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THE POSSIBILITIES OF USING MARC FOR MANUFACTURING PELLETS FOR ENERGY PURPOSES

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Abstract

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The contribution describe the possibilities of using marc for manufacturing pellets for energy purposes. Experiments associated with pellet production were performed in several variants. Biomass pellet variants consisted of different percentages of vine shoots from vineyards, as well as marc and hay. These test variants were measured for their calorific value, which ranged between 17.36 and 19.21 $MJ.kg^{-1}$. Bulk density was also determined, ranging between 619.27 and 630.9 $kg.m^{-3}$. Pellets produced with marc content were also tested for mechanical durability, which was between 96.15 and 96.82% for the test variants. The calorific value, alongside other parameters assessed, shows favourable characteristics towards use in combustion processes. The results obtained show that in terms of the parameters analysed, marc pellets could be an attractive commodity for combustion.

Keywords: vineyard, grape pomace, calorific value, pellets, bulk density, mechanical durability of pellets

INTRODUCTION

The current global energy system is based mainly on the use of fossil fuels. The growing energy consumption, high dependency on fossil fuels and negative impact on the environment have lead the European Union to re-evaluate its energy policy and strategies while adopting a number of measures. These measures are directed mainly towards using renewable energy sources, decreasing carbon dioxide emissions, decreasing the dependency on imported energy sources, diversifying energy sources and increasing international cooperation (Berndes *et al.*, 2003; Mantzos and Capros, 2006). The EU strategies relating to renewable energy include mainly the use of biomass, which by 2020 should represent more than 50% of total renewable energy sources in the EU-27 countries (Bentsen and Felby, 2012).

Prozil (2012) states that biomass from forestry and agriculture is finding use as an alternative energy source mainly in household heating and electricity production. In recent years, attention is being directed more and more towards the use of waste biomass from viniculture and wine-making, which represent a significant production sector in the EU (Freppaz *et al.*, 2004; Baydar *et al.*, 2007; Miranda *et al.*, 2011). Waste products produced regularly every year in large amounts include vine shoots after winter cutting of grapevine and marc produced during grape processing (Walg, 2007; Tangolar *et al.*, 2009).

An interesting alternative in the use of these resources in the area of bioenegetics is their pelletization. To obtain quality pellets, it is necessary to respect the mutual ratios of the input materials and their moisture content, which must not be higher than 14% (Burg *et al.*, 2015). Pastorek *et al.* (2004) states that the materials must be sufficiently homogenized and disintegrated.

Pellets are pressed at high pressure on extrusion breakers or can be produced on granular foodstuff production lines (Allen *et al.*, 1998).

The energy requirements for pelletization depend on the production technology, especially the output of the pellet production line. From the input material, in which approximately 3.6 kWh (1.6–1.8 kg) of energy is accumulated, it is possible to produce 1 kg of pellets with a calorific value of 4.8 kWh.kg^{-1} (McCormick and Kåberger, 2007).

The goal of the study is to explore the possibilities of using marc for pellet production for energy purposes and evaluate their selected mechanical-physical properties.

MATERIALS AND METHODS

Chemical Analysis of the Elemental Composition of Marc

The elemental composition, ash content, moisture content and sulphur content of vine shoot biomass were determined according to EN 15104:2010, EN 14775:2009 and EN 14774-1:2009 standards using a TOC/TN analyser multi N/C 2100S with HT 1300 furnace and Trace GC ultra gas chromatograph.

Characteristics of the Pellet Production Line

The pellet production made use of an MGL 400 pellet production line consisting of a screw dosing device with closed funnel, a stirrer, a pellet press, a pellet sorter with a cooler, a suction system and an electric switchboard. The electric input power of the MGL 400 line is 19 kW, power output when using 6 mm holes in the matrix is between 80 to 280 kg.h^{-1} depending on the type of the processed material.

Determination of the Heat of Combustion and Calorific Value

One of the most important parameters of biomass are the heat of combustion value and the calorific value. Determination of the heat of combustion for solid biofuels is performed according to the ČSN P CEN/TS 14918 and DIN 51 900-3 standards. The principle lies in the determination of the heat of reaction, which is released during the combustion of solid biofuels. Based on Hess's law, which determines the relationship between the heat of reaction and heat of formation, and on the knowledge of the composition of the fuel and its products of combustion, we can then calculate the heat of combustion and the calorific value of the fuel.

In the evaluated samples of pellets, dry matter determination was performed according to the ČSN EN 14346 standard. Dry matter determination made use of the LMH 07/12 muffle furnace. For the determination of the heat of combustion, an Anton Parr MCR 6400 calorimeter was used. Accurate measurement of the weight of the sample to be combusted was performed using analytical balance Ohaus Adventurer Pro AV264C.

The heat of combustion values obtained were converted to the calorific value using relation (1):

$$Q_i^r = Q_s^r - \gamma \,.\, (W_t^r + 8.94 \,.\, H_t^r)\ [\mathrm{MJ.kg^{-1}}], \qquad (1)$$

where

Q_s^r........heat of combustion of the original sample [MJ.kg^{-1}],

γ...........coefficient corresponding to the heating and evaporation of 1% H_2O [MJ.kg^{-1}] at a temperature of 25 °C; γ = 0.02442 MJ.kg^{-1},

8.94.....coefficient of the conversion of hydrogen weight to water [–],

W_t^r.......total water content in the original sample [%],

H_t^r........hydrogen content in the original sample [%].

Determination of the Mechanical Durability of the Pellets

Mechanical durability measures the durability of pressed fuels against impact or abrasion due to handling and transport. The test sample of pellets was subjected to controlled impacts against the walls of a chamber in a rotating testing drum. From the weight of the sample which remains after removing the abraded or finely crushed particles, the mechanical durability is calculated.

Samples for the determination of mechanical durability are taken in accordance with CEN/TS 14778 and are distributed via quartation according to CEN/TS 14780 into 4 equal portions. The minimum permissible weight of the sample is 2.5 kg. One portion is used for the determination of the total water content in accordance with CEN/TS 14774, part 1 or 2. The two remaining portions are weighed and manually sifted through a sieve; the undersize is separated Sifting is performed in such a way as to separate the fine particles but prevent the creation of new ones during the process. This is usually achieved by shaking 1 to 1.5 kg of the sample portion and rotating a sieve with a 400 mm diameter five to ten times. The amount of pellets on the sieve is weighed and the original amount of particles in the samples which passed through the 3.15 mm sieve is calculated and expressed as a mass fraction in %.

The retrieved test portion of sifted pellets, weighed with a 0.1 g accuracy is placed into a rotary drum and rotated 500 times at a speed of 50 rpm. After completion, the sample is taken out and manually sifted through a sieve. The same procedure as with the first sifting is followed; the only difference is that shaking is performed with 0.5 kg of the test portion. The sifting must be complete. The sample on the sieve is weighed and the percentage of whole pellets is calculated.

The mechanical durability is expressed by equation (2):

$$M_o = \frac{m_p}{m_k} \cdot 100\,, \qquad (2)$$

where
M_o ....mechanical durability [%],
m_p ....weight of the sifted pellets before rotation in the drum [g],
m_k ....weight of the sifted pellets after rotation in the drum [g].

Determination of the Total Bulk Density

Bulk density along with the calorific value is used for the determination of energy density. This in practice allows the evaluation of the required storability or space requirements during transport. Determination of the bulk density is performed according to ČSN P CEN/TS 15103. It is the determination of the weight of biomass after pouring into a standardized container and weighing. Therefore, when determining the bulk density, it must be taken into account whether the test is conducted for pellets or briquettes, which differ from each other in size. Based on this, it is also necessary to obtain a container of proper size, and suitable scales. Bulk density is expressed in $kg.m^{-3}$.

RESULTS AND DISCUSSION

Tab. I lists the median values of the elemental composition of the evaluated mixed samples of marc from white must grapevine varieties. The moisture content of the analysed samples of marc was between 8.86 and 9.51% after drying.

Marc was used as one of the input raw materials for the production of pellets along with vine cuttings and hay. The experiment was performed in 3 variants with different amounts of these materials, as shown in Tab. II. Before filling into the hopper, the materials were first ground using a stationary grinder SG–3060 with output of up to 220 $kg.h^{-1}$. The pellet production line reached an output of 110 to 128 $kg.h^{-1}$.

Representative pellet samples from individual test variants were retrieved and analysed using an Anton Parr MCR 6400 calorimeter. The measured heat of combustion values were then used to calculate the calorific value of the pellets, as shown in Tab. III.

To evaluate the conclusiveness of the differences between the test variants evaluated, a variance analysis was performed (significance level $\alpha = 0.05$). Tukey's HSD test was employed as a subsequent testing method with significance level $\alpha = 0.05$. The results of the statistical evaluation (Tab. IV, Fig. 1) show that the influence of marc on the calorific value of pellets is statistically significant.

The results indicate that pellets consisting 60% of marc, 20% of vine shoots and 20% of hay have an average calorific value of 19.22 $MJ.kg^{-1}$. The second highest calorific value is in pellets made 50% of marc, 25% of vine shoots and 25% of hay, reaching an

I: *Median values of the elemental composition of marc*

Variety	C [%]	H [%]	O [%]	N [%]	S [%]	ash [%]
Mixed sample of white varieties	52.91	5.88	34.20	0.51	3.90	2.19

II: *Amount of individual materials in the selected mixture*

Variant	Marc share [%]	Shoots share [%]	Hay share [%]
1	60	20	20
2	50	25	25
3	40	30	30

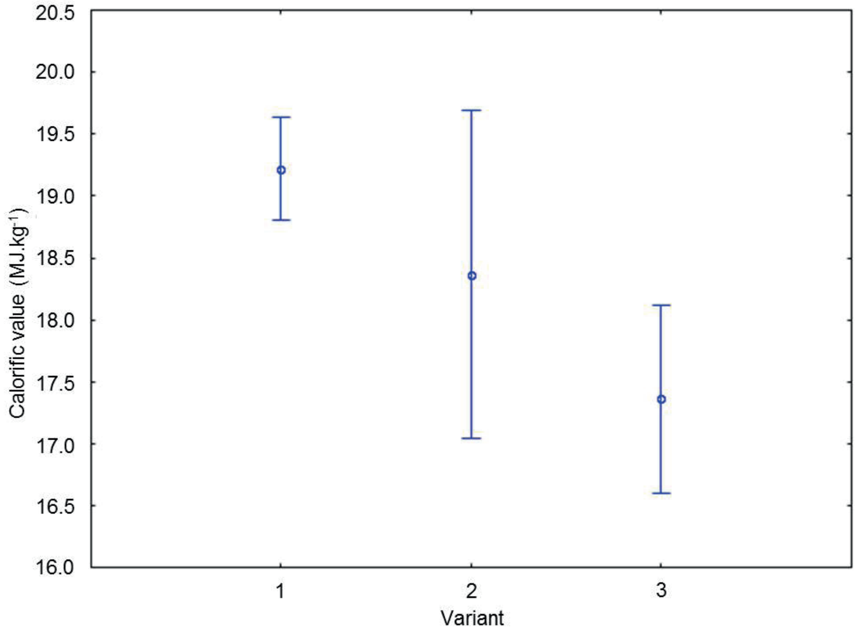
III: *Calorific values of pellets*

Material composition of pellets	Calorific value [$MJ.kg^{-1}$]				
	1. repetition	2. repetition	3. repetition	Average	Standard deviation
Variant 1	19.2171	19.3866	19.0510	19.2188	0.34
Variant 2	18.0595	18.0538	18.9821	18.36513	0.10
Variant 3	17.4954	17.5780	17.0131	17.36217	0.06

IV: *Subsequent testing method – Tukey's HSD*

Number	Tukey's HSD test; Variable 2 (Tab. I) Error: intergroup mean square = 0.13558, degrees of freedom = 6,0000			
	Variable 1	Variant 1 19.218	Variant 2 18.365	Variant 3 17.362
1	1		0.066718	0.002187**
2	2	0.066718		0.036233*
3	3	0.002187**	0.036233*	

*Note: * indicates significantly different pairs; ** indicates very significantly different pairs*



1: *Graphical representation of the average pellet calorific values*

V: *Pellet mechanical durability values*

Pellets based on the mixture used	Mechanical durability (%) by	
	Austrian standard	ČSN EN 15210-2
Variant 1	98.30	96.82
Variant 2	98.15	96.69
Variant 3	97.68	96.15

average value of 18.37 MJ.kg^{-1}. The lowest calorific value, 17.36 MJ.kg^{-1}, was measured in pellets consisting of 40% marc, 30% vine shoots and 30% hay.

For example, Ping *et al.* (2011) performed a determination of the calorific value of pellets made of vine stalk. The results have shown that these pellets have a calorific value of 16.7 MJ.kg^{-1}, which is lower than that obtained from soft wood, 18.2 MJ.kg^{-1}. Van Loo (2003) assessed the calorific value of pellets depending on the waste material used. The measured calorific value of pellets made of peat was 20.3 MJ.kg^{-1}, from wheat straw 17.23 MJ.kg^{-1} and from spruce 18.69 MJ.kg^{-1}.

Pellets produced with marc content were also tested for mechanical durability. This test is one of the most important parameters. All the measurements were performed in the accredited laboratory of the Crop Research Institute in Prague. When handling pellets, chips and dust particles may be created which lead to unstable combustion; dust particles also increase the risk of explosion. In accordance with proper methodology, the pellets were weighed, sifted and placed in a testing drum, where mechanical abrasion was performed. Three samples of each variant of the pellets produced were tested. The results of the samples were added up and the arithmetic mean was determined. The results were substituted into formula (2) for the calculation of mechanical durability and the values for mechanical durability of the individual pellet types were calculated for Austrian and Czech standards (Tab. V).

The abrasion of pellets should not exceed 2.3% of the weight for DIN 51731, DIN Plus and ÖNORM M7135 and the mechanical durability according to ČSN P CEN/TS 15210 should not be less than 90%. According to ČSN EN 14961-2 Solid biofuels – Fuel specifications and classes – Part 2: Wood pellets for non-industrial use, an acceptable mechanical durability is 96.5%. The results indicate that the pellets based on the mixture Variant 1 a 2 produced from marc fulfil these requirements. Sladký *et al.* (2002) states that marc is responsible for better cohesiveness of pellets and prevents the breakdown of the material during the pressing process thanks to the cellulose content in the skins. Annamalai *et al.* (1987) and Miranda *et al.* (2011) state that with increasing share of marc in pellets, the ash content decreases. On the other hand, pellets with higher marc content show higher values of fixed carbon.

Maga (2008) states that an important parameter of pellets in terms of their requirements for storage capacity is the bulk density, which is usually around 550 to 750 kg.m^{-3}. The results of the evaluation of bulk density in the pellets studied are listed in Tab. VI.

VI: *Bulk density values*

Material composition of pellets	Bulk density [kg.m^{-3}]				
	1. repetition	2. repetition	3. repetition	Average	Standard deviation
Variant 1	615.3	635.5	646.7	630.9	15.9
Variant 2	615.7	621.7	620.4	619.27	3.16
Variant 3	620.1	625.4	618.6	621.37	3.57

CONCLUSION

Pellet production has a number of ecologically and economically positive aspects. Aside from the obvious economically positive balance, pelletization allows the use of waste which would otherwise end up in a dump or would remain unused. The aim of the study was to study the possibility to use marc for the production of pellets for energy purposes and asses their selected mechanical-physical properties. An analysis of pellets consisting of a mixture of marc, vine cuttings and hay was performed. The results obtained show that the highest calorific value (19.22 MJ.kg^{-1}) is achieved by pellets consisting of 60% marc, 20% vine cuttings and 20% hay. The results have confirmed the hypothesis that the calorific value of pellets is dependent on their quality and composition. The calorific value, alongside other parameters assessed, shows favourable characteristics towards use in combustion processes. The results obtained show that in terms of the parameters analysed, marc pellets could be an attractive commodity for combustion.

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