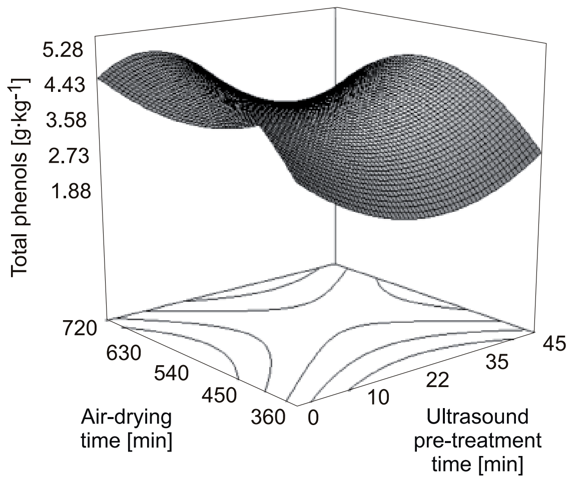

Fig. 3. Response surface plots of total phenol content of fresh and dried pears affected by the ultrasound pre-treatment and duration of air drying.

Total phenols are expressed as gallic acid equivalents per kilogram of dry matter.

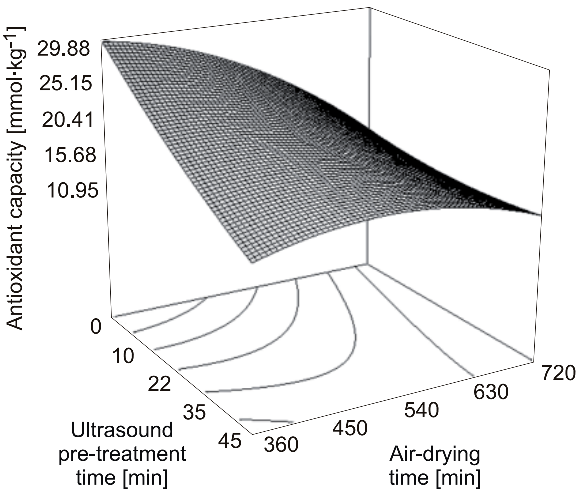

Fig. 4. Response surface plots of the antioxidant capacity determined by the ABTS assay of fresh and dried pears affected by the ultrasound pre-treatment and duration of air drying.

Antioxidant capacity is expressed as Trolox equivalents per kilogram of dry matter.

RESULTS AND DISCUSSION

By considering the weight loss of dried pears and their bioactive content as the responses in this study, the response surfaces obtained by comparing the processing parameters and the evaluated responses provided an insight in the effect of air drying and ultrasound pre-treatment duration, and helped to reveal the optimum combination of processing conditions in order to preserve the highest contents of nutritionally beneficial compounds. The response surface is a three-dimensional graphic that shows the influence of two variables in relation to the response. The estimated response surfaces (Fig. 1–4) confirmed that the ultrasound pretreatment and air drying time differently affected the investigated parameters of dried pears. According to Fig. 1, the ultrasound pre-treatment prolongation increased the weight loss of pears at low and medium levels of processing time, whereas at longer processing duration, the effect of weight loss was reduced. Also, it can be observed that air drying time had no significant influence on the weight loss of pears. It was previously established that deformation of porous solid materials, such as fruits, caused by ultrasonic waves is responsible for the creation of microscopic channels that reduce the diffusion boundary layer and increase the convective mass transfer in the fruit [33–35]. As a consequence, the fruit submitted to ultrasound pre-treatment will dry faster during the air drying stage compared to fresh fruit with no pre-treatment.

The results of our study reveal that prolongation of ultrasound pretreatment (considering the same air drying procedure) caused a significant water loss of the pears. In comparison to pears dried for 720 min without the pre-treatment, the pears submitted to 45 min of ultrasound pre-treatment and dried for the same time lost by 2.1% more water (Tab. 1). These findings were also observed by FUENTE-BLANCO et al. [35], who noticed that ultrasonic pre-treatment affected the fruit tissue making easier for the water to diffuse during air drying, and showed that the microscopic channels may contribute to higher water diffusivity.

According to the response surfaces, the content of total saccharides (Fig. 2) was also to a higher extent affected by the ultrasound pre-treatment time than the air drying time, since the highest total saccharides were observed in non-treated pears and pears treated by shorter ultrasound treatment. Fig. 3 and Fig. 4 show that air drying had a significant influence on both TPC and the antioxidant capacity determined by the ABTS method. Namely, by prolonging the air drying, a decrease in TPC and antioxidant capacity occured, while these parameters remained unchanged in pears submitted to short or medium durations of ultrasound treatment. Generally, the obtained response surfaces indicated that low or medium processing duration were optimal for obtaining dried fruits with a good nutritive quality.

Effect of ultrasound pre-treatment and air drying time on the content of saccharides

Since the content of saccharides is directly related to taste and sensory properties of a food product, and the content of bioactive compounds (in particular natural antioxidants) is being increasingly regarded as a nutritive parameter of a food, the contents of saccharides and polyphenolic compounds, as well as the antioxidant capacity of processed pears were evaluated in this study. The saccharides content of pears affected by the ultrasound pre-treatment and air drying is presented in Tab. 1. The saccharides of pears comprise fructose, sorbitol, saccharose and glucose [36, 37, 2]. In a study conducted by LI et al. [38], the average content of fructose, glucose and saccharose of fresh pear was 53.0 g·kg^{-1}, 42.0 g·kg^{-1} and 12.1 g·kg^{-1} as eaten, respectively, but the examined cultivar was not specified. Also, FOURIE et al. [36] found 53.6 g·kg^{-1} of fructose, 16.1 g·kg^{-1} of glucose and 13.9 g·kg^{-1} of saccharose in fresh pears, obtained as the mean values of six pear cultivars. The contents of fructose, glucose and saccharose in our study of "Abate Fetel" pear cultivar were 74.8 g·kg^{-1} of sample, 55.2 g·kg^{-1} of sample

Tab. 1. The effect of ultrasound pre-treatment and air drying duration on water and saccharides content of pear.

Ultrasound pre-treatment [min]	Drying time [min]	Water content [%]	Saccharides [mg·kg^{-1}]			Total saccharides [mg·kg^{-1}]
			Glucose	Fructose	Saccharose	
0	0 (fresh)	83.1 ± 1.2	326.91 ± 38.34	442.75 ± 18.98	52.05 ± 1.13	821.71
	360	11.3 ± 0.4	137.93 ± 11.42^{ab}	347.57 ± 18.21^{de}	12.06 ± 0.93^{j}	497.56
	720	9.1 ± 0.2	279.84 ± 22.45	324.38 ± 17.29^{fg}	24.87 ± 2.36^{k}	629.09
10	540	10.2 ± 0.4	199.25 ± 11.32	381.95 ± 15.28	9.73 ± 0.77^{jl}	590.93
22	540	9.7 ± 0.2	164.86 ± 15.11	316.94 ± 19.25^{h}	28.52 ± 2.32	510.32
	720	8.3 ± 0.1	173.61 ± 10.65	361.67 ± 07.42^{dfi}	23.46 ± 1.71^{kn}	558.74
35	540	8.8 ± 0.4	135.35 ± 7.64^{ac}	353.12 ± 22.02^{ei}	18.73 ± 1.15^{m}	507.10
45	360	10.0 ± 0.2	46.17 ± 7.73	135.67 ± 11.04	7.34 ± 0.26^{l}	189.18
	720	7.3 ± 0.2	133.12 ± 7.01^{bc}	322.52 ± 12.58^{gh}	20.61 ± 2.36^{mn}	476.25

Results are expressed as milligrams per kilogram of dry matter ± standard deviation.
The content of all saccharides is statistically significant ($p < 0.05$) in all samples when compared to control (fresh sample). Values superscripted with the same letter (a–n) are not significantly ($p > 0.05$) different.

and 8.8 g·kg^{-1} of sample (fresh pear), respectively, slightly higher than previously reported saccharide contents. According to our results, fructose predominated among saccharides, as well as among all analysed compounds; it was followed by glucose with about one half or third of the fructose content (Tab. 1), while the content of saccharose was the lowest. The content of saccharides, as well as other compositional characteristics of pears, depend primarily on the pear cultivar and the level of maturity [6, 37]. There are many studies examining the effects of harvest date, ripening or storage period on the nutritive composition of pears, which have determined a significant influence of cultivation practices, climatic conditions and genetic differences between pears on their quality characteristics [39, 40]. Taking these factors into consideration, it is not surprising that the content of saccharides cannot be directly compared to the results of other studies.

The content of fructose after the ultrasound pre-treatment and air drying was the highest in pears exposed to ultrasound for 10 min and air-dried during 540 min (381.95 mg·kg^{-1} of dry matter of sample), the content of glucose was the highest in pears dried for 720 min, without previous ultrasound treatment (279.81 mg·kg^{-1} of dry matter of sample), while the content of saccharose was the highest in pears after 22 min of ultrasound pre-treatment and 540 min of air drying (28.52 mg·kg^{-1} of dry matter of sample). It can be seen from Tab. 1 that the content of saccharides varies depended on the ultrasound pre-treatment and on drying conditions. According to the obtained results, duration of ultrasound pre-treatment and air drying significantly affected ($p < 0.05$) the content of fructose and glucose, while the content of saccharose did not differ significantly ($p > 0.05$) depending on the processing conditions. More specifically, the prolongation of ultrasound pre-treatment led to a higher saccharide loss. Similar effects were previously observed by Fernandes et al. [22,23], who also observed a saccharide loss at using the ultrasound pre-treatment for melon and papaya.

Effect of ultrasound pre-treatment and air drying time on the content of polyphenols

The overview of the scientific literature provides information about the polyphenolic content of fresh pears [5, 41–43], however, there is only one study on the polyphenolic content of dried pears [44]. Phenolic compounds contribute to colour and flavour but, during drying that is usually carried out at temperatures close to 80 °C, degradation of phenolics is very rapid, due to both enzymatic and thermal reactions that induce browning phenomena [45]. Moreover, evaporation of water and relocation of food components during drying add substantially to the mechanical strength of the material, making the extraction of some components difficult. Thus, it could be expected that a decrease in the polyphenolic content of dried pears would occur. Considerable research has been devoted to the influence of ultrasonic pre-treatment and air drying on the content of saccharides and polyphenols of fruit, but a clear explanation of the effect of drying on the phenolic content and antioxidant activity of fruit is lacking. The majority of research reported a decrease in the polyphenol content of dried fruits [44, 46, 47], although some authors observed a contradictory increase in the antioxidant capacity [48], however, no explanation was provided.

Fresh "Abate Fetel" pear evaluated in our study exhibited a TPC of 3.02 g·kg^{-1} of dry matter (expressed as GAE). In a study on the content of various fruit metabolites of fresh pear (cv. Anjou), the pulp contained 4.7 g of total polyphenols per kilogram on a dry weight basis, while the peel contained 13.4 g of total polyphenols per kilogram on a dry weight basis, the results being expressed as *p*-coumaric acid equivalents [42]. Although data on TPC of fresh pears were published, the results are difficult to compare with those obtained in our study, due to the different expression of results, mainly because of the use of different standard compounds, or different way of expression of the results.

Although our results are expressed on a dry matter basis, Ishiwata et al. [44] found 11.96 mg·kg^{-1} dry weight (expressed as GAE) of TPC in dried pears, which is considerably lower than in our study, but it was not clearly defined if the dried fruits were obtained from the same fresh fruits. As can be seen in Fig. 5, the highest TPC of the processed pears in our study was determined in non-treated pear dried for 720 min (4.33 g·kg^{-1} of dry matter, expressed as GAE), and the lowest TPC was determined in pear subjected to the longest ultrasound pre-treatment (45 min) and 360 min of air drying (2.70 g·kg^{-1} of dry matter, expressed as GAE). According to these results, the pears treated ultrasonically for a longer time (22, 35 and 45 min) exhibited a decrease in TPC, with regard to fresh pear. A higher TPC of pears pre-treated with ultrasound during 45 min and air-dried for 720 min can be explained by a more intensive loss of water due to the longer air drying. Also, as can be seen in comparison to fresh pear, an increase in TPC of pears without the ultrasound pre-treatment and those treated ultrasonically for 10 min and 22 min appeared. This can

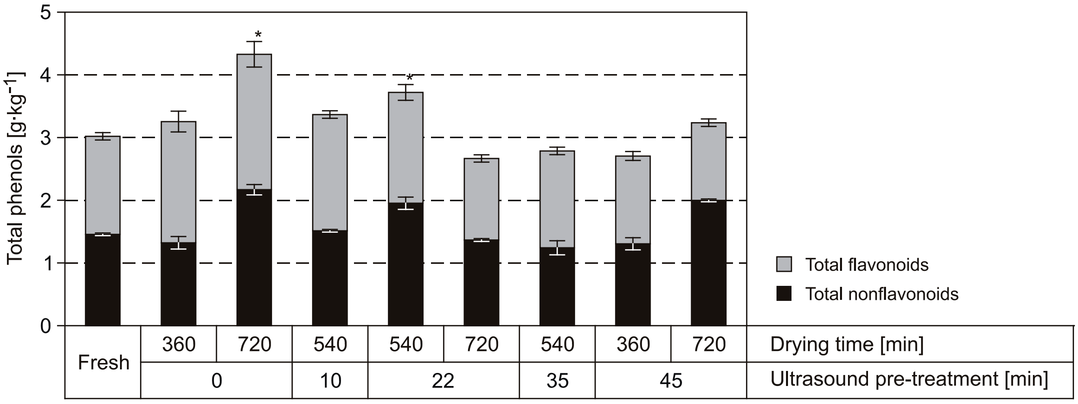

Fig. 5. Total non-flavonoid and flavonoid contents of fresh and treated pears.

Results are expressed as gallic acid equivalents per kilogram of dry matter ± standard deviation. The height of bars represents the total phenol content, obtained as the sum of flavonoids and non-flavonoids. Values of total phenol content superscripted with the same mark (*) are significantly ($p < 0.05$) different when compared to control (fresh sample).

be explained with the ununiformity of the sample used for the analysis. Namely it was previously mentioned that TPC of pears depends on the fruit part used, i.e. the fruit pulp and peel do not contain the same amounts of metabolite compounds. Thus, it could be that during sampling of the differently processed pears, an unequal distribution of pear pulp and peel was used for the extraction, resulting with some discrepancies among the results. Also, these results can be explained by the lack of selectivity of Folin-Ciocalteu reagent [49], which reacts not only with phenols but also with other reducing compounds such as carotenoids, amino acids, saccharides and vitamin C [50], which are known to be constituents of pears.

Total flavonoid content (TFC) and total non-flavonoid content (TNC) were in accordance with the previously observed TPC. No significant differences ($p > 0.05$) between TFC and TNC were determined, indicating an equal content of both, flavonoid and non-flavonoid constituents of pear, which is in agreement with its known composition. Regarding the content of saccharides, TPC, TFC and TNC, these were significantly ($p < 0.05$) affected by the duration of ultrasound pre-treatment and air drying. According to the results displayed in Fig. 5, 720 min of air drying without the pre-treatment was found to be the most efficient combination for delivering the highest TPC of pears. As previously mentioned, by increasing the duration of ultrasound treatment the tissue structure of pears is affected, which leads to a higher weight loss after air drying. According to the obtained results, the same structural appearances also influenced glucose, fructose and saccharose contents in our study, yielding lower contents in the treated samples. Such observations are analogical to those previously described in a study on the effect of ultrasound pre-treatment and air drying on apples [51], where it was also confirmed that longer ultrasound pre-treatment duration caused adverse effects on sensory and quality characteristics of dried apples. As previously mentioned, ultrasonic treatment leads to a physical disruption of the tissue structure [52]. Both cell walls and cell membranes are disrupted due to cavitation (implosion of gas bubbles within the material) causing particle size reduction, which increases the surface area in contact between the solid and the liquid phases. Therefore, ultrasound induces a better penetration of solvent into cellular materials, which improves mass transport rates within the tissue and facilitates the transfer of components from the cell into the solvent leading to the enhancement of the extraction operation [21, 53]. The results show that longer exposure of pears to ultrasound led to a better extraction efficiency of pear polyphenols, which were then degraded and decomposed during air drying.

Summarizing the obtained results it can be assumed that medium duration of ultrasonication, as a pre-treatment for air drying, can positively influence the polyphenol content of dried pears. Such observation implies that the consumption of dried pears may contribute to the intake of dietary polyphenols in an even greater extent than the fresh pears.

Effect of ultrasound pre-treatment and air drying time on the antioxidant capacity

As with the saccharides and polyphenols, all dried pears exhibited significant antioxidant ca-

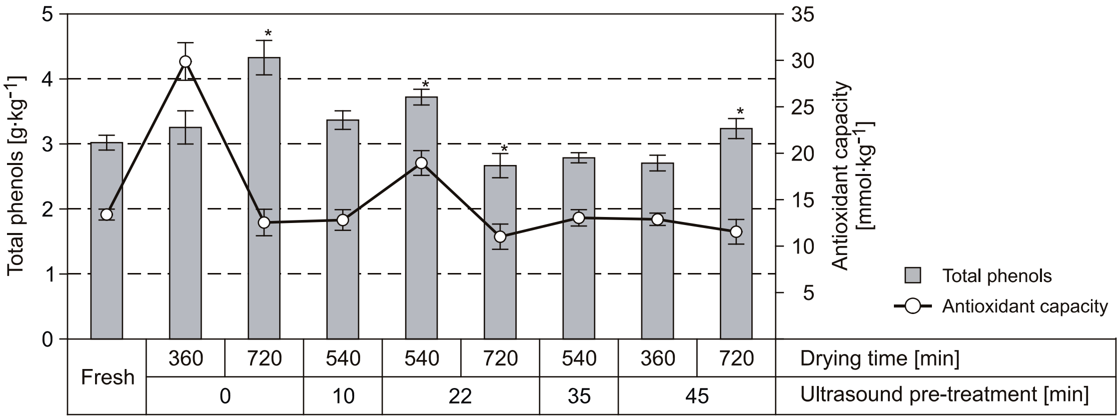

Fig. 6. Total phenols content and antioxidant capacity of fresh and treated pears determined by ABTS assay.

Results of antioxidant capacity are expressed as Trolox equivalents ± standard deviation (millimoles of Trolox per kilogram of dry matter). Values superscripted with the same mark (*) are significantly (p < 0.05) different when compared to control (fresh sample).

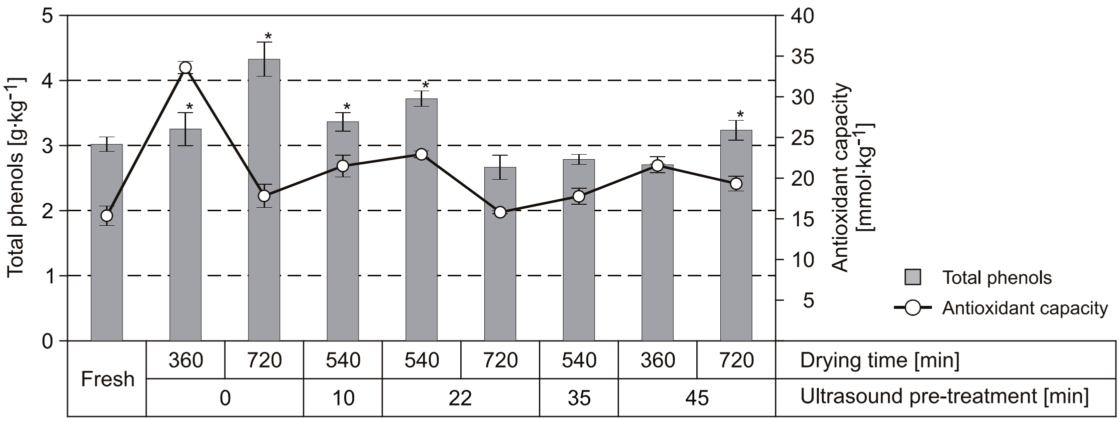

Fig. 7. Total phenol content and antioxidant capacity of fresh and treated pears determined by FRAP assay.

Results of antioxidant capacity are expressed as Fe(II) equivalents ± standard deviation (millimoles of Fe(II) per kilogram of dry matter). Values superscripted with the same mark (*) are significantly (p < 0.05) different when compared to control (fresh sample).

pacity, which was influenced by the ultrasound pre-treatment. According to our results, the antioxidant capacity of dried pears determined by ABTS assay (Fig. 6), was the highest in pears dried for 360 min without the ultrasound pre-treatment (29.88 mmol·kg^{-1} dry matter, expressed as Trolox equivalents). This was also confirmed by the reducing capacity according to FRAP assay (33.60 mmol·kg^{-1} dry matter, expressed as Fe(II); Fig. 7). In our study, the further prolongation of ultrasound pre-treatment (up to 45 min) as well as air drying time (720 min) significantly influenced the antioxidant capacity of pears. The prolongation of air drying to 720 min resulted in the lowest antioxidant properties of pears, determined by both assays. Some previously conducted studies stated a contradictory increase of antioxidant capacity of dried fruit, despite the decrease in polyphenolic content. In our study, an increase in the antioxidant capacity with regard to fresh pear was observed, but with significant fluctuations. Although a high linear correlation between the results of the two used antioxidant capacity assays was determined (r = 0.919), lower correlation coefficients were determined between the ABTS assay and TPC (r = 0.149), as well as between the FRAP assay and TPC (r = 0.130). According to Pinelo et al. [54], the increase in the antioxidant capacity may be explained by the strong tendency of polyphenols to undergo polymerization reactions, whereby the resulting oligomers possess larger areas available for charge delocalization.

These results can be explained by the previously stated lack of selectivity of the Folin-Ciocalteu reagent [49], which is known to overestimate the polyphenolic content. In addition, the ABTS radical-scavenging assay determines free antioxidants in food samples, whereas the assay of total phenols with the Folin-Ciocalteu reagent determines both free phenolics and bound phenolics [55].

Sensory analysis of dried pears

In order to obtain an insight in the effect of different pre-treatment and drying effects on the sensory attributes of final product, visual, olfactory and textural properties of dried pears were evaluated by consumers. Since taste, flavour and appearance are considered as the most significant sensory categories for describing a food product [56, 57], these attributes along with textural properties and overall acceptability were scored by consumers using a 9-point hedonic scale. Also, because the change in colour of the fruit caused by drying can reduce the marketability, the colour also has an important economic impact on the sensory characteristics of dried fruit. The means of scores for each attribute are presented in Tab. 2. According to the results of sensory analysis, significant differences ($p < 0.05$) were observed between the sensory properties of dried pears, depending on the duration of ultrasound pre-treatment and air drying. Generally, the lack of specific brownish colour, or the appearance of brown spots, followed by the loss of sweet taste and grainy mouth feel contributed to lower sensory acceptance of longer ultrasound pre-treated samples. Ultrasound pre-treatment for the longest time (35 min and 45 min), combined with longer drying periods, resulted in shrivelled pears (including splits and voids in the edible surface of the pear slice), which became hard and dark in colour.

Both ultrasound pre-treatment and air drying duration significantly influenced the sensory properties of dried pears, since the differences in the mean scores among different samples (pre-treated and dried for different times) were usually > 2 points. Fresh pear was rated with the highest score (9) for all sensory attributes, since it conforms to all sensory characteristics of fresh pears. Among the treated samples, pears pre-treated with ultrasound for 10 min and dried for 540 min were scored highest for all sensory properties. The overall acceptability of this sample amounted to high 8.14 points which signifies "like very much" in the used hedonic scale of 9 points. Prolongation of ultrasound pre-treatment negatively affected the colour, taste and flavour of dried pears, but textural properties were retained when the pears were dried for 720 min. Correspondingly, the pears treated ultrasonically for 45 min and air-dried during 720 min exhibited the lowest sensory scores and acceptability by the consumers. Among the non-treated samples, air drying duration also affected the sensory characteristics, since it was observed that longer drying time (720 min) yielded lower sensory acceptance of colour, taste and flavour, but better textural properties compared to shorter drying (360 min). Also, the assessors preferred pears dried during longer period (720 min),

Tab. 2. Mean scores of sensory attributes for pears affected by different pre-treatment and drying duration.

Ultrasound pre-treatment [min]	Drying time [min]	Colour	Taste	Flavour	Chewiness	Crispness	Overall acceptability
0	0 (fresh)	9	9	9	not evaluated	not evaluated	9
	360	6.26 ± 0.23^{ab}	7.09 ± 0.45^{fg}	6.45 ± 0.14^{l}	5.23 ± 0.25^{no}	5.45 ± 0.34^{r}	6.34 ± 0.37^{u}
	720	5.75 ± 0.12^{a}	6.63 ± 0.15^{fh}	6.25 ± 0.34^{l}	6.76 ± 0.45^{p}	6.26 ± 0.65^{s}	6.92 ± 0.41
10	540	6.83 ± 0.32^{b}	7.79 ± 0.38^{g}	7.12 ± 0.22	7.12 ± 0.14^{p}	8.06 ± 0.43	8.14 ± 0.63
22	540	4.12 ± 0.25^{c}	6.20 ± 0.33^{h}	5.04 ± 0.15	6.25 ± 0.27	5.12 ± 0.37^{r}	6.15 ± 0.13^{u}
	720	3.32 ± 0.17^{de}	4.96 ± 0.32^{ik}	3.28 ± 0.16^{m}	5.49 ± 0.23^{nq}	6.94 ± 0.17^{t}	4.89 ± 0.47^{v}
35	540	3.89 ± 0.08^{cd}	4.78 ± 0.17^{ij}	4.07 ± 0.25	5.20 ± 0.12^{oq}	6.23 ± 0.32^{s}	5.12 ± 0.34^{v}
45	360	3.26 ± 0.12^{e}	4.45 ± 0.26^{jk}	3.25 ± 0.27^{m}	4.53 ± 0.32	3.45 ± 0.27	3.49 ± 0.29
	720	2.21 ± 0.12	3.01 ± 0.04	2.63 ± 0.09	3.13 ± 0.18	6.87 ± 0.49^{t}	4.08 ± 0.31

The results are displayed as means ± standard deviation corresponding to scores from all consumer answers in a 9-point hedonic scale (1 – dislike extremely, 9 – like extremely).
The values of sensory attributes are statistically significant ($p < 0.05$) in all samples when compared to control (fresh sample).
Values superscripted with the same letter (a–v) are not significantly ($p > 0.05$) different.

and rated the overall acceptability of this pear with 6.92 points. Torregiani and Bertolo [58] postulated that the variations observed in the sensory properties of dried fruit may be linked to the nature of the raw material, its chemical composition, and/or its structure that influences the intensity of the mass transfer phenomena and other reactions leading to the formation of compounds involved in texture and flavour perception [58]. Since the results of our study confirmed that ultrasound pre-treatment and air drying affect both the saccharides content and polyphenolic compounds (contributing to taste and flavour) of pears, it seems that the nutritive parameters also influenced the final sensory characteristics of dried pears.

The results of this study may be aplicable to other pear cultivars, however, since the texture (structure), as well as the nutritive and bioactive composition of different pear cultivars varies, also due to seasonal differences (maturing time), further research on other cultivars is needed in order to determine the exact effect of this type of processing on their properties.

CONCLUSIONS

The present study provides a reliable information regarding the development of an economically acceptable process for the preservation of pears and production of dried pears. Using a combination of spectrophotometric methods, the effect of ultrasound pre-treatment and air drying on saccharides and polyphenolic contents of pears, as well as their antioxidant capacity and sensory properties were evaluated. The contents of fructose and glucose, as well as phenolic content and antioxidant capacity of pears, varied depending on the ultrasound pre-treatment duration. By increasing the ultrasound pre-treatment duration, saccharides content and TPC decreased, while the prolongation of ultrasound pre-treatment (up to 45 min) as well as air drying time (720 min) resulted in the worst antioxidant properties of pears, as determined by both assays. Consumer sensory analysis revealed that short ultrasound pre-treatment and medium drying duration may contribute to preserving the colour and flavour, as well as textural properties of dried pears. The obtained results may contribute to the improvement of process yields and production of dried fruits with predictable quality attributes.

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