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EVALUATION OF THE PRESSING PROCESS DURING OIL EXTRACTION FROM GRAPE SEEDS

Patrik Burg, Vladimír Mašán, Kazimierz Rutkowski

ABSTRACT

This study evaluated the physical properties and oil extraction from grape seeds from three white (Welschriesling, Green Veltliner, Hibernal) and two red (Zweigelt and Saint Laurent) must varieties of grapevine by cold screw pressing as the appropriate extraction process. Pressing was carried out by a screw press UNO FM 3F by Farmet Company, Czech Republic. The pressing device consists of a matrix, 220 mm screw, head, heating mantle, nozzle holder, and a nozzle of 10 mm in diameter. The minimal and maximal screw rotation speeds were chosen within the press characteristics in order to achieve a correct expression and to avoid press overload. For successful pressing of the seeds and their storage, their initial moisture content was lowered from 40 to 45% to about 5 to 8% in a chamber dryer. The temperature in the chamber dryer did not exceeded 40 °C. Seeds of all varieties were pressed at the same speeds of 20, 40, 60, and 80 rpm. The characteristics of the grape seeds are as follows: The density ranges from 602.7 to 606.3 $kg.m^{-3}$, thousand seeds weigh is between 21.9 – 26.6 g, humidity between 5.6 – 7.1% of dry matter and seed oil content, determined by extraction and depending on the variety, ranges from 15.3 to 17.5% in dry basis. The results have confirmed that when the screw rotation speed is changed from 20 to 80 rpm, the press capacity increases on average from 0.84 $kg.h^{-1}$ to 1.75 $kg.h^{-1}$, but simultaneously the oil yield reduces from 9.85 to 6.75%. This means that one kilogram of seed may produce 67.5 to 98.5 g of oil. The quantity of the pressed oil ranges from 67.5 to 98.5 $g.kg^{-1}$ and thus depends on the variety. The measured results can be used in commercial practice for optimizing the pressing process for pressing of oil from grape seeds.

Keywords: grape seeds; grape seed oil; screw press; rotation speed; physical properties

INTRODUCTION

A large volume of winery waste remains unexploited every year on an international level. Grape production is considered to be one of the most important agro-economic activities in the world, with more than 77 million tons of grapes (*Vitis vinifera* L.) produced globally in 2013, with about 45 million tons of them produced in the European Union **(FAO, 2013)**. Grape processing and subsequent production of wine is associated with the production of large quantities of waste. The most common among them are grape marc and wine lees.

Winemaking wastes, traditionally considered an economic and environmental problem, are now increasingly becoming recognised as valuable commodities for the production of value added products, such as grappa or vine seed oil **(Passos, 2009)**.

Oil from grape seeds can be obtained in two ways. Mechanical extraction (pressed oil) and chemical or solvent extraction (Soxhlet methods and hexane as solvent) are the most common and widespread methods of extracting grape seed oil. To ensure higher oil quality, mechanical pressing is preferred. It uses lower process temperature and no solvent however, lower yields between 55 – 95% are achieved depending on the processed raw material **(Singh and Bargale, 2000)**. Screw pressing has been studied for a large variety of oilseeds, including linseed, canola, crambe, and chia seeds **(Savoire et al., 2013)**.

In this respect, the major aim of this research work is to explore possible ways for the use of winery wastes, specifically separation of seeds from grape marc and their subsequent extraction by a small-capacity screw press.

According to the Codex Standards for Fats and Oils from Vegetable Sources, grape seed oil is the oil which is produced from the grape seeds of *Vitis vinifera* L. The oil content in the grape seeds and the content of bioactive compounds in whole grapes are characteristics specific for each variety and depend on environmental conditions **(Pardo et al., 2009)**. For commonly grown varieties of grapes in Central European conditions these data are not yet available. According to data from literature, the amount of oil in dried seeds is between 5 – 20% **(Tobar et al., 2005, Baydar et al., 2007, Tangolar et al., 2009, Yousafi et al., 2013)**.

The grape seed oil is rich in linoleic acid (65 to 72%), oleic acid (12 to 23%), palmitic acid (4 to 11%), and stearic acid (8.5 to 15%). Linoleic acid found in grape seed oil plays an important role as it is not synthesized in the human body itself and this is why products containing it have significant nutritional value. Corresponding recommendations in linoleic acid has sunflower oil, soybean oil, safflower oil (member of the sunflower family), corn oil, and poppy seed oil. The oleic acid also contributes to nutritional value of oil as it affects the oxidative stability of oils **(Aparicio et al., 1999, Frančáková et al., 2015)**.

This paper is aimed at determining the physical properties and mechanical extraction (pressed oil) from different varieties of grape seeds using a small-capacity screw press.

MATERIAL AND METHODOLOGY

Grape seeds

Collection of grape marc for the separation of seeds was carried out in the 2015 processing season at the Agropol Mikulov Company. A prototype of vibratory separator was used to separate the seeds from marc. This machine applies the principle of mechanical vibrations transmitted on three flat screens with different shapes and sizes of holes. Separation of seeds was carried out separately from marc from three white (Welschriesling – VR, Green Veltliner – VZ, and Hibernal – HIB) as well as two red (Zweigelt – ZW and Saint Laurent – SV) must varieties of grapevine. For successful pressing of the seeds and their storage, their initial moisture content was lowered from 40 to 45% to about 5 to 8% in a chamber dryer. The temperature in the chamber dryer did not exceeded 40 °C. Material was kept in a closed bag, at room temperature until screw pressing.

Determination of water content and density

Water content of grape seeds was determined by dehydration at 103 °C according to CSN EN ISO 665 (461025) Oilseeds – Determination of moisture and volatile matter content. 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. Determination of water content was performed in triplicate. Density of oil was determined pycnometrically according to CSN EN ISO 6883. This international standard specifies a method for the determination of the conventional mass per volume ("litre weight in air") of vegetable fats and oils.

Determination of the total lipid content in the seeds through extraction

To determine the total lipid content, the Soxhlet extractor was used with hexane as a solvent.

Crushing the seeds of a given variety always took place immediately prior to the extraction of oil using an ETA grinder. Emphasis was always placed on precise cleaning of the grinder in order to avoid distorting the results. For seeds of each variety after grinding, the water content of the sample. 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 32 hours. Subsequently, the hexane was evaporated and the sample weighed twice at intervals of two days. During this time, the sample of oil was kept in a dark environment.

Screw press parameters

Screw press type UNO FM 3F from the Farmet Company, Czech Republic, served for experimental measurements. This model is intended for pressing of 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 is composed of an electric motor (1.5 kW power), transmission, pressing device, motor starter, and frequency converter, which allows precise adjustment of rpm. The screw rotation speed could be adjusted from 10 to 150 rpm. The pressing device consists of a matrix, 220 mm screw, head, heating mantle, nozzle holder, and a nozzle of 10 mm in diameter.

Pressing process and experimental domain

Four variables, named factors hereafter, were investigated: the seeds of evaluated grape varieties, the screw rotation speed, the press performance, and oil yield (the preheating temperature).

Before screw pressing experiments, the press head was pre-heated at the desired temperature for 20 minutes using a temperature-regulated heating ring. Pressing experiments were conducted without external heating (cold pressing). During pressing, grape seeds were fed into the press on demand by gravity through the hopper and seeds level was maintained constant to ensure a constant press performance. The minimal and maximal screw rotation speeds were chosen within the press characteristics in order to achieve a correct expression and to avoid press overload. Seeds of all varieties were pressed at the same speeds of 20, 40, 60, and 80 rpm.

Statistical analysis

The data were analysed using a linear model with interactions by using the linear regression tool of Excel software **(Microsoft, 2012)**. The *p*-values were used as a tool to check the significance of the effects and interactions. For all statistical tests a 95% confidence level was used.

RESULTS AND DISCUSSION

The values of the main parameters, namely seed density, weight of thousand seeds, as well as water and oil contents were determined in the grape seed varieties by the procedures described in the methodology (Table 1).

The measured values indicate that densities of seeds range from 602.7 to 606.3 kg.m^{-3}. Other authors **(Hardie et al., 1996)** studied the determination of density of seeds and listed its values from 600 to 612 kg.m^{-3}, while **(Kiliçkan et al., 2010)** showed the values to range between 613.1 – 626.1 kg.m^{-3}.

The determined weight of thousand seeds in the evaluated samples ranged from 21.9 to 26.6 g, with humidity between 5.6 – 7.1% of dry matter. The highest values occurred in the Saint Laurent variety (25.4 g), while the lowest rates were in the Riesling variety (21.9 g). The mass of thousand grape seeds at moisture ranging from

Table 1 Characteristics of the processed grape seeds.

Seeds from grape variety	Densities of seeds (kg.m^{-3} ±SD)	Thousand grain weight (g ±SD)	Water content (% dry basis ±SD)	Oil content (% dry basis ±SD)
Welschriesling	602.7 ±1.1	21.9 ±0.5	5.6 ±0.2	17.5 ±0.4
Green Veltliner	605.1 ±0.2	25.3 ±0.4	6.3 ±0.2	15.9 ±0.7
Hibernal	604.5 ±0.5	25.2 ±0.1	6.1 ±0.1	16.8 ±1.5
Zweigelt	604.4 ±0.4	26.6 ±0.1	6.5 ±0.3	15.3 ±0.3
Saint Laurent	606.3 ±0.6	25.4 ±0.1	7.1 ±0.2	16.7 ±0.3

8.26 to 26.14% in dry basis varies between 23.39 – 24.82 g **(Kiliçkan et al., 2010)**.

The Soxhlet type extractor was used to determine the oil content of ground seeds. The oil content was expressed as the weight of extracted oil relative to the dry weight of the seed. The results indicate that the seed oil content, depending on the variety, ranges between 15.3% in Zweigelt and 17.5% in Riesling. The oil content in seeds of grape varieties grown in Turkey ranged from 11.6 to 19.6% (v/w) **(Baydar and Akkurt, 2001)**. More authors reported similar values for different grape cultivars the oil content to range between 9.9 – 20.0% **(Ohnishi et al., 1990, Schuster, 1992)**.

The pressing of seeds was carried out at speeds 20, 40, 60, and 80 rpm, while the screw rotation speed significantly affected the press capacity. When the screw rotation speed changes from 20 to 80 rpm, the press capacity increases on average from 0.84 kg.h^{-1} to 1.75 g.h^{-1} as indicated by the results (Table 2 and Figure 1 – Figure 4). At the same time, the results also indicate that at higher speeds of the press, the oil yield drops from 9.85 to 6.75%. This means that one kilogram of seed may produce 67.5 to 98.5 g of oil. The higher screw rotation speed reduces the oil yield **(Savoire et al., 2013)**. This effect could be attributed to the conveying capacity of the press that increases with screw rotation speed **(Vadke and Sosulski, 1988, Poustkova et al., 2010)**.

Cold pressing on a small-capacity UNO FM 3F press can thus generate, depending on the variety of seeds, between 42 – 54% of the total amount of oil contained in the seeds. The remaining amount of 46 to 58% of oil, contained in the residue after pressing (cake), may optionally be at a loss in quality obtained by the above extraction. The density of oil, depending on the variety, ranges between 904 – 942 kg.m^{-3}.

When evaluating the values listed (Figure 1, Figure 2, Figure 3 and Figure 4), we have used their linear trend-line, determined regression equations, and reported the coefficient of determination R2. All evaluated variants show a very strong dependency.

The screw rotation speed significantly affected the oil yield **(Savoire et al., 2013, Rombaut et al., 2015)**. Oil

Table 2 Values of oil yield (%) and the press performance (kg.h^{-1}) depending on the speed.

Variety	Densities of oil (kg.m^{-3})	Controlling factor	Revolutions per minute (rpm)			
			20	**40**	**60**	**80**
Welschriesling	904	Values of oil yield (%)	9.85	9.43	9.18	8.94
		Press performance (kg.h^{-1})	0.87	1.18	1.53	1.92
Green Veltliner	942	Values of oil yield (%)	9.35	9.03	8.76	8.72
		Press performance (kg.h^{-1})	0.81	1.04	1.50	1.68
Hibernal	928	Values of oil yield (%)	7.38	7.28	6.90	6.75
		Press performance (kg.h^{-1})	0.85	1.11	1.52	1.77
Zweigelt	935	Values of oil yield (%)	9.10	8.78	8.63	8.32
		Press performance (kg.h^{-1})	0.85	1.15	1.51	1.75
Saint Laurent	913	Values of oil yield (%)	9.15	8.95	8.74	8.58
		Press performance (kg.h^{-1})	0.82	1.05	1.42	1.63

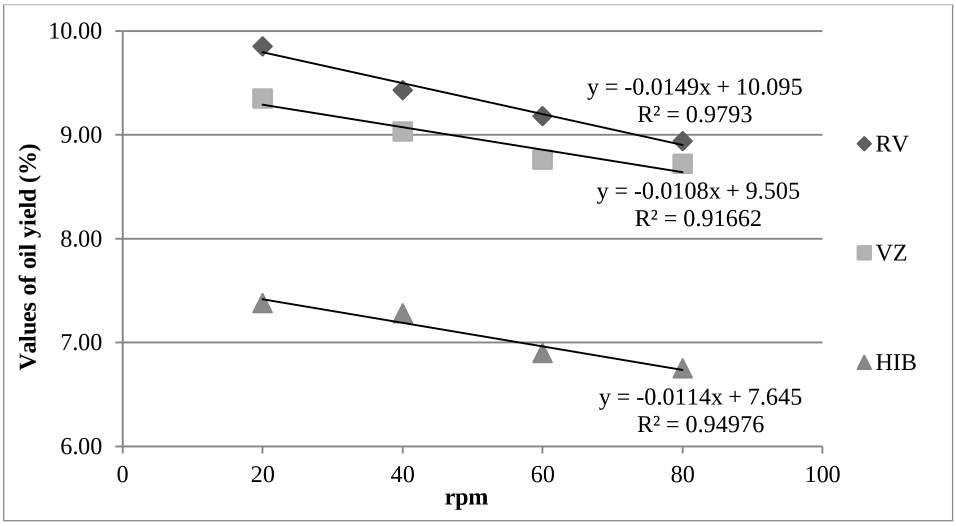

Figure 1 Effect of the number of revolutions of the press spindle for oil yield (%) in seeds of white grape varieties.

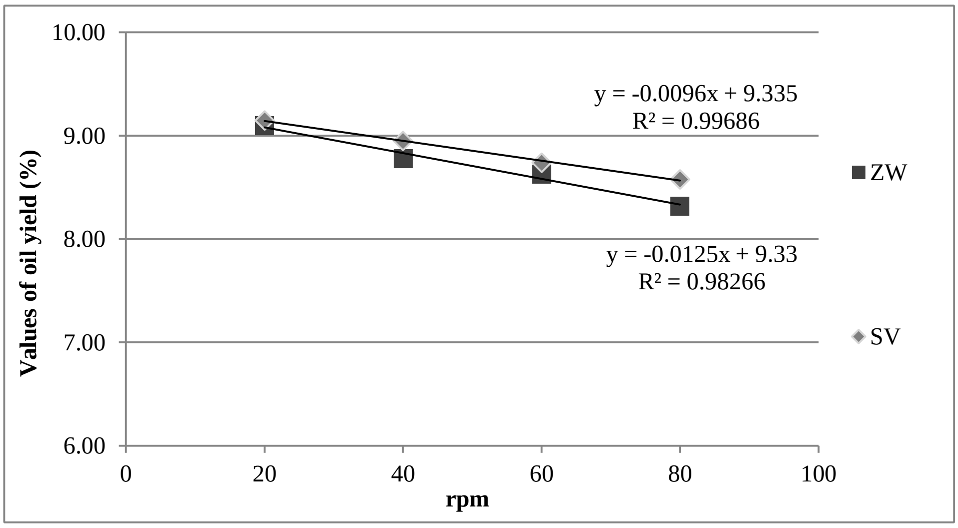

Figure 2 Effect of the number of press spindle revolutions on the oil yield (%) in seeds of red grape varieties.

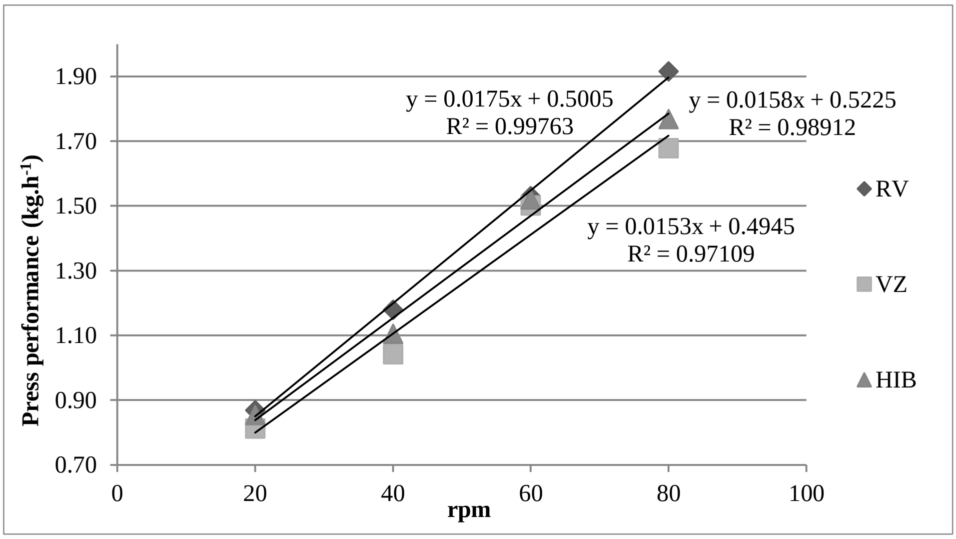

Figure 3 Effect of the number of press spindle revolutions on press capacity ($kg.h^{-1}$) in seeds of white grape varieties.

yield decreased on average from 58.6% at 40 rpm to 52.8% at 70 rpm. This effect already observed, especially **(Vadke and Sosulski, 1988)**, is attributed to a decrease of pressure within the barrel with screw rotation speed.

Oil yield depends on the pressing speed, attained pressing pressure, duration of pressure action, conditions of outflow of oil at a maximum pressure, viscosity, and oil temperature **(Black and Bewley, 2000)**.

The material throughput and thus the achieved press performance can be increased by providing higher purity of pressed wine seeds **(Savoire et al., 2013)**. It is therefore appropriate to ensure a high quality and efficient

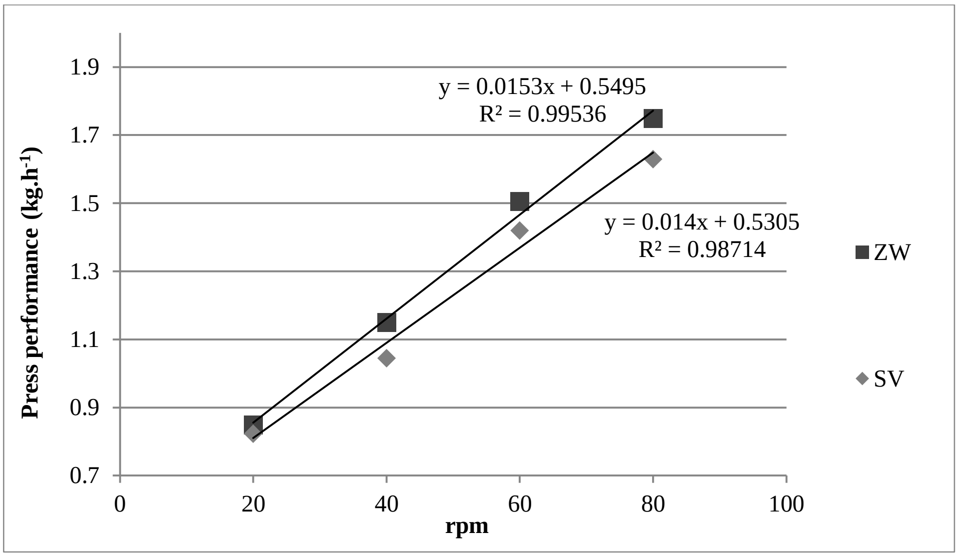

Figure 4 Effect of the number of revolutions of the press on press capacity (kg.h^{-1}) in seeds of red grape varieties.

separation of seeds and to remove the bulk of small impurities in the form of fragments or residues of stem and peel, which degrade the obtained product and prevent its further use for pressing. The quantity of foreign particles may comprise 12 to 18% of the total volume of mechanically separated seeds and may cause clogging of the press head.

In determining the grape oil yield and the associated economics of pressing operation, it is necessary not to forget the varietal difference in oil content of seeds collected from different grape varieties, including varietal differences in dimensions, size, and hardness of seeds **(Kulp and Ponte, 2000)**. Decisive influence on the pressing process has the moisture content of seeds entering the press and the content of impurities entering together with the seeds into the press.

CONCLUSION

At present, the technology of producing grape seed oil has been technologically sufficiently mastered. However, in the conditions of the Central European countries, it is not widespread among viticultural activities. Grape seeds containing very important biologically active substances end up in most cases as completely unused waste material. Our experiments have focused on the evaluation of seeds in five must varieties of grapevine, namely Green Veltliner, Welschriesling, Hibernal, Zweigelt, and Saint Laurent. The characteristics of the grape seeds indicate that the density ranges from 602.7 to 606.3 kg.m^{-3}, thousand seed weight ranges from 21.9 to 26.6 g, at a humidity of between 5.6 and 7.1% of dry matter, and seed oil content, determined by extraction, depending on the variety ranges between 15.3 and 17.5%. Seed samples were pressed using a screw press (UNO FM 3F made by Farmet, Czech Republic) at various speeds of 20, 40, 60, and 80 rpm. The results confirmed that when increasing the speed from 20 to 80 rpm, the efficiency of the press is increased by more than 100%. However, at the same rpm, oil yield decreases on average by approximately 46%. The statistical evaluation of all the analysed samples has shown a very strong dependency. Obtained data also indicate that one kilogram of seed can produce 67.5 – 98.5 g of oil through pressing. The measured results can be used in commercial practice for optimizing the pressing process for pressing of oil from grape seeds.

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Contact address:

Patrik Burg, Mendel University in Brno, Faculty of Horticulture, Department of Horticultural Machinery, Valtická 337, 691 44 Lednice, Czech Republic, E-mail: patrik.burg@mendelu.cz

Vladimir Masan, Mendel University in Brno, Faculty of Horticulture, Department of Horticultural Machinery, Valtická 337, 691 44 Lednice, Czech Republic, E-mail: vladimir.masan@mendelu.cz

Kazimierz Rutkowski, University of Agriculture, Faculty of Production and Power Engineering, Institute of Agricultural Engineering and Informatics, ul. Balicka 116 B, pok. 402, 30-149 Krakow, Poland, E-mail: kazimierz.rutkowski@ur.krakow.pl