

POSSIBILITIES OF USING GRAPE MARC FOR MAKING FUEL PELLETS

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Abstract. The paper called 'Possibilities of using grape marc for making fuel pellets' is focused on the topic of efficient usage of grape marc as a renewable energy source. From a global point of view, grapevine pressings, a byproduct of the wine industry, present a significant source of biomass. The organisation Internationale de la Vignette et du Vin (OIV) estimates that there are over 66.5 mil. tons of grapevines manufactured globally, from which 38 mil. tons in Europe. This means that only in European conditions, there are approximately 8 mil. tons of grape pomace produced. Empirical measurements took place in the years 2013-2015 at grape marc samples from viticulture subjects in the wine-growing area Morava. The results of this paper are divided into two main parts – grape marc usage for energy purposes and for pellet production. There was implemented a wide range of calorimetric measurements of combustion heat and calorific power of grape marc in its original state, grape marc after seed separation (assumption of oil pressing usage), and in seeds themselves. The results indicate that the heating power varies between 16.07-21.14 MJ·kg⁻¹. The highest heating power values were stated by seeds and grape marc in its original state. It could be presumed that the main reason is rather high oil component in grapevine seeds. Moreover, the measurement set was supplemented by results focused on grape marc usage for pellet production. Different proportions of dried grape marc combined with wine shoots and hay were used as the input materials. The measured values imply that the highest heating power (19.22 MJ·kg⁻¹) was obtained from pellets composited from 60 % grape marc, 20 % wine shoots, and 20 % hay. Their apparent density is 630.9 kg·m⁻³. The produced pellets correspond with the norm CSN EN 15210-2 from the perspective of mechanical ruggedness.

Keywords: grapevine, grape pomace, calorific value, grape pomace pelletizing.

Introduction

On a global scale, grapevine is grown on the area of 7,519,000 hectares. Spain has the largest area of vineyards in Europe – 1,000,000 ha, France – 800,000 ha, Italy – 769,000 ha and Portugal – 239,000 ha [1].

The production of grape and its processing in the production of wine is closely related to the production of grape marc. During compressing of 1,000 kg of grapes, in the processed product, there are contained stems in the amount of 40-60 kg, grape marc in the amount of 230-300 kg, the rest is pressed must. Marc itself consists of remnants of pulps, peels, seeds and in some cases even of stems, which together represent approximately one quarter of the mass of grapes [2]. Schieber et al., Baydar et al. and Rubio et al. [3-5] also state that from the total quantity of processed grapes, the share of marc creates, depending on the variety, degree of ripeness, used pressing equipment, quantity of pressing cycles, up to 15-25 % of the volume weight 400-800 kg·m⁻³ and moisture between 30 to 50 %.

Legislative regulations of the EU and increasingly stricter regulations of the Czech Republic in the field of waste management lead to searching of new waste-free technologies, which would provide effective and efficient use of waste products from production processes [6]. In terms of waste management, marc represents secondary biotic waste produced in the sector Food-Drink-Milk, which cannot be disposed to municipal waste landfills [7].

In the past few years, in central European conditions, the attention has been focused on possibilities of effective utilization of marc as an energy source for direct combustion or as an input material for biogas plants.

There is available a large amount of literature sources about the calorific value of materials from the wine production, e.g., grapevine, which is stated in the works of [8; 9]. However, in relation to grape marc, these data appear quite sporadically [10].

The objective of the work is to determine the combustion heat and calorific value of grape marc by the calorimetric method, including evaluation of its use in the production of pellets.

Materials and methods

Grape marc of evaluated varieties

The subject of the research was grape marc from selected must varieties of grapevine. With regard to the varietal composition of vineyards in the Czech Republic, there were selected varieties with the highest proportion of plantations, in which we can assume their real use in the operational practice. With regard to the varietal composition in cooperating subjects, there was carried out collection and analysis of grape marc samples in the years 2013-2015 of the following varieties: Grüner Veltliner (VZ), Müller Thurgau (MT), Rhine Riesling (RR), Welschriesling (RV), St. Laurent (SV), Blaufränkisch (FR), Zweigeltrebe (ZW) and Blauer Portugieser (MP).

Determination of the energy value of grape marc

The energy value of grape marc was verified by a set of calorimetric measurements in order to determine the combustion heat and calorific value. These measurements were carried out in grape marc in the original condition, grape marc after separation of seeds (intended to be used for oil extraction) and grape seeds themselves, always in triplicate.

The determination of the combustion heat for solid biofuels was carried out according to the standard CSN P CEN/TS 14918. The prerequisite of determination is the analysis of elementary composition, which was provided through the TOC/TN analyser multi N/C 2100S and the gas chromatograph Trace GC ultra. In all analysed samples, there was simultaneously determined dry mass according to the standard CSN EN 14346.

For the determination of the calorific value, there was used the calorimeter Anton Parr 6400, for the accurate determination of the weight of a combusted sample there was used the analytical weighting machine Ohaus Adventurer Pro AV264C. The obtained combustion heats were in accordance with CSN ISO 1928 calculated to the calorific value according to formula 1.

$$Q'_i = Q'_s - \gamma \cdot (W'_t + 8,94 \cdot H'_t), \quad (1)$$

- where Q'_i – calorific value of the evaluated sample, MJ·kg⁻¹;
 Q'_s – gross heating value of the original sample, MJ·kg⁻¹;
 γ – ratio of evaporation of 1 % H₂O, MJ·kg⁻¹, at temperature 25 °C, $\gamma = 0,02442$ MJ·kg⁻¹;
 8.94 – hydrogen to water conversion ratio;
 W'_t – total water content in the original sample, %;
 H'_t – total hydrogen content in the original sample, %.

Use of grape marc for the production of pellets

The production of pellets was carried out on the pelletizing line MGL 400. For purposes of the experiments, there were selected three input materials, i.e. grape marc (humidity 10 %), grape cane (humidity 11 %), and hay (humidity 15 %). These materials were mixed together to form a mixture with various percentage of grape marc:

- Variant 1 (60 % grape marc, 20 % grape cane and 20 % hay);
- Variant 2 (50 % grape marc, 25 % grape cane and 25 % hay);
- Variant 3 (40 % grape marc, 30 % grape cane and 30 % hay).

For the pellets made in this way, there was carried out the determination of mechanical ruggedness, apparent density, combustion heat and the calorific value.

By the mechanical ruggedness, there is measured shock proofness of pellets and attrition resistance caused by handling and transport. During manipulation of pellets, there may occur the formation of fragments and dust particles, which may lead to unstable combustion and due to the formation of dust particles, there increases the risk of explosion.

During testing, a pellet sample is subjected to controlled bumping by mutual smashing of pellets to chamber walls in a defined rotating testing drum. From the weight of the sample remaining after the separation of abraded and firmly shredded particles, there is calculated the mechanical ruggedness according to formula 2.

$$M_o = \frac{M_p}{M_k} \cdot 100, \quad (2)$$

where M_o – mechanical ruggedness, %;
 M_p – weight of sieved pellets before rotating in a drum, g;
 M_k – weight of sieved pellets after rotating in a drum, g.

The apparent density, together with the calorific value, is used for the determination of the energy density. In practice, it enables to evaluate the required storability and space requirements during transportation. The determination of apparent density is carried out according to CSN P CEN/TS 15103. It is determination of the weight of biomass after pouring into a standard container and weighting. The apparent density is expressed in $\text{kg} \cdot \text{m}^{-3}$.

Results and discussion

In Table 1, there are stated mean values of elementary composition of the evaluated samples of grape marc and seeds from white and blue must varieties of grapevine, which were used for the determination of the calorific value from the combustion heat.

Table 1

Mean values of elementary composition of grape marc and seeds

Evaluated samples	Mean values of observed attributes					
	C, %	H, %	O, %	N, %	S, %	ash, %
Grape marc – white varieties	52.9	5.82	34.24	0.55	4.12	2.25
Grape marc – blue varieties	41.34	5.95	44.91	0.67	3.37	3.51
Grape seeds - mixture	51.55	5.97	38.42	1.47	3.96	1.92

In Figure 1, there are stated the average calorific values for the two-year period, which were calculated in accordance with CSN ISO 1928, based on the determined values of combustion heat in the evaluated samples of grape marc in the original state, grape marc after separation of seeds and seeds themselves.

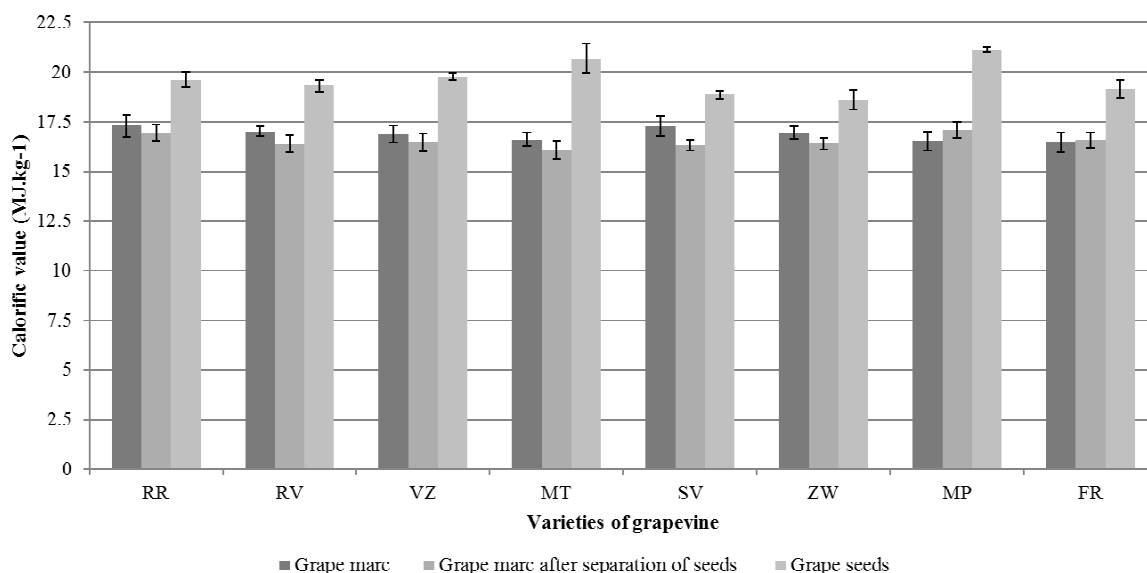


Fig. 1. Calorific values in evaluated samples

Figure 1 implies that the highest calorific values were determined in seeds themselves, where the maximum was reached by the variety Blauer Portugieser $21.14 \text{ MJ} \cdot \text{kg}^{-1}$. Conversely, the lowest calorific values were determined for grape marc after separation of seeds, where it reached the value $16.07 \text{ MJ} \cdot \text{kg}^{-1}$ in the variety Müller Thurgau.

It is clear from the data about the calorific value of grape marc carried out in the previous measurements, that it is a material with a very good calorific value, which is comparable with the

calorific values of, e.g., cereals ($18.00 \text{ MJ}\cdot\text{kg}^{-1}$) or brown coal ($18.10 \text{ MJ}\cdot\text{kg}^{-1}$), it even exceeds the calorific value of wood chips ($12.50 \text{ MJ}\cdot\text{kg}^{-1}$) and wood ($14.60 \text{ MJ}\cdot\text{kg}^{-1}$). Annamalai et al. [11] also state calorific values of grape marc at the level $20.34 \text{ MJ}\cdot\text{kg}^{-1}$. Available literature sources imply that in countries with developed viticulture, there are verified methods of grape marc use in the production of briquettes and pellets. The main problem in these technologies is high humidity of grape marc. For example in Italy, this state is solved by natural drying of grape marc under ventilated sheds. In Germany, there appear references about the use of waste heat from biogas plants or equipment for regulation of temperature during fermentation. In the Czech Republic, this technology has not been solved yet.

For these reasons, the latter part of the experimental measurement was oriented to the production of pellets from crushed grape cane, hay and grape marc in varying percentage representation. All measurements were performed in the year 2015 in an accredited laboratory of MENDELU in Brno. During testing of the mechanical ruggedness, the pellets were weighted according to the applicable methodology, sieved and inserted into a testing drum, where mechanical abrasion occurred. There were always three samples of pellets from each experimental variant tested. Table 2 states the obtained results, which were compared to the limit value, which is stated by the Czech standard CSN EN 15210-2.

Table 2

Values of mechanical ruggedness of pellets

Pellets – material composition	Average value of mechanical ruggedness, %	Limit value of mechanical ruggedness according to CSN EN 15210-2, %
Variant 1	96.82	96.50
Variant 2	96.69	
Variant 3	96.15	

According to the standard CSN EN 15210-2 Solid biofuels – specification and fuel classes – part 2: wood pellets for non-industrial use, there is permitted the mechanical ruggedness of 96.5 %. The results imply that the variants 1 and 2 meet this condition, where the values of mechanical ruggedness range between 96.69-96.82 %. Only the variant 3 with the lowest share of grape marc did not meet the requirement of the standard (40 %), where the values of mechanical ruggedness amounted to 96.15 %.

Benetto et al. [12] state that grape marc is responsible for better adhesion of pellets and it also prevents disintegration of the material in the process of pressing thanks to the pulp content in peels. Miranda et al. [13] state that with an increasing share of grape marc in pellets, there is a decreasing share of ash. On the other hand, pellets with a higher proportion of grape marc show higher values of fixed carbon [14].

In Table 3, there are stated average values of apparent density of the evaluated pellet samples.

Table 3

Values of apparent volume density

Pellets – material composition	Average value of apparent density, $\text{kg}\cdot\text{m}^{-3}$	Standard deviation
Variant 1	630.90	15.90
Variant 2	621.37	3.57
Variant 3	619.27	3.16

As the results of measuring imply, the apparent density ranged between $619.27\text{-}630.90 \text{ kg}\cdot\text{m}^{-3}$. For example, Larsson, Rudolfsson [15] state that an important parameter of pellets from the perspective of their requirements for storage is apparent density, which usually ranges between $550\text{-}750 \text{ kg}\cdot\text{m}^{-3}$.

In Table 4, there are stated the calorific values of the pellets according to individual variants.

The results show that the highest calorific value ($19.22 \text{ MJ}\cdot\text{kg}^{-1}$) is produced by the pellets of the variant 1, which consist by 60 % of grape marc, 20 % of grape cane and by 20 % of hay, conversely,

the pellets of the variant 3 have the lowest calorific value ($17.36 \text{ MJ}\cdot\text{kg}^{-1}$), which consist by 40 % of grape marc, 30 % of grape cane and 30 % of hay. Thus, based on the results, there is the evident influence of grape marc share on the calorific values of the evaluated pellet variants. A statistically significant difference at the chosen level of significance ($\alpha = 0.05$) was proved between the variant 1 and the variant 3, as stated in Fig. 2.

Table 4

Calorific values of pellets

Pellets – material composition	Calorific value, $\text{MJ}\cdot\text{kg}^{-1}$				
	1 st repeating	2 nd repeating	3 rd repeating	Average	Standard deviation
Variant 1	19.21	19.39	19.05	19.22	0.34
Variant 2	18.06	18.05	18.98	18.37	0.10
Variant 3	17.49	17.58	17.01	17.36	0.06

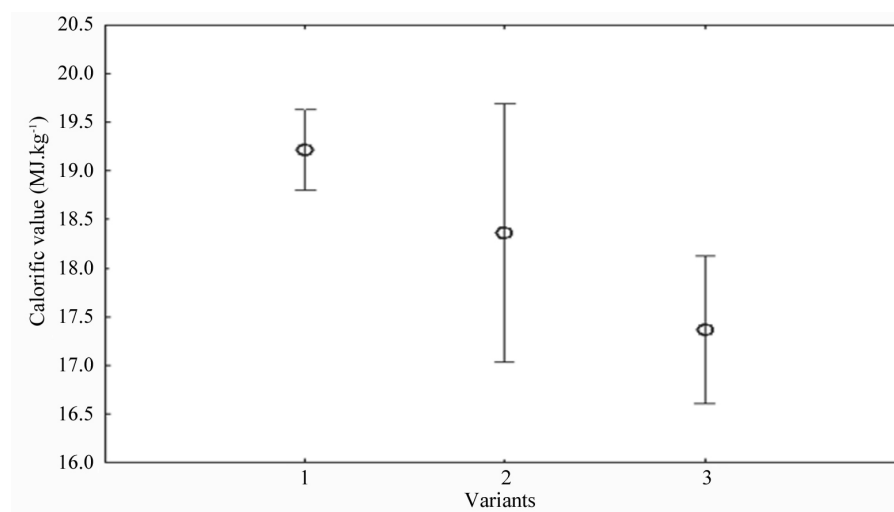


Fig. 2. Results of ANOVA evaluation of the calorific value of pellets

For example, Prozil et al. [16] carried out determination of the calorific value of pellets made of grape stems. The results of his measurement imply that these pellets had the calorific value $16.7 \text{ MJ}\cdot\text{kg}^{-1}$. McCormick, Kåberger and Freppaz et al. [17; 18] dealt with the issue of energy use in various alternative sources of energy. The results of their work imply that the calorific value of pellets from fast growing trees was around $18.5 \text{ MJ}\cdot\text{kg}^{-1}$, pellets from crop biomass at the level of $16 \text{ MJ}\cdot\text{kg}^{-1}$, pellets from peat at the level of $20.3 \text{ MJ}\cdot\text{kg}^{-1}$ and pellets from pomace $14.2 \text{ MJ}\cdot\text{kg}^{-1}$. Souček et al. [8] dealt with the evaluation of the calorific value of another waste product of vineyard production, which is grape cane obtained from winter cutting of vineyard with humidity under 10 %. The calorific values of individual varieties were stated in a range from $14.39\text{-}16.66 \text{ MJ}\cdot\text{kg}^{-1}$.

Conclusions

1. The energetic value of grape marc was verified by a set of calorimetric measurements, in which there were stated the values of combustion heat and calorific values. Thanks to the obtained results, there was confirmed the hypothesis about high calorific values of grape marc. Depending on the nature of the tested sample – grape marc in the original state, grape marc after separation of seeds and seeds themselves, it ranged between $16.07\text{-}21.14 \text{ MJ}\cdot\text{kg}^{-1}$.
2. The conducted measurement showed the possibility of usage of grape marc together with other kinds of input materials (hay, grape cane) for the production of pellets.
3. In testing of mechanical ruggedness of pellets, the variant 3 did not meet the limit value 96.50 % according to CSN EN 15210-2, consisting by 40 % of grape marc, 30 % of grape cane and 30 % of hay.
4. The values of apparent density in all three experimental variants ranged between $619.27\text{-}630.90 \text{ kg}\cdot\text{m}^{-3}$

5. For the pellet samples, there was determined the calorific value ranging between $17.36 \text{ MJ}\cdot\text{kg}^{-1}$ in the variant 3, to $19.22 \text{ MJ}\cdot\text{kg}^{-1}$ in the variant 1. Between these variants, there was carried out the variance analysis at the level of significance ($\alpha = 0.05$), which proved a statistically significant difference.

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