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THE EVALUATION OF EXTRACTION OF SOME NUT OILS USING SCREW PRESSING

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ABSTRACT
Today's consumers prefer low-sugar, low-calorie, natural, and so-called safe products. These trends are also reflected in nuts products and groceries. Globally, the European Union is the largest importing market of edible nuts. Considering the increasing demand for new sources of food, the importance becomes the efficiency of production. This study evaluates the influence of rotation speed in the extraction of almond nut, walnut, hazelnut, cashew nut, and peanut oils using screw pressing. In tested samples, the oil content was on average between 69.14 ±0.79% (walnut) and 46.7 ±1.45% (peanut). From the pressing of oils, it is seen that the oil yield decreased when pressing speed increased (from 30 rpm to 90 rpm, for example in walnut from 0.36 kg to 0.16 kg.h^{-1}) and that the oil sediment yield increased when speed increased (for example in hazelnut nut from 8.51% to 17.37%). The highest amount of oil yields had hazelnut with 3.03 ±0.05 kg.h^{-1}, then walnut with 2.05 ±0.02 kg.h^{-1}, almond nut with 2.34 ±0.05 kg.h^{-1}, peanut with 2.15 ±0.01 kg.h^{-1}, and finally cashew nut with 2.07 ±0.03 kg.h^{-1}.

Keywords: pressing time; oil yield; sediment yield; Soxhlet extraction; cake oil residue

INTRODUCTION
The European Union can produce only little amount of nuts within its area and therefore the EU is the largest importing market for edible nuts in the world, representing more than 40% of the total world imports **(CBI, 2018)**. Import in the year 2016 was 86,450 tons and volume is steadily increasing, but export was just 36,764 tons **(FAOSTAT, 2018)**.

Nuts are well known due to their high polyunsaturated fatty acids (PUFA) content and overly are very beneficial for health **(Christopoulos and Tsantili, 2015; Gharibzahedi et al., 2013; Kendall et al., 2011)**.

Consumers currently prefer low-sugar, low-calorie, natural, and so-called safe products which are the same for nuts groceries and products. The intentions of the food and confectionery industry are to exploit the full potential of nuts. Not only by adding them directly to products, but by making the most of their potential, for example by pressing oil and making use of cakes.

Oil from walnut kernel can be obtained in three ways, which are mechanical extraction (pressed oil), chemical or solvent extraction, and supercritical CO2 extraction **(Bhuiya et al., 2020; Zanqui et al., 2020; Alves et al., 2019; Singh and Bargale, 2000)**. The extraction by mechanical screw presses is one of the methods that are presently used and is typical for a lower proportion of collected oil **(Chapuis et al., 2014; Karaj and Müller, 2011)**. But benefits of screw pressing are to produce high-quality oil containing bioactive compounds, the possibility of using the cake residue, has relatively low initial and operation cost **(Al Juhaimi et al., 2018; Rabadán et al., 2018; Roncero et al., 2016; Alonge and Olaniyan, 2006; Alonge et al., 2003)**. The amount and quality of pressed oil are dependent on factors such as press time, temperature, the particular size of nuts, etc. **(Jokić et al., 2016; Gong and Pegg, 2015; Labuckas, Maestri and Lamarque, 2014; Teh and Birch, 2013)**.

The main objective of this study is to verify oil production from the imported seeds of hazelnut, walnut, almond nut, peanut, cashew nut and to compare its yield parameters.

Scientific hypothesis
The values of the pressing process for example yield, amount of sediment, or oil temperature of nut oils depend on the pressing speed.

MATERIAL AND METHODOLOGY
Nuts and kernels
Nuts and kernels (Figure 2), that were subject to this study, were vacuum-packed and purchased in the wholesale market. Before pressing, the water content in the nuts and kernels was assessed. They were ground in a stainless-steel mill with a pro-homogenization sample to

the fraction of size from 0 mm to 6 mm. Then, the material was pressed (Figure 1).

Determination of water content of nuts and kernels

The water content of nuts and kernels was determined by dehydration at 103 °C in a drying oven according to the **CSN EN ISO 665 (461025) (2001)**. The analysis was made on 5 g of grinded sample, weighted with an accuracy of 0.1 mg. Results are expressed as the ratio of water loss per gram of dried sample.

Screw press

The screw press type UNO FM 3F made by the Farmet Company in the Czech Republic was used for experimental measurements. The press allows precise adjustment of rpm from 0 to 200. The pressing device components are a matrix, 220 mm screw, head, heating mantle, nozzle holder, and nozzles of different in diameter (6, 8, and 10 mm). From the pre-test, the 8 mm nozzle was chosen as optimal. After the pressing process was the sediment separated and yield parameters of oils were determined. The oil temperature was measured directly on the press head every second by Testo 176 T4 – Temperature data logger (Testo SE & Co. KGaA, Germany) with stainless steel food probe.

Determination of the total fat content in the nuts, kernels, and cakes through extraction

To determine the total fat content, we used the Soxhlet extractor with hexane as a solvent. Crushing the walnut kernels always took place immediately before the oil extraction and from the pressed cakes directly after the pressing. For this purpose, the IKA MF 10 basic (IKA-Werke GmbH & Co. KG) on the sieve with an average of 3 mm was used. Precise cleaning of the grinder to avoid distorting results was always emphasized. The temperature of the extraction mixture was kept by the heating mantle closely around the boiling point of hexane (70 °C). Extraction was always carried out for 8 hours. Subsequently, the hexane was evaporated on the vacuum evaporator, type IKA RV 10 (IKA-Werke GmbH & Co. KG) control at the pressure of 200 kilopascals until the hexane was evaporated. After that, the pressure was lowered down to 60 kilopascals for another 2 hours at a constant temperature of 40 °C. The weight of total fat was then measured on the scales type KERN EG 2200-2NM (KERN & SOHN GmbH).

Statistical analysis

Analytical determinations were done in triplicate and data were reported as means ± standard deviation. Tukey's honestly significant difference (HSD) tests were conducted to determine the differences among which means that the statistical significance was declared at $p \leq 0.05$. The differences were analyzed only within the specific sample, not between the different samples. These statistical evaluation methods were applied using the computer software package "Statistica 12.0" (StatSoft Inc., USA).

RESULTS AND DISCUSSION

Table 1 and Table 2 shows the values of the main parameters. The average water content was at 3.95 ±1.21%, while the maximum content has hazelnut 5.8%, which corresponds to the values recommended for storage **(Poggetti et al. 2018; WCO HS 0802, 2017; Gong and Pegg, 2015; Christopoulos and Tsantili 2015)**. A most important parameter in the production of cold-pressed oils is oil content in nuts and kernels and the yield of producing oil. In samples, the oil content was on average between 46.7 ±1.45% until 69.14 ±0.79%.

From Table 1 and Table 2, it can be seen that the oil yield decreased when pressing speed increased **(Savoire, Lanoisellé and Vorobiev, 2013)**. This results confirmed Table 3 as a significant negative correlation between speed and yield of oil. The sediment is made by the imperfect separation of oil from the pressed material and represents an undesirable residual during the pressing process. It is also a signal that the press is not optimally set. Table 3 shows the significant correlation between speed and sediment in oils in Hazelnut, Walnut, and Almond nut, but not in Peanut and Cashew nut.

The results in Table 3 significantly proved that the amount of oil in pressed cakes and the efficiency of the press depends on the extraction parameters **(Rabadán et al., 2018; Jokić et al., 2016; Rombaut et al., 2015; Labuckas, Maestri and Lamarque, 2014; Teh and Birch, 2013)**, in our case on the rotation speed. Hourly performance increased with increasing speed, but not directly proportionally. At higher speeds, the efficiency of the press was lower due to the greater amount of sediment produced in the oil and the imperfect extraction of oil from the material. Therefore, the oil content in cakes increased. Oil temperature decreased in most of the cases while the speed was increasing. The evolution of the temperature of nut oils using screw pressing during oil extraction corresponds to the results of **Rabadán et al. (2018)**.

Many authors state, that in the pressed cakes, the leftover is between 5 – 31% of oil **(Gong and Pegg, 2015; Labuckas, Maestri and Lamarque, 2014; Acheheb, Aliouane and Ferradji, 2012)** and the value of sediment in pressed oil range from 7.95 to 17.57%.

The optimum speed for maximum oil yields for all samples was 30 rpm. But the higher speeds of the press increase the press capacity (yield of oil per hour), which is important for producers of oils. This is the reason why the setting of the pressing process is important according to the needs of each producer.

Hazelnut

Many authors reported that oil content in hazelnut ranged from 51 to 75% **(Kornsteiner-Krenn, Wanger and Elmadfa, 2013; Xu, Hanna and Josiah, 2007; Ebrahem et al. 1994)**. Our sample has a total fat content of 60.31 ±0.62%. The screw press makes it possible to achieve yield 50% **(Jokić et al., 2016)**, which was confirmed by this experiment and the total maximum weight of pressed oil was 51%, with 8.51% of sediment.

Table 1 The values of oil yield depended on speed.

Sample	Water content (%)	Total oil content (%)	Speed (rpm)	Weight of pressed oil (kg)	Weight of oil without sediment (kg)	Oil temperature (°C)
Hazelnut	5.8 ±0.57	60.31 ±0.62	30	0.51[a] ±0.01	0.47[c] ±0.02	49.2
			50	0.48[a] ±0.01	0.41[a] ±0.01	48.3
			70	0.45[b] ±0.01	0.41[a] ±0.00	43.7
			90	0.44[b] ±0.02	0.36[b] ±0.01	42.6
Walnut	4.2 ±0.66	69.14 ±0.79	30	0.42[d] ±0.01	0.36[a] ±0.01	47.6
			50	0.35[c] ±0.01	0.33[a] ±0.01	51.3
			70	0.29[b] ±0.01	0.24[c] ±0.03	42.1
			90	0.22[a] ±0.01	0.16[b] ±0.02	39.6
Almond nut	4.1 ±0.68	52.23 ±1.03	30	0.42[d] ±0.01	0.40[d] ±0.02	50.4
			50	0.39[c] ±0.01	0.36[c] ±0.01	50.1
			70	0.33[b] ±0.01	0.31[b] ±0.01	46.2
			90	0.29[a] ±0.01	0.24[a] ±0.01	37.7
Peanut	3.8 ±0.39	46.7 ±1.45	30	0.45[d] ±0.01	0.41[c] ±0.01	65.3
			50	0.42[c] ±0.01	0.37[b] ±0.02	62.0
			70	0.36[b] ±0.01	0.31[a] ±0.01	57.6
			90	0.31[a] ±0.01	0.27[a] ±0.03	56.2
Cashew nut	2.8 ±0.27	48.5 ±1.47	30	0.45[d] ±0.01	0.40[b] ±0.01	45.8
			50	0.43[c] ±0.01	0.40[b] ±0.02	43.6
			70	0.39[b] ±0.01	0.34[a] ±0.02	43.2
			90	0.36[a] ±0.01	0.32[a] ±0.02	39.4

Note: Alphabetical superscripts indicate significant differences (p <0.05) among values in columns for each sample.

Walnut

Many studies report, that walnut kernels have high oil content which varies from 52 to 72%. The fat content in tested raw material was determined at 69.14 ±0.73%, which is a rather higher percentage in comparison with other authors **(Kornsteiner-Krenn, Wagner and Elmadfa, 2013; Labuckas, Maestri and Lamarque, 2014)** and was the highest of tested samples. By pressing, the production of oil yield was 42%, with 12.94% of sediment. The results match with the results of **Gharibzahedi et al. (2013)** who indicates the highest yield crude pressed oil 34.9% and **Labuckas, Maestri and Lamarque (2014)** who states oil extraction in between 41.0 – 44.4% and a little lower than stated by **Sena-Moreno et al. (2016)** 57 ±3%.

Almond nut

Almond oil is extracted mainly from sweet almonds, which contain around 50% **(Fernandes et al., 2017)**, or 54.3% of oil **(Kornsteiner-Krenn, Wagner and Elmadfa, 2013)**. **Tungmunnithum et al. (2020), Prats (2000) and Roy, Mukherjee and Jana (2019)**, obtained yields of oil at 40 – 45%, which matches with our results 43% (with 6.98% of sediment) and **Sena-Moreno et al. (2016)** declare higher yield, almost 53 ±2%. This particular difference might be caused for example by the specific sample. To compare, our sample had total oil content 52.23%.

Peanut

Peanut seeds have oil content at 45 – 50% **(Kornsteiner-Krenn, Wagner and Elmadfa, 2013; Grosso et al., 1997)**. **Nader, Afif and Louka (2016)** state the yield production at 70% (when using the hydraulic press). At our experiment, we achieved the total maximum yield production of 45%, with 8.83% of sediment.

Cashew nut

The total oil content is on average between 45.2% **(Kornsteiner-Krenn, Wagner and Elmadfa., 2013)** to 52.08% **(Acheheb, Aliouane and Ferradji, 2012)**, with the highest oil yield 44.17% when the moisture content was 3.97%. The total maximum oil yield in this experiment was 45%, with 9.68% of sediment.

Table 2 The values of residues depended on speed.

Sample	Speed (rpm)	Amount of sediment in oil (%)	Weight of pressed cakes with oil (kg)	Weight of oil in pressed cakes (kg)	Amount of oil in pressed cakes (%)	Press capacity of oil ($kg.h^{-1}$)
Hazelnut	30	8.51^{a} ±1.29	0.43^{a} ±0.01	0.14^{b} ±0.02	31.59^{b} ±2.79	1.04^{b} ±0.04
	50	15.16^{bc} ±2.31	0.46^{a} ±0.01	0.19^{a} ±0.01	42.16^{a} ±2.13	1.90^{c} ±0.02
	70	10.65^{ab} ±1.58	0.49^{b} ±0.01	0.20^{a} ±0.01	40.60^{a} ±1.17	2.72^{a} ±0.02
	90	17.37^{c} ±3.00	0.50^{b} ±0.02	0.24^{c} ±0.01	47.83^{c} ±1.92	3.03^{a} ±0.05
Walnut	30	12.94^{a} ±0.91	0.54^{a} ±0.01	0.33^{a} ±0.01	60.80^{a} ±0.30	0.74^{a} ±0.05
	50	5.64^{a} ±4.74	0.61^{b} ±0.01	0.36^{a} ±0.01	59.39^{a} ±2.20	1.05^{b} ±0.05
	70	17.53^{ab} ±7.33	0.67^{c} ±0.01	0.45^{b} ±0.03	67.82^{b} ±3.21	1.80^{c} ±0.04
	90	27.74^{b} ±4.97	0.74^{d} ±0.01	0.53^{c} ±0.02	72.22^{b} ±1.30	2.05^{d} ±0.02
Almond nut	30	5.56^{a} ±2.76	0.54^{a} ±0.01	0.13^{a} ±0.02	23.28^{a} ±2.25	0.82^{a} ±0.02
	50	6.86^{a} ±3.88	0.57^{b} ±0.01	0.16^{b} ±0.01	28.35^{b} ±1.97	1.44^{b} ±0.05
	70	5.48^{a} ±4.17	0.63^{c} ±0.01	0.21^{c} ±0.01	33.48^{c} ±1.46	2.04^{c} ±0.05
	90	19.54^{b} ±1.44	0.67^{d} ±0.01	0.29^{d} ±0.01	43.05^{d} ±0.57	2.34^{d} ±0.05
Peanut	30	8.83^{a} ±4.25	0.51^{a} ±0.01	0.06^{b} ±0.01	11.18^{b} ±2.17	0.85^{a} ±0.04
	50	13.40^{a} ±2.83	0.54^{b} ±0.01	0.10^{c} ±0.02	18.63^{c} ±2.68	1.51^{b} ±0.03
	70	13.82^{a} ±4.42	0.60^{c} ±0.01	0.16^{a} ±0.01	26.12^{a} ±1.90	1.84^{c} ±0.03
	90	12.84^{a} ±6.55	0.65^{d} ±0.01	0.19^{a} ±0.03	29.87^{a} ±3.65	2.15^{d} ±0.01
Cashew nut	30	9.68^{a} ±2.48	0.52^{a} ±0.01	0.08^{a} ±0.01	15.58^{a} ±1.28	0.66^{a} ±0.03
	50	7.00^{a} ±4.62	0.54^{b} ±0.01	0.09^{a} ±0.02	16.24^{a} ±2.97	1.12^{b} ±0.06
	70	12.87^{a} ±2.90	0.58^{c} ±0.01	0.15^{b} ±0.02	24.84^{b} ±3.01	1.73^{c} ±0.06
	90	13.71^{a} ±7.15	0.61^{d} ±0.01	0.16^{b} ±0.02	26.58^{b} ±3.33	2.07^{d} ±0.03

Note: Alphabetical superscripts indicate significant differences ($p < 0.05$) among values in columns for each sample.

Table 3 Correlation analysis between speed and production parameters in specific samples.

Sample		Weight of pressed oil (kg)	Amount of sediment in oil (%)	Amount of oil in pressed cakes (%)	Oil temperature (°C)	Press capacity of oil (kg/h)
Hazelnut	Speed (rpm)	-0.941*	0.628*	0.868*	-0.959*	0.981*
Walnut		-0.994*	0.698*	0.870*	-0.813*	0.979*
Almond nut		-0.986*	0.701*	0.967*	-0.916*	0.987*
Peanut		-0.982*	0.322	0.947*	-0.983*	0.979*
Cashew nut		-0.979*	0.432	0.856*	-0.952*	0.993*

Note: *Correlation is significant at the level 0.05.

Figure 1 Peanut oil pressing.

Figure 2 Samples of raw oils (from left peanut, walnut, almond, hazelnut).

CONCLUSION

The food and confectionery industry intend to exploit the full potential of nuts, for example by pressing oil and making use of cakes. The extraction by mechanical screw presses is one of the methods that is used for the production of cold-pressed oils.

In tested samples was oil content on average between 46.7 ±1.45% (peanut) until 69.14 ±0.79% (walnut). From the experiment, it is seen that the oil yield decreased when pressing speed increased (from 30 rpm to 90 rpm, for example in walnut from 0.42 kg to 0.22 kg.kg^{-1}) and that the oil sediment yield increased when speed increased (for example in almond nut from 5.56% to 19.54%).

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