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# ANTIOXIDANT CAPACITY, TOTAL PHENOLIC COMPOUNDS AND FATTY ACIDS COMPOSITION IN WALNUT OIL AND BAGASSE PELLETS PRODUCED AT DIFFERENT PARAMETERS OF THE SCREW PRESS

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## Abstract

Different rotational speeds and nozzle diameters of screw press were used to process walnut kernels. To evaluate the influence of pressing conditions on the quality of walnut oil and bagasse pellets the oil pressing temperature, yield of oil, total phenolic compounds, antioxidant capacity and fatty acid composition were measured. The results show that the pressing at different conditions affected the antioxidant capacity and TPC of either bagasse pellets and pressed oil. Higher values of antioxidant capacity and TPC were measured in bagasse pellets than in pressed oils. Higher amount of pressed oil was yielded by using lower nozzle diameter, however, by lowering the nozzle diameter the oil pressing temperature was rising, which affected the fatty acids. Positive correlations with oil pressing temperatures were calculated at saturated fatty acids, while the correlation coefficients of polyunsaturated fatty acids were positive, but not significant. Monounsaturated fatty acids were negatively affected by higher oil pressing temperatures showing, that monounsaturated fatty acids were more susceptible to higher temperatures than polyunasturated and saturated fatty acids.

Keywords: antioxidant capacity, total phenolic compounds, fatty acids, walnut oil, bagasse pellets, screw press

## INTRODUCTION

Walnut kernels are consumed worldwide, fresh or as an industrially modified product or their secondary products as an ingredient in the food. In 2013 walnut trees were grown on area of 1 million hectares worldwide. The biggest producers are the USA and China (FAO, 2016).

The most valuable parts of the walnut tree are the kernels. Regular consumption of walnuts reduces the risk of diabetes (Kendall *et al.,* 2011), has positive effect on brain function (Hou *et al.,* 2014) and reduces the amount of cholesterol in the blood (Kodad *et al.,* 2016; Uzunova *et al.,* 2015; Avanzato, 2010; Park *et al.,* 2008).

Walnut kernels have high oil content varying from 52 to 72% (Poggetti *et al.,* 2017; Slatnar *et al.,* 2015; Labuckas *et al.,* 2014; Martínez *et al.,* 2006; Zwarts *et al.,* 1999). One of the uses of walnut kernels is the production of edible oil, which has high positive sensory properties by consumers and is a well known nutrient-rich food mainly due to its profile of fatty acids with antioxidant capacity and phenolic compounds (Burg *et al.,* 2017; Slatnar *et al.,* 2015; Özcan, 2009). Walnuts have elevated levels of positive omega-6 and omega-3 fatty acids. Contained phenolic compounds are significant constituents owing to their scavenging competence on free radicals (Kaur *et al.,* 2015; Slatnar *et al.,* 2015).

Oil from walnut kernels can be produced by three technologies, mechanical extraction (pressed oil), chemical or solvent extraction and supercritical $CO_2$ extraction (Singh and Bargale, 2000). The extraction by mechanical screw presses is typical for lower proportion of collected oil, which on the other hand is high-quality and contain bioactive compounds (Ezeh *et al.,* 2016; Ling *et al.,* 2016; Sena-Moreno *et al.*, 2016; Wang, 2016; Mridula *et al.,* 2015; Savoire *et al.,* 2013).

The yield of oil from kernels by pressing is approximately 46%, whereas the rest, around, 12% of oil stays in the bagasse pellets. Bagasse pellets are due to oil remainings and other biologically active compounds used, for example, in food industry for flour production (Bakkalbasi *et al.,* 2015).

The quality and the composition of positive substance depends on gentle and fast pressing process, pressing temperature and avoiding of photo-oxidative degradation (Slatnar *et al.,* 2015), however, Gharibzahedi *et al.* (2013) concluded that the fatty acid content was not influenced by extraction method.

The aim of the presented study was to evaluate the influence of different parameter settings of screw press on the quality, namely content and composition of fatty acids, antioxidant capacity and total phenolic content of pressed oil and bagasse pellets.

## MATERIALS AND METHODS

### Walnut Kernels

Walnut kernels originating in the Czech Republic were purchased in the supermarket chain, mixed together vacuum-packed and stored at 4 °C in dark place. Prior pressing, the water content in the kernels was assessed (2.95 ± 0.21%). Kernels were ground in a stainless-steel mill to the fraction of the size from 0 mm to 6 mm. Then, the material was pressed.

### Screw Press Parameters

The screw press type UNO FM 3F (Farmet a. s., Česká Skalice, Czech Republic) was used for experimental measurements. This model is suitable for pressing all kinds of oilseeds. The drive is configured for three-phase voltage with variable speed of the main drive using a frequency converter, which enables better optimization of pressing parameters. The press components are: an electric motor (1.5 kW power), transmission, pressing device, motor starter and frequency converter (allows precise adjustment of revolutions per minute – rpm). The screw rotation speed was adjusted on 30, 50, 70 and 90 rpm. The pressing device components were: a matrix, 220 mm screw, head, heating mantle, nozzle holder and nozzles with different diameters (6 mm, 8 mm and 10 mm). The variants were then combinations of different rotational speeds (30, 50, 70 and 90 rpm) and different nozzle diameters (6 mm, 8 mm and 10 mm).

### Oil Temperature

The oil temperature was measured directly on the press head by Testo 176 T4 – Temperature data logger (Testo SE & Co. KGaA, Glen Marais, Republic of South Africa) with stainless steel food probe.

### Determination of the Total Fat Content in the Walnut Kernels and Bagasse Pellets

To determine the total fat content, the Soxhlet extractor with hexane as a solvent was used. Samples of kernels were taken immediately prior to the oil extraction and the bagasse pellets were taken directly after the pressing. The samples were grinded by the IKA MF 10 basic (IKA-Works, Staufen, Germany) grinder using the 3 mm sieve. Emphasis was always taken on precise cleaning of the grinder in order to avoid distortion of the results. The temperature of the extraction mixture was kept by the heating mantle closely around the boiling point of hexane (70 °C). Extraction was carried out for 8 hours. Subsequently, the hexane was evaporated on the vacuum evaporator IKA RV 10 Control (IKA-Works, Staufen, Germany) at the pressure of 200 kPa until the hexane was evaporated. After that, the pressure was lowered down to 60 kPa for another 2 hours at the constant temperature of 40 °C. The weight of total fat was then measured by KERN EG 2200-2NM (Kern & Sohn, Balingen, Germany).

### Analysis of Fatty Acids

The preparation for fatty acids analysis was performed by transesterification. The oil samples from pressed oil, oil extracted from bagasse pellets or kernels was dissolved in 2 ml of isooctane and homogenized in ultrasound. After adding 2 ml of methanol sodium, the mixture was heated under condenser for 5 minutes. Subsequently, 2 ml $BF_3$ was added (through the cooler) and the mixture was heated again under the same condenser for another 5 minutes. After that, 2 ml of isooctane was added to the mixture, shook and left for 1 minute to settle down. At the very end, 5 ml of saturated sodium chloride solution was added.

The analysis of fatty acids was performed on the gas chromatograph HP 4890D (Hewlett Packard, USA) with a flame ionizing detector (GC-FID). The separation was performed on column DB-23 (60 m × 0.25 mm × 0.25 μm). Every sample was measured in triplicates.

### Total Phenolic Compounds (TPC) and Antioxidant Capacity (DPPH Radical Scavenging)

The preparation to determine the antioxidant capacity and total phenolic compounds in kernels and each sample of pressed oil and bagasse pellets was as follows: 0.5 g of sample was weighed while and extracted into 7.5 ml of 50% methanol, sonicated for 60 min at the room temperature and then centrifuged at 16 100 g for 20 min at 4 °C. After centrifugation, the methanol phase was removed.

The analysis of antioxidant capacity was determined using 1,1-diphenyl-2-picrylhydrazyl (DPPH) and the test was performed on the spectrophotometer Boeco S-200 (Boeco, Hamburg, Germany) where the absorbance at the wavelength of 534 nm was measured. The result was calculated to mg of Trolox equivalent activity (TEA) per gram of sample. Every sample was measured in triplicates.

The analysis of total phenol content was performed on the spectrophotometer Boeco S-200 (Boeco, Hamburg, Germany) where the absorbance at the wavelength of 660 nm was measured. The result was calculated to mg of gallic acid equivalent (GAE) per gram of sample. Every sample was measured in triplicates.

### Statistical Analysis

As determinations were done in triplicate the data were reported as means ± standard deviation. Analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) tests were conducted to determine the differences with the statistical significance at $p \leq 0.05$. Further correlation coefficients were calculated between the content of fatty acids and oil pressing temperatures with the statistical significance at $p \leq 0.05$. Statistical analyses were performed by the software Statistica 12.0 (StatSoft Inc., Tulse, USA).

## RESULTS AND DISCUSSION

### Yield of Oil and Oil Temperature

The total oil content was 0.70 kg oil/kg kernels (Tab. I). The oil yield of different nozzle diameters and rotational speed ranged from 0.12 to 0.41 kg oil/kg kernels. The highest yields were performed by the 6 mm nozzle diameter (0.33–0.41 kg oil/kg kernels) while the lowest yields were performed by the 10 mm nozzle diameter (0.12–0.28 kg oil/kg kernels). The rotational speed influenced the yield as well, showing higher yields of oil at lower speeds and lower yield at higher speeds. The lowest yield was then performed by using 10 mm nozzle diameter at 90 rpm (0.12 kg oil/kg kernels) and the highest yield by using 6 mm nozzle diameter at 30 rpm (0.41 kg oil/kg kernels).

The oil temperature during pressing reached 38.33 to 63.67 °C (Tab. I). Again the highest temperatures were recorded when the 6 mm nozzle diameter was used. At other nozzle diameters, the temperatures were similar and ranged from 38.33 to 55.33 °C. Results show, that at 90 rpm the oil temperatures were the lowest, however, at 6 mm nozzle diameter, the data for 90 rpm are missing as the press could not process the kernels.

### Total Phenolic Compounds (TPC)

The TPC of kernels was 140.59 ± 4.59 mg of gallic acid equivalent (GAE)/g (Tab. I). After pressing, all oils had lower TPC than of the kernels, while all bagasse pellets, except for 10 mm nozzle diameter at 30 rpm, had higher TPC showing that the phenolic compounds were concentrated predominantly in the solid phase. According to Slatnar *et al.* (2015), the majority of phenolic compounds of walnut kernels are located in the skin of the kernel.

The results also showed that the TPC in pressed oils was increasing with the rotational speed, where at all nozzle diameters the highest TPC was measured at oils produced at 90 rpm or 70 rpm at 10/8 mm and 6 mm nozzle diameter, respectively (Tab. I). The highest TPC had oil produced at 6 mm nozzle diameter at 90 rpm (116.72 ± 3.81 mg GAE/g), while the TPC of oil pressed at 8 mm nozzle diameter at 30–70 rpm were zero (Tab. I).

There was no effect of rotational speed on the TPC in bagasse pellets. However, the highest TPC was measured in bagasse pellets produced by 6 mm nozzle diameter at 30 rpm (203.88 ± 6.66 mg GAE/g) and the lowest by 10 mm nozzle diameter at 30 rpm (138.65 ± 4.53 mg GAE/g) (Tab. I).

### Antioxidant Capacity (DPPH Radical Scavenging)

The antioxidant capacity of kernels was 232.02 ± 7.58 mg Trolox equivalent activity (TEA)/g (Tab. I). After pressing, all oils had significantly lower antioxidant capacity than of the kernels and ranged from 46.51–50.59 mg TEA/g, with no significant difference between each other (Tab. I). There was no effect of rotational speed on the antioxidant capacity of oils.

The antioxidant capacity of bagasse pellets ranged from 205.58–241.16 mg TEA/g (Tab. I). The antioxidant capacity of bagasse pellets produced at 8 and 10 mm nozzle diameter were lower, significantly only at the bagasse pellets produced at 10 mm nozzle diameter at 50 rpm, than the antioxidant capacity of the kernels. Higher antioxidant capacity than of the kernels was measured at bagasse pellets produced by 6 mm nozzle diameter, however with no significant differences (Tab. I).

I: *Values of oil yield, oil pressing temperature, antioxidant capacity and total phenolic content of pressed oil and bagasse pellets produced at different nozzle diameters and rotational speeds of a screw press*

| Nozzle diameter (mm) | Rotational speed (rpm) | Yield (kg oil/kg kernel) | Oil temp. (°C) | Antioxidant Capacity (DPPH) (mg TEA/g) | | Total Phenolic Content (mg GAE/g) | |
|---|---|---|---|---|---|---|---|
| | | | | Pressed oil | Bagasse pellets | Pressed oil | Bagasse pellets |
| 10 mm | 30 | 0.28 | 55.33 | 48.41 ± 1.58$^{a}$ | 227.72 ± 7.44$^{abc}$ | 25.95 ± 0.85$^{a}$ | 138.65 ± 4.53$^{a}$ |
| 10 mm | 50 | 0.24 | 49.33 | 46.51 ± 1.52$^{a}$ | 205.58 ± 6.71$^{a}$ | 36.80 ± 1.2$^{b}$ | 157.42 ± 5.14$^{ab}$ |
| 10 mm | 70 | 0.16 | 41.33 | 47.21 ± 1.54$^{a}$ | 213.09 ± 6.96$^{ab}$ | 51.66 ± 1.69$^{c}$ | 156.40 ± 5.11$^{ab}$ |
| 10 mm | 90 | 0.12 | 38.33 | 49.68 ± 1.62$^{a}$ | 217.18 ± 7.09$^{abc}$ | 82.59 ± 2.70$^{d}$ | 175.28 ± 5.72$^{bc}$ |
| 8 mm | 30 | 0.27 | 48.00 | 50.59 ± 1.65$^{a}$ | 207.46 ± 6.78$^{ab}$ | 0.00 ± 0 | 186.12 ± 6.08$^{cd}$ |
| 8 mm | 50 | 0.31 | 55.33 | 48.93 ± 1.60$^{a}$ | 211.81 ± 6.92$^{ab}$ | 0.00 ± 0 | 184.97 ± 6.04$^{cd}$ |
| 8 mm | 70 | 0.20 | 40.67 | 44.78 ± 1.46$^{a}$ | 208.13 ± 6.80$^{ab}$ | 0.00 ± 0 | 155.63 ± 5.08$^{ab}$ |
| 8 mm | 90 | 0.15 | 38.33 | 45.77 ± 1.49$^{a}$ | 207.75 ± 6.79$^{ab}$ | 75.21 ± 2.46$^{d}$ | 179.03 ± 5.85$^{c}$ |
| 6 mm | 30 | 0.41 | 58.33 | 48.90 ± 1.60$^{a}$ | 241.16 ± 7.88$^{c}$ | 43.14 ± 1.41$^{b}$ | 203.88 ± 6.66$^{de}$ |
| 6 mm | 50 | 0.38 | 62.00 | 46.91 ± 1.53$^{a}$ | 240.24 ± 7.85$^{c}$ | 40.82 ± 1.33$^{b}$ | 157.57 ± 5.15$^{ab}$ |
| 6 mm | 70 | 0.33 | 63.67 | 49.51 ± 1.62$^{a}$ | 239.54 ± 7.82$^{c}$ | 116.72 ± 3.81$^{e}$ | 221.58 ± 7.24$^{e}$ |
| Kernels | | 0.70[1] | | 232.02 ± 7.58$^{b/b}$* | | 140.59 ± 4.59$^{f/a}$* | |

Values are means±standard deviations of a triplicate measurements. Alphabetical superscripts indicate significant differences ($P < 0.05$) among values in columns. rpm: revolution per minute; TEA: trolox equivalent activity; GAE: gallic acid equivalent; [1] kg of oil per kg of kernels determined by extraction with organic solvent (hexane); * letter/letter in superscript means statistical result among pressed oil/bagasse pellets

Higher antioxidant capacity in bagasse pellets can be contributed to high values of TPC (Gunduc and El, 2003), however, the lower but constant values of antioxidant capacity of pressed oils can be contributed to other compounds diluted in the oils such as tocopherols (Arranz *et al*., 2008).

## Fatty Acids Composition

Linoleic, vaccenic, alfa-linolenic, palmitic and stearic acids were the predominant fatty acids in the kernels, pressed oil and the bagasse pellets (Tab. II and III), which confirms the results of Maguire *et al*. (2004).

The highest content of pressed oils and oils extracted from bagasse pellets was represented by polyunsaturated fatty acids (PUFA) which ranged from 71.75 to 72.24% (Tab. II) and from 71.85 to 72.64% (Tab. III), respectively, whereas the PUFA content in oil extracted from kernels represented 72.88%, showing slightly higher value than of the PUFA in pressed oils and oils from bagasse pellets.

The monounsaturated fatty acids (MUFA) and saturated fatty acids (SFA) in pressed oil represented from 18.75 to 19.41%; and 8.81 to 9.00%, respectively, whereas the MUFA and SFA content in oil extracted from kernels was 18.40 and 8.71%, respectively, showing lower values than MUFA and SFA content in pressed oil (Tab. II). The MUFA and SFA in oil extracted from bagasse pellets ranged from 17.96 to 19.20% and 8.86 to 9.06%, respectively (Tab. III). Content of SFA in oils extracted from bagasse pellets was higher than of the oil extracted from the kernels. The same situation was observed at MUFA, however in oils extracted from bagasse pellets produced at 6 mm nozzle diameter at 50 and 70 rpm the MUFA content was lower than of the oil extracted from kernels (Tab. III).

Eicosaenoic and eicosatetraenoic acids were the only fatty acids, where no significant differences were observed between pressed oil variants or oils extracted from bagasse pellets variants (Tabs. II and III). Except for the linoleic and alfa-linolenic acids, the concentrations of the other fatty acids in oil extracted from kernels were in the lower range than the concentrations of the same fatty acids in pressed oils and oils extracted from bagasse pellets.

## Relation of the Oil Pressing Temperature and Fatty Acid Content

Correlation between the oil pressing temperature and the fatty acid content was calculated to stress out the influence of the temperature on the oil quality. Not all fatty acids showed significant correlation with the increasing oil pressing temperature. Among pressed oils, significant moderate positive correlation with oil pressing temperature was observed at palmitic (0.513) and adrenic (0.456) acid and significant moderate negative correlation at linoleic acid (-0.581) (Tab. IV).

Higher number of significant correlations were observed at oils extracted from bagasse pellets, where significant positive moderate correlation was observed at myristic (0.691), palmitoleic (0.501), stearic (0.678), vaccenic (0.579), gamma-linolenic (0.509), eicosaenoic (0.539) and adrenic (0.680) acid and significant negative moderate correlation was

II: *Fatty acid composition of pressed oil produced at different nozzle diameters and rotational speeds of a screw press*

| | Nozzle diameter (mm) | 10 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 6 | 6 | 6 | Kernels[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rotational speed (rpm) | 30 | 50 | 70 | 90 | 30 | 50 | 70 | 90 | 30 | 50 | 70 | |
| Fatty acid composition (%) (v/w) | C14:0/myristic | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{a}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{bc}$ | 0.03 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{abc}$ |
| | C16:0/palmitic | 6.47 ± 0.01$^{bc}$ | 6.35 ± 0.00$^{ab}$ | 6.36 ± 0.02$^{ab}$ | 6.35 ± 0.01$^{ab}$ | 6.43 ± 0.01$^{abc}$ | 6.31 ± 0.01$^{a}$ | 6.41 ± 0.01$^{abc}$ | 6.31 ± 0.02$^{a}$ | 6.39 ± 0.03$^{ab}$ | 6.41 ± 0.07$^{abc}$ | 6.54 ± 0.02$^{c}$ | 6.30 ± 0.09$^{a}$ |
| | C16:1n7/ palmitoleic | 0.08 ± 0.00$^{cdef}$ | 0.08 ± 0.00$^{ab}$ | 0.08 ± 0.00$^{abcd}$ | 0.08 ± 0.00$^{abcde}$ | 0.08 ± 0.00$^{bcdef}$ | 0.08 ± 0.00$^{abc}$ | 0.08 ± 0.00$^{cdef}$ | 0.08 ± 0.00$^{bcdef}$ | 0.08 ± 0.00$^{ef}$ | 0.08 ± 0$^{cdef}$ | 0.08 ± 0.00$^{def}$ | 0.07 ± 0.00$^{a}$ |
| | C18:0/stearic | 2.47 ± 0.01$^{de}$ | 2.49 ± 0.01$^{ef}$ | 2.46 ± 0.00$^{cd}$ | 2.43 ± 0.00$^{b}$ | 2.40 ± 0.00$^{ef}$ | 2.50 ± 0.00$^{f}$ | 2.47 ± 0.00$^{def}$ | 2.47 ± 0.00$^{de}$ | 2.44 ± 0.00$^{bc}$ | 2.45 ± 0.02$^{bcd}$ | 2.43 ± 0.00$^{b}$ | 2.38 ± 0.01$^{a}$ |
| | C18:1n7/vaccenic | 18.09 ± 0.01$^{cde}$ | 18.32 ± 0.00$^{de}$ | 18.07 ± 0.01$^{bcd}$ | 18.00 ± 0.01$^{cde}$ | 18.11 ± 0.00$^{cde}$ | 18.35 ± 0.01$^{e}$ | 18.04 ± 0.01$^{cde}$ | 18.18 ± 0.00$^{cde}$ | 18.28 ± 0.01$^{cde}$ | 17.95 ± 0.04$^{bc}$ | 17.68 ± 0.01$^{ab}$ | 17.38 ± 0.34$^{a}$ |
| | C18:1n9C/oleic | 0.79 ± 0.00$^{b}$ | 0.79 ± 0.00$^{b}$ | 0.79 ± 0.00$^{bcd}$ | 0.79 ± 0.00$^{b}$ | 0.80 ± 0.00$^{bcde}$ | 0.79 ± 0.01$^{bc}$ | 0.81 ± 0.00$^{de}$ | 0.81 ± 0.00$^{cde}$ | 0.81 ± 0.00$^{e}$ | 0.81 ± 0.01$^{de}$ | 0.81 ± 0.00$^{e}$ | 0.77 ± 0.00$^{a}$ |
| | C18:2n6C/linoleic | 59.94 ± 0.00$^{abc}$ | 59.98 ± 0.00$^{bc}$ | 60.10 ± 0.02$^{de}$ | 60.23 ± 0.01$^{f}$ | 60.02 ± 0.02$^{cd}$ | 59.98 ± 0.01$^{abc}$ | 59.95 ± 0.01$^{abc}$ | 60.17 ± 0.00$^{ef}$ | 59.88 ± 0.03$^{a}$ | 59.91 ± 0.02$^{ab}$ | 60.10 ± 0.03$^{de}$ | 60.74 ± 0.08$^{g}$ |
| | C18:3n6/gamma-linolenic | 0.05 ± 0.00$^{b}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{ab}$ |
| | C18:3n3/alfa-linolenic | 11.70 ± 0.01$^{abc}$ | 11.54 ± 0.00$^{ab}$ | 11.73 ± 0.01$^{cde}$ | 11.70 ± 0.01$^{bcd}$ | 11.58 ± 0.01$^{bc}$ | 11.54 ± 0.01$^{ab}$ | 11.69 ± 0.01$^{bcd}$ | 11.37 ± 0.00$^{a}$ | 11.53 ± 0.01$^{ab}$ | 11.80 ± 0.01$^{de}$ | 11.81 ± 0.01$^{de}$ | 11.90 ± 0.17$^{f}$ |
| | C18:4n3/ stearidonic | 0.09 ± 0.00$^{c}$ | 0.08 ± 0.00$^{a}$ | 0.09 ± 0.00$^{ab}$ | 0.08 ± 0.00$^{a}$ | 0.09 ± 0.00$^{abc}$ | 0.08 ± 0.00$^{ab}$ | 0.09 ± 0.00$^{abc}$ | 0.09 ± 0.00$^{abc}$ | 0.09 ± 0.00$^{abc}$ | 0.09 ± 0.00$^{bc}$ | 0.09 ± 0.00$^{ab}$ | 0.09 ± 0.00$^{abc}$ |
| | C20:1/ eicosaenoic | 0.18 ± 0.00$^{a}$ | 0.18 ± 0.00 $^{a}$ | 0.18 ± 0.01$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.19 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.19 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ |
| | C20:4n3/ eicosatetraenoic | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ |
| | C20:5n3/ Eicosapentaenoic | 0.00 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{abc}$ | 0.00 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{bc}$ | 0.01 ± 0.00$^{c}$ | 0.00 ± 0.00$^{a}$ | 0.00 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{abc}$ | 0.00 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{abc}$ | 0.00 ± 0.00$^{ab}$ |
| | C22:4n6/adrenic | 0.03 ± 0.01$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.04 ± 0.03$^{a}$ | 0.02 ± 0.01$^{a}$ | 0.04 ± 0.01$^{a}$ | 0.12 ± 0.02$^{b}$ | 0.14 ± 0.04$^{b}$ | 0.12 ± 0.01$^{b}$ | 0.11 ± 0.03$^{b}$ | 0.03 ± 0.00$^{a}$ |
| | C22:5n6/ docosapentaenoic | 0.01 ± 0.00$^{ab}$ | 0.03 ± 0.01$^{bcd}$ | 0.02 ± 0.00$^{ab}$ | 0.02 ± 0.00$^{ab}$ | 0.02 ± 0.01$^{abc}$ | 0.02 ± 0.01$^{abc}$ | 0.05 ± 0.01$^{d}$ | 0.04 ± 0.01$^{cd}$ | 0.02 ± 0.00$^{abc}$ | 0.02 ± 0.00$^{abc}$ | 0.02 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{a}$ |
| | C22:5n3/ clupanodonic | 0.02 ± 0.00$^{ab}$ | 0.02 ± 0.00$^{ab}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.01$^{a}$ | 0.03 ± 0.00$^{abc}$ | 0.02 ± 0.00$^{abc}$ | 0.06 ± 0.01$^{d}$ | 0.06 ± 0.00$^{d}$ | 0.04 ± 0.02$^{abcd}$ | 0.04 ± 0.01$^{cd}$ | 0.03 ± 0.01$^{abc}$ | 0.02 ± 0.00$^{abc}$ |
| | C22:6n3/ docosahexaenoic | 0.02 ± 0.01$^{ab}$ | 0.03 ± 0.00$^{b}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.02 ± 0.00$^{ab}$ | 0.02 ± 0.00$^{ab}$ | 0.02 ± 0.00$^{ab}$ | 0.03 ± 0.01$^{ab}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.02 ± 0.00$^{ab}$ |
| | SFA | 8.96 | 8.86 | 8.85 | 8.81 | 8.95 | 8.84 | 8.91 | 8.81 | 8.86 | 8.89 | 9.00 | 8.71 |
| | MUFA | 19.15 | 19.36 | 19.12 | 19.05 | 19.18 | 19.41 | 19.11 | 19.24 | 19.36 | 19.03 | 18.75 | 18.40 |
| | PUFA | 71.87 | 71.77 | 72.00 | 72.10 | 71.87 | 71.75 | 71.98 | 71.94 | 71.77 | 72.06 | 72.24 | 72.88 |

Values are means±standard deviations of a triplicate measurements. Alphabetical superscripts indicate significant differences ($P < 0.05$) among values in columns. rpm: revolution per minute; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; 1 oil from kernels was extracted with organic solvent (hexane)

III: *Fatty acid composition of oil extracted from bagasse pellets produced at different nozzle diameters and rotational speeds of a screw press. Oil was extracted from bagasse pellets by organic solvent (hexane)*

| | Nozzle diameter (mm) | 10 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 6 | 6 | 6 | Kernels[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rotational speed (rpm) | 30 | 50 | 70 | 90 | 30 | 50 | 70 | 90 | 30 | 50 | 70 | |
| Fatty acid composition (%) (v/w) | C14:0/myristic | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{b}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{a}$ | 0.03 ± 0.00$^{b}$ | 0.04 ± 0.00$^{c}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.00$^{ab}$ |
| | C16:0/palmitic | 6.50 ± 0.03$^{cd}$ | 6.40 ± 0.01$^{abc}$ | 6.42 ± 0.03$^{abc}$ | 6.42 ± 0.01$^{abc}$ | 6.48 ± 0.04$^{cd}$ | 6.46 ± 0.02$^{bcd}$ | 6.50 ± 0.01$^{cd}$ | 6.33 ± 0.04$^{ab}$ | 6.48 ± 0.04$^{cd}$ | 6.78 ± 0.03$^{e}$ | 6.58 ± 0.03$^{d}$ | 6.30 ± 0.09$^{a}$ |
| | C16:1n7/ palmitoleic | 0.09 ± 0.00$^{cde}$ | 0.09 ± 0.00$^{de}$ | 0.08 ± 0.00$^{bcd}$ | 0.08 ± 0.00$^{ab}$ | 0.08 ± 0.00$^{bcde}$ | 0.09 ± 0.00$^{cde}$ | 0.09 ± 0.00$^{cde}$ | 0.08 ± 0.00$^{bc}$ | 0.08 ± 0.00$^{bcde}$ | 0.09 ± 0.00$^{e}$ | 0.09 ± 0.00$^{cde}$ | 0.07 ± 0.00$^{a}$ |
| | C18:0/stearic | 2.50 ± 0.01$^{d}$ | 2.48 ± 0.00$^{d}$ | 2.43 ± 0.01$^{bc}$ | 2.41 ± 0.01$^{b}$ | 2.45 ± 0.00$^{c}$ | 2.50 ± 0.00$^{d}$ | 2.44 ± 0.00$^{c}$ | 2.52 ± 0.01$^{e}$ | 2.48 ± 0.01$^{d}$ | 2.56 ± 0.00$^{e}$ | 2.44 ± 0.00$^{c}$ | 2.38 ± 0.01$^{a}$ |
| | C18:1n7/vaccenic | 18.01 ± 0.02$^{def}$ | 17.92 ± 0.01$^{def}$ | 17.69 ± 0.03$^{cd}$ | 17.69 ± 0.01$^{cd}$ | 17.77 ± 0.02$^{de}$ | 18.01 ± 0.01$^{def}$ | 18.05 ± 0.01$^{ef}$ | 18.14 ± 0.01$^{f}$ | 17.87 ± 0.01$^{def}$ | 16.88 ± 0.00$^{a}$ | 17.28 ± 0.01$^{b}$ | 17.38 ± 0.34$^{bc}$ |
| | C18:1n9C/oleic | 0.80 ± 0.01$^{bcd}$ | 0.79 ± 0.01$^{abc}$ | 0.78 ± 0.02$^{ab}$ | 0.78 ± 0.00$^{abc}$ | 0.79 ± 0.01s$^{bc}$ | 0.80 ± 0.01$^{abcd}$ | 0.82 ± 0.00$^{d}$ | 0.79 ± 0.00$^{abc}$ | 0.82 ± 0.00$^{d}$ | 0.81 ± 0.01$^{cd}$ | 0.82 ± 0.00$^{d}$ | 0.77 ± 0.00$^{a}$ |
| | C18:2n6C/linoleic | 59.57 ± 0.04$^{b}$ | 59.84 ± 0.01$^{cd}$ | 59.97 ± 0.02$^{ef}$ | 60.05 ± 0.03$^{f}$ | 59.90 ± 0.02$^{de}$ | 59.76 ± 0.01$^{c}$ | 59.79 ± 0.02$^{cd}$ | 60.04 ± 0.00$^{f}$ | 59.80 ± 0.01$^{cd}$ | 59.43 ± 0.01$^{a}$ | 60.04 ± 0.03$^{f}$ | 60.74 ± 0.08$^{g}$ |
| | C18:3n6/gamma-linolenic | 0.06 ± 0.00$^{ab}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ | 0.06 ± 0.00$^{b}$ | 0.05 ± 0.00$^{a}$ | 0.05 ± 0.00$^{a}$ |
| | C18:3n3/alfa-linolenic | 11.91 ± 0.01$^{bc}$ | 11.94 ± 0.01$^{bcd}$ | 12.10 ± 0.02$^{de}$ | 12.06 ± 0.01$^{cd}$ | 12.06 ± 0.01$^{cd}$ | 11.95 ± 0.01$^{bcd}$ | 11.87 ± 0.00$^{b}$ | 11.64 ± 0.01$^{a}$ | 11.89 ± 0.00$^{bc}$ | 12.84 ± 0.00$^{f}$ | 12.25 ± 0.02$^{e}$ | 11.90 ± 0.17$^{bc}$ |
| | C18:4n3/ stearidonic | 0.10 ± 0.00$^{c}$ | 0.09 ± 0.00$^{abc}$ | 0.09 ± 0.00$^{ab}$ | 0.09 ± 0.00$^{a}$ | 0.09 ± 0.00$^{abc}$ | 0.09 ± 0.00$^{abc}$ | 0.09 ± 0.00$^{abc}$ | 0.10 ± 0.00$^{abc}$ | 0.10 ± 0.00$^{c}$ | 0.12 ± 0.00$^{d}$ | 0.10 ± 0.00$^{bc}$ | 0.09 ± 0.00$^{a}$ |
| | C20:1/eicosaenoic | 0.20 ± 0.00$^{b}$ | 0.18 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.19 ± 0.00$^{a}$ | 0.19 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ | 0.19 ± 0.00$^{a}$ | 0.18 ± 0.01$^{a}$ | 0.19 ± 0.00$^{ab}$ | 0.19 ± 0.00$^{ab}$ | 0.19 ± 0.00$^{a}$ | 0.18 ± 0.00$^{a}$ |
| | C20:4n3/ eicosatetraenoic | 0.03 ± 0.00$^{ef}$ | 0.03 ± 0.00$^{abc}$ | 0.02 ± 0.00$^{ab}$ | 0.02 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{bcde}$ | 0.03 ± 0.00$^{cde}$ | 0.03 ± 0.00$^{bcd}$ | 0.03 ± 0.00$^{bc}$ | 0.04 ± 0.00$^{f}$ | 0.05 ± 0.00$^{g}$ | 0.03 ± 0.00$^{def}$ | 0.02 ± 0.00$^{a}$ |
| | C20:5n3/ Eicosapentaenoic | 0.01 ± 0.00$^{ab}$ | 0.01 ± 0.00$^{ab}$ | 0.01 ± 0.00$^{ab}$ | 0.00 ± 0.00$^{ab}$ | 0.01 ± 0.00$^{ab}$ | 0.01 ± 0.00$^{ab}$ | 0.00 ± 0.00$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.00 ± 0.00$^{a}$ | 0.01 ± 0.00$^{b}$ | 0.01 ± 0.00$^{b}$ | 0.00 ± 0.00$^{a}$ |
| | C22:4n6/ adrenic | 0.09 ± 0.01$^{c}$ | 0.05 ± 0.01$^{abc}$ | 0.05 ± 0.04$^{abc}$ | 0.03 ± 0.00$^{ab}$ | 0.03 ± 0.01$^{ab}$ | 0.01 ± 0.01$^{a}$ | 0.01 ± 0.01$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.08 ± 0.01$^{bc}$ | 0.06 ± 0.01$^{abc}$ | 0.03 ± 0.03$^{ab}$ | 0.03 ± 0.00$^{ab}$ |
| | C22:5n6/ docosapentaenoic | 0.03 ± 0.01$^{abc}$ | 0.04 ± 0.01$^{bc}$ | 0.04 ± 0.01$^{c}$ | 0.03 ± 0.01$^{abc}$ | 0.02 ± 0.01$^{abc}$ | 0.02 ± 0.01$^{abc}$ | 0.01 ± 0.00$^{ab}$ | 0.01 ± 0.00$^{abc}$ | 0.03 ± 0.00$^{abc}$ | 0.04 ± 0.01$^{bc}$ | 0.03 ± 0.00$^{abc}$ | 0.01 ± 0.00$^{a}$ |
| | C22:5n3/ clupanodonic | 0.07 ± 0.03$^{c}$ | 0.03 ± 0.01$^{abc}$ | 0.03 ± 0.00$^{ab}$ | 0.06 ± 0.02$^{bc}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.01$^{a}$ | 0.01 ± 0.01$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.02 ± 0.01$^{ab}$ | 0.03 ± 0.01$^{ab}$ | 0.03 ± 0.00$^{ab}$ | 0.02 ± 0.00$^{ab}$ |
| | C22:6n3/ docosahexaenoic | 0.01 ± 0.01$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.01$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.01 ± 0.00$^{a}$ | 0.02 ± 0.01$^{a}$ | 0.02 ± 0.01$^{a}$ | 0.02 ± 0.00$^{a}$ | 0.02 ± 0.00$^{a}$ |
| | SFA | 9.03 | 8.91 | 8.88 | 8.86 | 8.96 | 8.99 | 8.97 | 8.89 | 8.99 | 9.38 | 9.06 | 8.71 |
| | MUFA | 19.10 | 18.98 | 18.74 | 18.73 | 18.83 | 19.08 | 19.15 | 19.20 | 18.97 | 17.96 | 18.37 | 18.40 |
| | PUFA | 71.85 | 72.09 | 72.37 | 72.38 | 72.18 | 71.90 | 71.83 | 71.87 | 72.03 | 72.64 | 72.57 | 72.88 |

Values are means±standard deviations of a triplicate measurements. Alphabetical superscripts indicate significant differences ($P < 0.05$) among values in columns. rpm: revolution per minute; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; [1] oil from kernels was extracted with organic solvent (hexane)

IV: *Correlation coefficients between fatty acids of pressed oils/bagasse pellets and oil pressing temperatures*

| Fatty acid | Pressed oil[1] | Bagasse pellets[2] |
|---|---|---|
| C14:0/myristic | 0.405 | 0.691* |
| C16:0/palmitic | 0.513* | 0.342 |
| C16:1n7/palmitoleic | 0.422 | 0.501* |
| C18:0/stearic | -0.195 | 0.678* |
| C18:1n7/vaccenic | -0.210 | 0.579* |
| C18:1n9C/oleic | 0.266 | 0.428 |
| C18:2n6C/linoleic | -0.581* | -0.547* |
| C18:3n6/gamma-linolenic | 0.168 | 0.509* |
| C18:3n3/alfa-linolenic | 0.352 | -0.528* |
| C18:4n3/stearidonic | 0.303 | 0.338 |
| C20:1/eicosaenoic | 0.095 | 0.539* |
| C20:4n3/eicosatetraenoic | 0.360 | 0.440 |
| C20:5n3/eicosapentaenoic | 0.017 | -0.109 |
| C22:4n6/adrenic | 0.456* | 0.680* |
| C22:5n6/docosapentaenoic | -0.358 | 0.332 |
| C22:5n3/clupanodonic | -0.089 | 0.381 |
| C22:6n3/docosahexaenoic | -0.225 | 0.195 |
| SFA | 0.507* | 0.709* |
| MUFA | -0.189 | -0.515* |
| PUFA | 0.103 | 0.312 |

Asterisk indicates statistical significant correlation ($P < 0.05$). SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; UFA: polyunsaturated fatty acids; [1]oil extracted by pressing in the screw press; [2] oil extracted from bagasse pellets by organic solvent (hexane)

observed only at linoleic (-0.547) and alfa-linolenic (-0.528) acid (Tab. IV).

SFA in pressed oils and oils extracted from bagasse pellets showed significant moderate and strong positive correlation, respectively, with oil pressing temperature (Tab. IV), showing, that the content of SFA was increasing with higher temperatures. PUFA showed positive correlation with oil pressing temperatures, however, the correlation coefficients were not significant and were lower than correlation coefficients of the SFA (Tab. IV). According to Sobajic and Gajic-Krstajic (2011), the PUFA are more prone to degradation than MUFA, however, in our study significant moderate negative correlation was observed at MUFA at oils extracted from bagasse pellets and nonsignificant moderate at pressed oil (Tab. IV), showing that MUFA were negatively influenced by higher temperatures during pressing.

Although the bagasse pellets had higher values of antioxidant capacity than pressed oils, indicating better protection of the fatty acids (Fukuda *et al*., 2003), higher number of significant correlations and values of correlation coefficients was shown in oils extracted from bagasse pellets when compared to pressed oils (Tab. IV). Therefore, if the bagasse pellets will be used as food resources, it should be kept in mind that the fatty acids in bagasse pellets are more affected by higher temperatures than in pressed oil.

## CONCLUSION

The separation ability of the press affected the antioxidant capacity and TPC of either bagasse pellets and pressed oil. Higher values of antioxidant capacity and TPC were measured in bagasse pellets than in pressed oils. Nozzle diameter affected the antioxidant capacity in bagasse pellets, however, not in pressed oil. Rotational speed did not affect antioxidant capacity in pressed oil, nor in bagasse pellets. Higher amount of pressed oil was yielded by using lower nozzle diameter, indicating better oil/bagasse separation, and resulted in higher concentration of phenolic compounds and antioxidant capacity than at higher nozzle diameters. However, by lowering the nozzle diameter the oil pressing temperature was rising, which affected the fatty acids. Positive correlations with oil pressing temperatures were calculated at SFA, while the correlation coefficients of polyunsaturated fatty acids were positive, but not significant. MUFA were negatively affected by higher oil pressing temperatures showing, that MUFA were more susceptible to higher temperatures than PUFA and SFA. Therefore, when considering the fatty acid content, higher temperatures during pressing should be avoided, especially when considering the use of bagasse pellets where the fatty acids were more affected by higher temperatures than in the pressed oil.

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