The effect of Ultrasound Pre-Treatment and Air-Drying on the Quality of Dried Apples

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Abstract: In order to develop environmentally sound, energy inexpensive and well scalable drying techniques that maintain high quality of dried fruit, optimisation of integrated process (ultrasound and air-drying) in the production of dried apples was conducted. Selected quality parameters of fresh and dried apples (variety Goldparmâne) resulting from different duration of ultrasonic pre-treatment and air-drying were compared. Sugars were determined spectrophotometrically using an enzymatic method. Content of total phenols and flavonoids was determined spectrophotometrically with the Folin-Ciocalteau assay, while the antioxidant capacity was evaluated by using ABTS (2,2-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) and FRAP (Ferric Reducing/Antioxidant Power) assays. Sensory properties of dried apples were investigated according to the Quantitative Descriptive Analysis. In combination with the same air-drying conditions, prolonged ultrasound pre-treatment led to a decrease in total phenols and flavonoids, as well as in the antioxidant capacity of dried apples. Difference in drying time had no significant effect on the content of total phenols and flavonoids, as well as antioxidant capacity. The sample dried without the ultrasound pre-treatment was evaluated as the most sensory acceptable. The content of glucose and fructose correlated well with total phenols and flavonoids, as well as with antioxidant capacity of apple samples.

Keywords: fresh apple; dried apple; ultrasound and air-drying process; sensory properties; phenols; flanonoid; antioxidant capacity

INTRODUCTION

Air-drying is one of the most commonly used procedures in dried fruit production, with main disadvantages being prolonged duration and high energy consumption. Ultrasound pre-treatment influences the energy efficiency of the drying process, as well as the sugar content in final product due to the changes in fruit tissue. Previous studies on ultrasound pre-treatment revealed a decrease in sugar content (21%–52%), without influence on drying duration (Fabiano *et al.* 2008).

Besides size, shape, colour and taste of the fruit, a new quality parameter is becoming increasingly popular – a bioactivity of the fruit and its health promoting effect for the consumer (Schirrmacher & Schempp 2003). Polyphenols are a group of widespread bioactive compounds in food, responsible for the antioxidant capacity of fruits (Lee *et al.* 2003). Apples are a major source of polyphenols (Vinson *et al.* 2001), and they may help to protect against cardiovascular diseases, cancer, asthma and diabetes (Bendini *et al.* 2006). The content and composition of polyphenols in apples are important because of their contribution to the sensory quality of fresh fruit and processed apple products.

In the present study, the effect of ultrasound pretreatment and air-drying of apples was analysed. Changes in the sugar content during the treatment were also evaluated, as well as the content of phenolic compounds and their antioxidant activity.

MATERIALS AND METHODS

Sample preparation for ultrasound treatment and air-drying. Apples (*Malus domestica*, Goldparmâne variety) were supplied from local apple orchard (Sveti Ivan Zelina, Croatia). The apples were washed, depitted and cut into 8 mm thick slices.

Parameter optimisation. Experiment design was performed by using central composite design with two variables (Design Expert 6.0). Moisture content, apple porosity, mass of samples, drying temperature and air flow were found to be the variables which influenced the drying duration and thus had to be kept constant in order to minimise their impact on obtained results.

Ultrasound pre-treatments. According to the performed central composite design, the ultrasound pre-treatment times were 0, 9, 22.5, 45 and 54 minutes. Samples were treated in ultrasonic bath Elmasonic S 120, nominal power 200 W, frequency 37 kHz, and intensity 0.02–0.03 W/cm^3.

Air-drying. Samples were dried in an air-drying oven (Alaska FD 1250), nominal power 250 W, with vertical air flow and average air temperature 71.5°C. Room temperature was kept at 24.1°C with relative moisture at 37.7%. After 360, 540 and 720 min drying, weight loss of samples was calculated. In all samples content of sucrose, glucose and fructose was determined using the Megazyme enzymatic assay.

Total phenol and flavonoid content.Sample extracts were prepared (Scalzo *et al.* 2005) and total phenol and flavonoid content was determined spectrophotometrically (Kramling & Singleton 1969; Lachman *et al.* 1998). The results, obtained from triplicate analyses, were expressed as mg/g of gallic acid equivalents (GAE).

Antioxidant capacity .The Ferric Reducing/Antioxidant Power (FRAP) assay (Benzie & Strain 1996) and 2,2'-azinobis (3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) radical scavenging assay (Re *et al.* 1999) were used.

Quantitative descriptive analysis (QDA). Quantitative descriptive analysis of dried samples was conducted for texture and external appearance, using a nine level interval scale, as described by Radovanović and Popov-Raljić (2001).

RESULTS AND DISCUSSION

The effects of ultrasound pre-treatment and air-drying on weight loss, QDA evaluation and sugar content are presented in Table 1. Generally, samples with longer ultrasound treatment produced less acceptable sensory characteristics but higher weight loss, due to the changes in tissue structure. Same structural changes also influenced glucose, fructose and sucrose content, yielding lower contents in the treated samples. According to the results displayed on Figure 2 the highest TPC was determined in sample 9 (5.47 mg GAE/g). The lowest TPC was determined in sample 7 (3.38 mg GAE/g), which was subjected to the longest ultrasound pre-treatment and drying. The TFC was in accordance with

Table 1. Effects of ultrasound pre-treatment and air-drying on weight loss, QDA evaluation and sugar content

Sample	Ultrasound (min)	Air-drying (min)	Weight loss (%)	QDA		Sucrose	D-Glucose	D-Fructose
				texture	appearance	(g/100 g)		
Fresh	0	0	0	–	–	1.64 ± 0.23	1.27 ± 0.40	8.72 ± 0.70
1	22.5	540.0	83.40	8	5	9.21 ± 0.11	14.65 ± 1.06	35.47 ± 1.07
2	0	360.0	79.89	8	5	9.21 ± 1.12	12.57 ± 1.06	30.82 ± 1.07
3	22.5	795.0	83.89	5	8	8.05 ± 0.76	5.65 ± 1.60	40.59 ± 1.76
4	45.	720.0	85.96	7	7	12.49 ± 2.51	10.03 ± 1.20	32.45 ± 1.40
5	0	720.0	82.33	9	8	15.78 ± 1.72	11.65 ± 1.06	35.01 ± 1.45
6	9.0	540.0	83.85	8	4	9.86 ± 1.79	10.96 ± 1.44	31.75 ± 1.40
7	54.0	540.0	85.35	6	6	1.97 ± 0.37	10.96 ± 0.80	36.17 ± 2.24
8	45.0	360.0	82.61	6	3	8.41 ± 1.46	10.73 ± 0.69	30.82 ± 0.40
9	22.5	720.0	84.17	7	7	7.23 ± 0.93	13.72 ± 0.40	36.17 ± 1.76

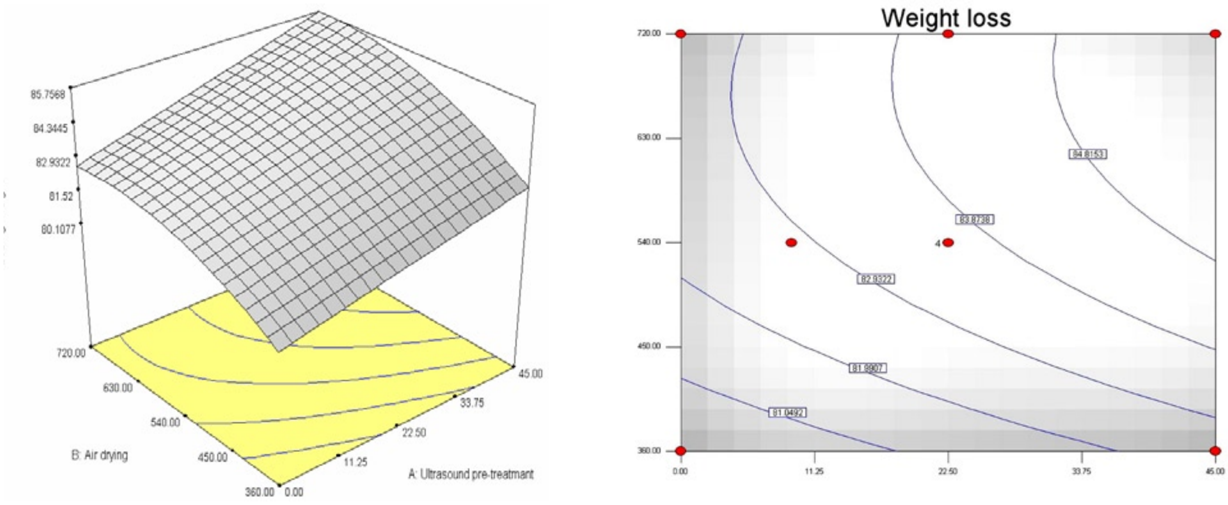

Figure 1. Influence of ultrasound pre-treatment and air-drying on weight loss

the previously observed TPC content. The TPC of the fresh apple was 6.1-fold lower than the average TPC of dried apples. Antioxidant capacity can be predicted based on the phenolic content (Katsube *et al*. 2004). Results obtained in this study are in compliance with this statement – antioxidant capacity of dried apples determined by ABTS assay (Figure 3), was the highest in the sample 9, and the lowest in sample 4, while results obtained from FRAP assay (Figure 3), were the highest in sample 9 and the lowest in sample 7. The results show that ultrasound pre-treatment influenced the observed sugar content and bioactive compounds as well as their antioxidant activity.

Quadratic model was chosen to describe the relationship between ultrasound pre-treatment, air-drying and weight loss of apples. The chosen model showed (R^2 = 0.9145) a good correlation between the parameters (Figure 1). In order to find the best combination of ultrasound pre-treatment and air-drying time for minimal energy consumption, process optimisation was performed. For all combinations of input parameters with desirability 1, the combination of 24.5 min of ultrasound pre-treatment and 467.51 min of air-drying showed to be the best combination for an energy efficient process. This combination is comparable to the one performed in sample 1 (22.50 min ultrasound pre-treatment and 540 min air-drying), which exhibited high total sugar content and good antioxidant properties.

CONCLUSION

There is a growing demand for processed and semi processed fruits, which can help to improve the fruit industry and make it more competitive.

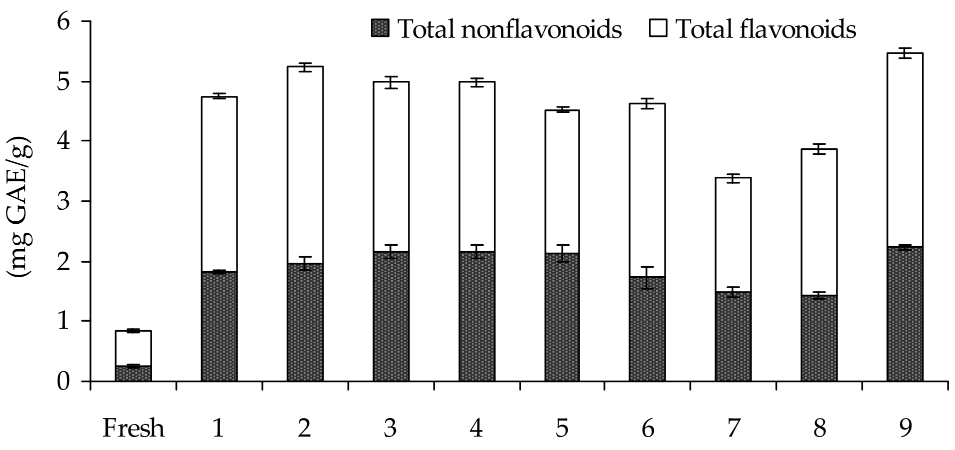

Figure 2. Total nonflavonoid and flavonoid content (mg GAE/g) of fresh and dried apples

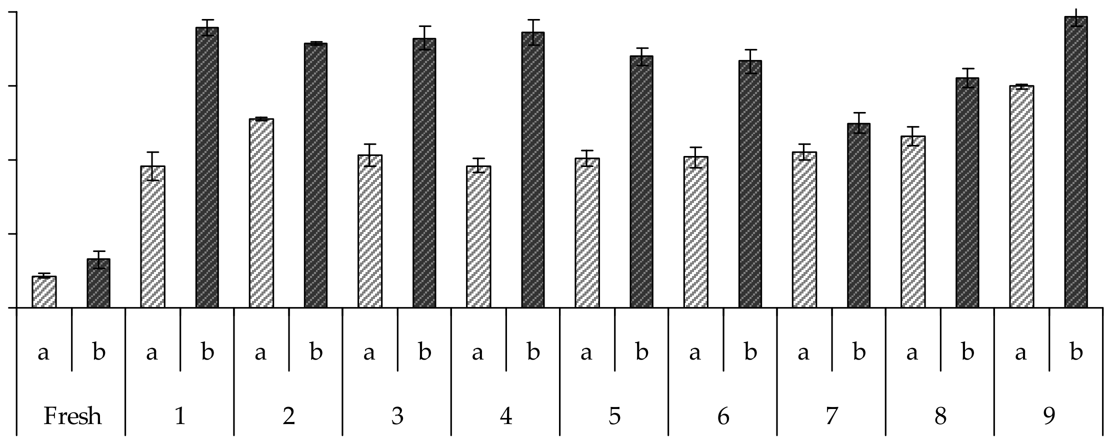

Figure 3. Antioxidant capacity of fresh and dried apples evaluated by ABTS (**a**/mM Trolox) and FRAP (**b**/mM Fe(II)) assays

Our study demonstrated the effect of ultrasound pre-treatment and air-drying on sugar content, bioactive compounds, antioxidant capacity and sensory properties in the processing of dried apples. Ultrasound pre-treatment combined with longer air-drying results with higher weight loss, but leads to a decrease in polyphenolic content and antioxidant capacity of dried apples. Therefore, more research is necessary to obtain a product with acceptable sensory characteristics and improved quality, especially with regard to bioactive compounds.

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