CHEMICAL ENGINEERING TRANSACTIONS
VOL. 75, 2019
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Sauro Pierucci, Laura Piazza

ISBN 978-88-95608-72-3; **ISSN** 2283-9216
DOI: 10.3303/CET1975004

Use of a Centrifugal Separator to Separate Grape Seeds from Marc: Mechanical Settings and Thermographic Evaluations

Antonia Tamborrino[a]*, Roberto Romaniello[b], Alessandro Leone[b]

[a]Department of Agricultural and Environmental Science, University of Bari Aldo Moro,via Amendola 165/A – 70126 Bari, Italy.
[b]Department of the Science of Agriculture, Food and Environment, University of Foggia, via Napoli, 25 - 71122 Foggia, Italy.
antonia.tamborrino@uniba.it

A centrifugal separator was used to find the best mechanical and electrical settings to separate grape seeds from marc efficiently. Three different reel rotation speeds (400, 500, and 600 rpm) and two different distances between blade and cylinder (A condition = 2.0 mm and B = 10.0 mm) were evaluated, while using a mass flow rate of fresh marc of 300 kg h^{-1}. The data shows that the minor axis length of grape seeds of the Negramaro variety belongs to a normal distribution, and the best separating conditions are obtained by setting a distance of 10.0 mm between reel and cylinder, and with rotation speeds at 400 and 500 rpm. Finally, thermographic analysis can be a useful tool for discriminating machine setting conditions as a function of separation performance.

1. Introduction

Grape marc is the by-product of the winemaking processes for red and white wines, and is composed of three different parts (skins, seeds, and stalks), which at the end of the process requires suitable disposal.
The use of the marc is often conditioned by the laws concerning the disposal of waste or the reuse of by-products, and these laws are often different between different countries. In some countries, as for example in Italy, governmental policies have mandated that wineries must track and record the quantity of marc generated to avoid alcohol distillation not authorized. (Law n. 7407 4/8/2010). For example, until 2010, Italy required fresh and fermented grape marc to be used only for distillation, but now the laws regarding by-products of the wine industry have recently changed, and other uses are permitted.
One common and traditional use of grape marc is producing a grape spirit (ethanol) by means of steam distillation, after the fermentation of available sugars (Silva et al., 2000). However, there are other different utilisations in the world, such as for energy use (Schönnenbeck et al., 2016), in a composting process (Paradelo et al., 2010), or for animal feed (Greenwood et al., 2012). To increase the potential use of the grape marc an elaboration of optimisation strategies for the residue must be performed. In fact, if grape seeds and soft solids (skin and stalk residues) can be properly separated from fresh marc, many other uses could be considered. Different authors reported the potential health benefits of phytochemicals (phenolics, pigments, anthocyanins, and resveratrol) extracted from grape skins (Ferri et al., 2016, Waterhouse et al., 2016). In Binaschi et al. 2018, enzyme treatments on grape skin are investigated not only to enhance phenols extraction but also to assess their influence on the cell wall fraction with the aim of producing innovative antioxidant fibre ingredients for the food industry. Considering the above phytochemicals from grape marc could be conveniently used for food, cosmetics, and pharmaceuticals. In addition, as reported in Bhosle and Subramanian in 2005, grape seeds contain approximately 10%–20% of an oil that can be used in the food, pharmaceutical, and cosmetic fields. This is because it is considered a dietary oil of high quality with a high concentration of unsaturated linoleic acid, vitamin E, and phytosterols, as reported in Beveridge et al., 2005 and Andjelkovic et al., 2005. Le et al. 2018 confirmed that grape oil residue are a highly potential antioxidant source with 19 - 29 mg/L, highlighting the possible uses as an ingredient of functional or enriched foods.
Currently, the separation of soft solids and grape seeds is achieved using a rotary sieve, but these separation technologies are not very efficient, and are only able to work on dried marc (not fresh marc).

Paper Received: 16 June 2018; Revised: 14 September 2018; Accepted: 4 January 2019

The aim of this study is to use of a centrifugal separator to optimise separation of grape seeds and soft solids from fresh marc, and to define the mechanical settings of such a machine.

2. Materials and Methods

2.1 Grape marc characterisation

All of the research activities were carried out in CANTINA DUE PALME s.r.l. (Cellino San Marco, BR, Italy) in September 2018, by using fresh grape marc collected at the end of a red wine process using grapes of the Negramaro variety. Different parts of the marc (skins, seeds, and residuals of stalks) were separated by using standard sieves having holes with different minor diameters (Retsch Test Sieve, Retsch Italia - Verder Scientific S.r.l., Torre Boldone, BG, Italy), and were followed by hand processing until perfect separation was achieved. The separation of the marc was carried out on 4 different samples of 2 kg of fresh marc, sampled during a week of a winemaking process. The moisture of the fractions was determined according to the analytical method of UNI EN 14774:2009.

2.2 Centrifugal separator

The separator (Figure 1) was assembled by the research team using components built by MORI-TEM s.r.l., Tavernelle Val di Pesa (FI, Italy). The machine is constructed in AISI 304 stainless steel.

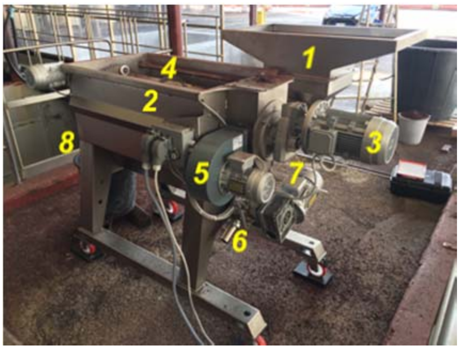


Figure 1: Centrifugal separator during the tests

In Figure 1, all of the following components are shown: (1) hopper for marc loading, (2) seeds/soft solids separation section constituted by a perforated cylinder and reel, (3) 3-phase electric motor having a nominal power of 4 kW, with a gear for driving the reel, (4) scraper of the cylinder connected to the 3-phase electric motor with gear, (5) centrifugal fan moved by the 3-phase electric motor, (6) collection section for the soft solids, (7) pump connected to the 3-phase electric motor with gear for discharge of the soft solids, and (8) seed discharge section. The core of the machine is the seeds/soft solids separation section, comprising the perforated cylinder and reel. Both components are shown in Figure 2.

Figure 2: Perforated cylinder and reel with blades

All tests used a perforated cylinder having holes of 2.0 mm in diameter, a length of 1000 mm, and a minor diameter of 300 mm. Inside the cylinder, there was a reel with 3 blades arranged in a 120° configuration, with three adjustable blades to regulate the distance between blade and cylinder. Each blade was soldered on the reel with a rotation of 2° with respect to the longitudinal axis.
During the work, the marc from the hopper is transferred to the perforated cylinder, where the 3 rotating blades in the reel disrupt the marc and force the soft solids out of the holes, while the seeds run through the cylinder until being discharged at the opposite end of the feeder.

2.3 Experimental plan

Separation tests were carried out by detecting three different rotation speeds of the reel: 400, 500, and 600 rpm, and by setting the frequency of the electric motor connected to the reel. For each rotation speed, the experimental conditions included two different distances between blades and cylinder (A condition: 2.0 mm and B condition: 10.0 mm). Each test condition was evaluated for 0.5 h of operation of the machine, with a flow rate of 300 kg h^{-1}. Each test was replicated four times.
To evaluate the efficiency of the separation by the machine, the seeds of each condition were sampled, and following that, were separated by using standard sieves having holes with different minor diameters (Retsch Test Sieve, Retsch Italia - Verder Scientific S.r.l., Torre Boldone, BG, Italy). Sieves of 3, 4, 5, 6, and 7 mm were used to obtain 6 frequency classes: 2–3 m, 3–4 mm, 4–5 mm, 5–6 mm, 6–7 mm, and 7–8 mm. The frequency distributions of the seeds' minor diameters were compared to a control distribution test. The seeds' minor diameter distribution in the control test was obtained by analysing the seeds separated from the fresh marc, as previously described in chapter 2.1.

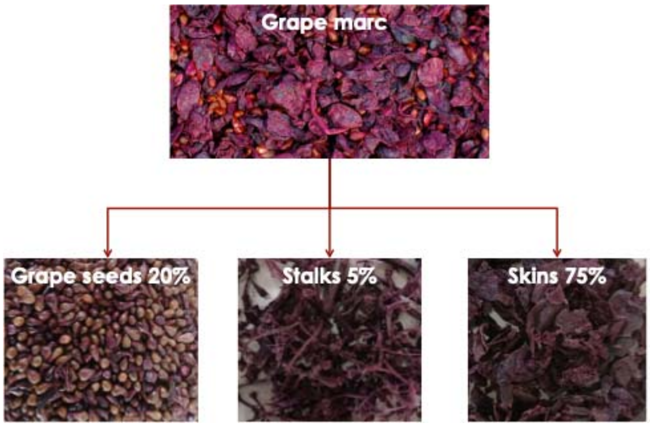


Figure 3: Grape marc composition

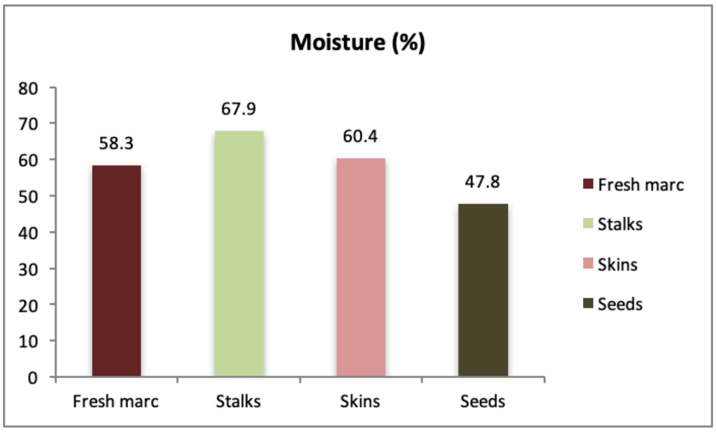


Figure 4: Graphic of the moisture of the marc and its components

2.4 Thermographic evaluations

Thermal images of the machine (perforated cylinder) were acquired to evaluate the performance of the separation. The evaluation of the thermographic profile of the cylinder gave useful information regarding the friction that was caused between the reel and cylinder, which in turn causes crushing of grape seeds.
A set of thermal images were acquired in each trial 25 min after the start of the machine, using a forward-looking infrared (FLIR) Thermacam model E45bx (FLIR Systems, Inc.). This to permit the temperature stabilisation on the cylinder's surface. The acquisition distance was set to 2 m, and a tripod was used to hold the thermal camera in a fixed position with respect to the machine. Temperature profiles were obtained by analysing the thermal images through factory software (FLIR Tools, FLIR Systems inc.).

2.5 Results and Discussion

As shown in Figure 3, the marc composition was 20.0 % seeds, 5.0 % stalks, and 75.0 % skins. In Figure 4, the moisture of the components is reported.

2.6 Minor diameter distribution of the seeds

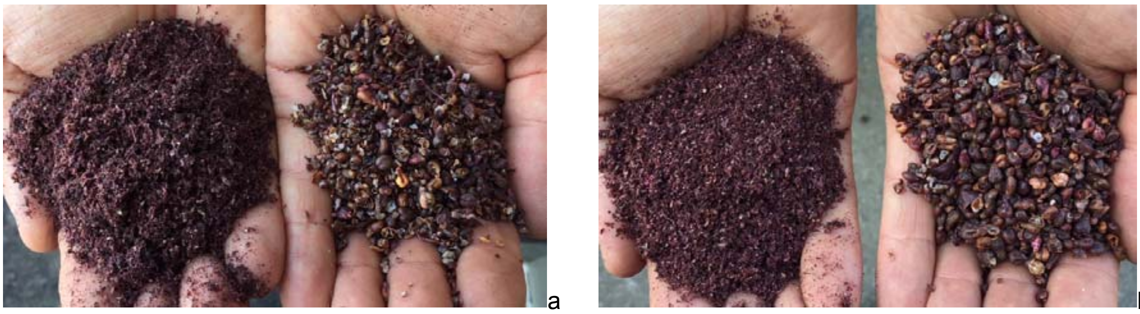
Table 1 shows the density (%) of each frequency class for each condition test, the standard deviation, and a statistical analysis. A T-test between the control test and each condition for each frequency class has been performed at p-level=0.05.

Table 1: Minor diameter distribution of the seeds

Test condition	Density (%) of frequency classes					
	2-3 mm	3-4 mm	4-5 mm	5-6 mm	6-7 mm	7-8 mm
Control	3.65 ± 0.31 a	14.10 ± 1.43 a	40.30 ± 0.48 a	36.20 ± 1.55 a	5.68 ± 0.50 a	0.10 ± 0.14 a
A-condition 400rpm	17.20 ± 4.95 b	46.70 ± 2.59 b	23.80 ± 7.82 b	12.30 ± 1.72 b	0.00 ± 0.00 b	0.00 ± 0.00 a
A-condition 500rpm	51.90 ± 2.46 b	29.10 ± 3.94 b	14.80 ± 3.62 b	4.23 ± 0.80 b	0.00 ± 0.00 b	0.00 ± 0.00 a
A-condition 600rpm	50.40 ± 4.93 b	7.25 ± 3.59 b	40.90 ± 5.05 b	1.48 ± 0.41 b	0.00 ± 0.00 b	0.00 ± 0.00 a
B-condition 400rpm	3.73 ± 1.20 a	15.60 ± 2.14 a	40.60 ± 2.75 a	34.60 ± 1.85 a	5.35 ± 0.31 a	0.15 ± 0.19 a
B-condition 500rpm	3.85 ± 1.13 a	16.50 ± 3.84 a	40.90 ± 5.05 a	34.40 ± 2.20 a	4.15 ± 0.99 a	0.18 ± 0.21 a
B-condition 600rpm	7.60 ± 0.73 b	21.80 ± 3.1 b	54.50 ± 2.64 b	14.40 ± 2.19 b	1.78 ± 0.85 b	0.00 ± 0.00 a

Different letter denotes significant differences (t-test, p<0.05).

In the A condition, for each rotation speed for all frequency classes, there is a significant difference with respect to the control, except for the last class where the density of the control is very low (equal to 0.1). This means that a fraction of the seeds was destroyed by the blade, and that their minor diameter resulted in smaller sizes than the integer-sized seeds. Figure 5a shows the soft solids and the seeds separated in the A condition at 500 rpm. From observing the grape seeds, it is possible to appreciate their high level of breakage and damage. This condition was also found at the other two rotation speeds of the reel, i.e. 400 and 600 rpm (images not shown).



a b

Figure 5 Soft solids and the seeds separated in A-condition (a) and B-condition (b) at 500 rpm

In the B condition (i.e. with the larger distance between blade and cylinder), the 400 and 500 rpm speeds do not show significant differences as compared to the control (Table 1), whereas at 600 rpm, the differences in four out of five classes are significant. This means that by increasing the distance between the blade and the cylinder, it is possible to reduce friction actions that occur on the grape seeds, greatly reducing their breaking. In addition, at 600 rpm, the significant differences as compared to the control indicates that grape seed breaking occurs not because of the friction between blade and cylinder, but probably owing to the impact between blade and seeds caused by the high rotation speed.

In Figure 5b, the soft solids and the seeds are separated in the B condition at 500 rpm. The image shows a greater integrity of the obtained grape seeds as compared to those shown in Figure 5a.
More information regarding the breaking of grape seeds as compared to the cylinder length has been obtained by means of thermographic images. In Figures 6 and 7, the thermographic profiles of the cylinder for the A condition and B condition blade settings are shown, respectively, with both at 500 rpm. Left of the figure there is the loading part and to the right the discharge part.

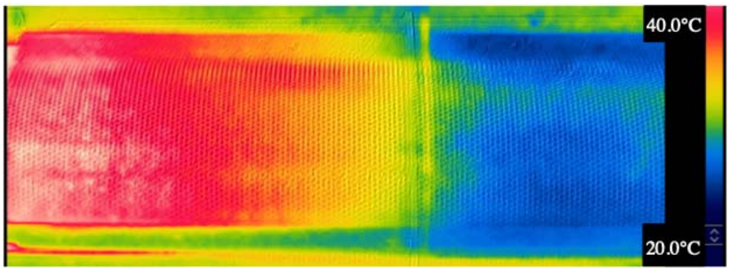


Figure 6 Thermographic profile of the cylinder for A-condition at 500 rpm

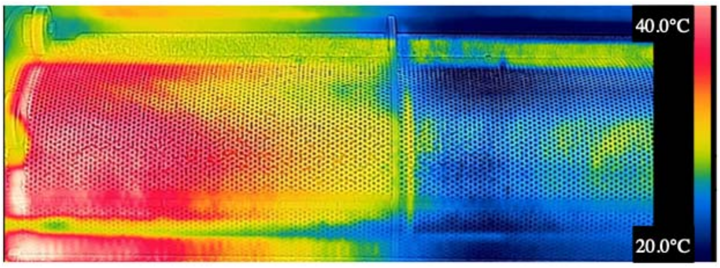


Figure 7 Thermographic profile of the cylinder for B-condition at 500 rpm

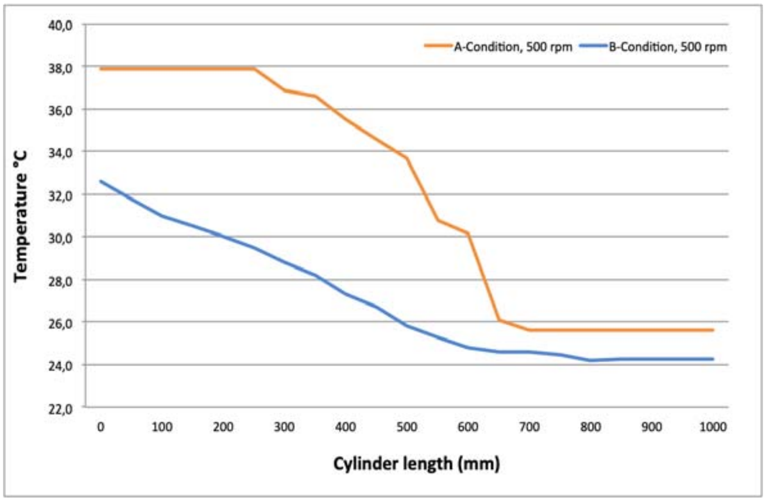


Figure 8 Soft solids and the seeds separated in B-condition at 500 rpm

In Figure 8, the graphic depicts the thermal profile for the cylinder. Comparing the figures 6 and 7 with the graph in figure 8 the thermographic profile shows that at the same rotation speeds of the reel, the temperature difference is 5.3 °C at the beginning of the loading part. Then up to about 250 mm in length of the cylinder, in A-condition the temperature is about 38 ° C, while in B-condition it decrease until about 29 °C. From 250 mm to 650 mm in both configurations there is a decreasing of the temperature. In this stretch of length there is a peak of thermal difference between the two configurations equal to 8.5 °C at 350 mm that decreasing until 5.4 °C at 600 mm.. From 600 mm to the end of the cylinder, both thermal profiles are reduced, with temperatures between about 24 and 26 °C. The thermal profile of the cylinder makes it clear that in the A-condition, most grape seeds break in the first part of the cylinder where the greatest frictions between the blade and cylinder occur, with a consequent heat development above 30 °C. Consequently a higher percentage of broken grape seeds will escape from the cylinder and will be remixed in the soft fraction, this will reduce the percentage of seeds extracted.

3. Conclusions

In this study, the use of a centrifugal separator to separate grape seeds and soft solids from fresh marc was evaluated, and the optimisation of the mechanical settings of the machine were determined.
The study demonstrated that the machine can work by means of an adequate design, and adjustment of the machine to identify the correct distance between blade and cylinder and the right rotation speed of the reel.
Between the two different configurations tested, the configuration that showed the optimal result was the one with the distance between blade and cylinder of 10 mm, while the distance of less than 2 mm increased the percentage of broken seeds and consequently the external temperature of the cylinder.
About the speed of rotation of the reel between the different tested conditions it emerged that up to a speed of 500 mm, in B-condition do not show significant differences for frequency of minor seeds, whereas at 600 rpm, the differences in four out of five classes are significant. The study showed that thermographic analysis can be a useful tool for discriminating the machine setting conditions as a function of separation performance. The development and the improvement of this technology will increase the potential uses of the grape marc, and accordingly increase the economic income of the wine supply chain.

Acknowledgements

This study was funded by Puglia Region “Guidelines for Research and Experimentation in Agriculture 2012–2014”, SOLBIOGRAPE – Mechanical plant solutions for the enhancement of the bioactive component of the grape marc produced in the wine-making process.

References

Andjelkovic D.D., Valverde M., Henna P., Larock F. Li, R.C., 2005, Novel thermosets prepared by cationic copolymerization of various vegetable oils-synthesis and their structure–property relationships. Polymer 46, 9674–9685.

Beveridge, T.H.J., Girard B., Kopp T., 2005, Yield and composition of grape seed oils extracted by supercritical carbon dioxide and petroleum ether: varietal effects. J. Agric. Food Chem. 53, 1799–1804.

Bhosle, B.M., Subramanian, R., 2005, New approaches in deacidification of edible oils – a review. Journal of Food Engineering 69, 481–494.

Binaschi, M., Duserm Garrido, G., Cirelli, C., Spigno, G., 2018, Biotechnological Strategies to Valorise Grape Pomace for Food Applications, Chemical Engineering Transactions, 64, 367-372.

Ferri, M., Bin, S., Vallini, V., Fava, F., Michelini, E., Roda, A., Minnucci, G., Bucchi, G., Tassoni, A., 2016, Recovery of polyphenols from red grape pomace and assessment of their antioxidant and anti-cholesterol activities, New Biotechnol. 33, 338–344.

Greenwood, S., Edwards, G., Harrison, R., 2012, Short communication: Supplementing grape marc to cows fed a pasture-based diet as a method to alter nitrogen partitioning and excretion, J. Dairy Sci. 95, 755–758.

Phung Thi Kim Le, Huy Pham Hoang Vo, Quan Thi Hong Vu, Tuyet Thi Ngoc Nguyen, Kien Anh Le, 2018, Grape Processing By-Product as a Source of Nutraceutical Components. Chemical Engineering Transactions, 63, 205-210.

Paradelo, R., Moldes, A.B., Barral, M.a.T., 2010, Utilization of a factorial design to study the composting of hydrolyzed grape marc and vinification lees, J. Agric. Food Chem. 58, 3085–3092.

Schönnenbeck, C., Trouvé, G., Valente, M., Garra, P., Brilhac, J., 2016, Combustion tests of grape marc in a multi-fuel domestic boiler, Fuel, 180, 324–331.

Silva, M., Macedo, A., Malcata, F., 2000, Review: Steam distilled spirits from fermented grape pomace Revision: Bebidas destiladas obtenidas de la fermentación del orujo de uva, Rev. Agroquim. Tecnol. Aliment., 6, 285–300.

Waterhouse, A.L., Sacks, G.L., Jeffery, D.W., 2016, Introduction to Phenolics, Understanding Wine Chemistry. John Wiley & Sons Ltd., 99–104.

Law n. 7407 4 agosto 2010.

https://www.politicheagricole.it/flex/cm/pages/ServeAttachment.php/L/IT/D/5%252Fa%252F8%252FD.4e04019aa9d12413e631/P/BLOB%3AID%3D3663/E/pdf