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COMPARISON OF ASH CONTENT IN VINEYARD PRUNING RESIDUES FROM MORAVIAN REGION

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This study presents the thermogravimetric analysis results of various samples of vineyard pruning residues from Rakvice Stand in the Moravian viticultural region. The samples of Welschreising, Grüner Veltliner, Gewürztraminer, and Palava were investigated in several heating-isotherm steps. Based on the results, three of these samples were found to not meet the conditions for the B category ($\leq 3\%$) according to the EN ISO 17225 in terms of ash content. Only the Palava sample showed 2.76% of ash content in dry matter, which makes it suitable for technological applications, such as combustion in small residential biomass boilers. Considering the other samples, the results indicate that it is more appropriate to combust them as a part of mixture with added content of different wood biomasses.

Keywords: thermogravimetry; grapes; biomass; decomposition

Energy consumption is increasing worldwide, with estimated 30% increase in consumption by 2040 (IEA, 2017). For this reason and issues associated to it, the European Union Renewable Energy Directive (RED) 2009/28/EC was established, obliging the EU to increase the share of renewable energy in gross final energy consumption from 8.5% to 20% by 2030 (Gerritsen, 2015).

Utilization of targeted biomass (SRCs – short rotation crops, maize monocultures, etc.) brings significant environmental impacts, such as biodiversity change, land-use change, food availability, etc. (Gallagher, 2008; Popp et al., 2014; Genbach et al., 2018). A more suitable approach would be to utilize the secondary products from agriculture, forestry, and other activities as renewable energy sources. Such exploitation of these residue materials can bring environmental, economic and energy benefits (Spöttle et al., 2013; Dhaundiyal and Hanon, 2018). Furthermore, the costs arising due to processing of these residues can be compensated by the profit from the energy obtained. Pruning vineyard residues can be considered such a source. In addition to this, grapes are also profitable crops in the country (Alves et al., 2019). The residues of agricultural products, especially biomass by-products from vineyards, are used as a strategic fuel source of in many European countries (Beccali et al., 2009; Velazquez-Marti et al., 2011; Scarlat et al., 2011).

Burning of plant residue of this nature in an open fire is a worldwide and long-term bad practice. This is a fast and cheap method of processing large volumes of material residue, yet it is not environmentally friendly (Alves et al.,

2019); moreover, the emissions from this type of burning have negative impacts on air quality, human health, and environment (Chen et al., 2017; Zhao et al., 2017; Liu et al., 2018; Malaťák et al., 2020). Therefore, it is advisable to carry out the burning under controlled conditions in boilers. In order to facilitate the feeding of these materials prior combustion in boilers, they can be either pelletized or chipped (Holubčík et al., 2018; Hamedani et al., 2019).

The relatively high ash and moisture contents can cause issues to small residential biomass boilers (Zanetti et al., 2017). The yield of vineyard pruning residue material can reach up to approx. $1 \text{ t} \cdot \text{ha}^{-1}$, making it suitable for application in boilers under domestic conditions. However, Zanetti et al. (2017) measured ash content of vineyard pruning residues (3.3–5.5%) and compared it with biomass wood ash content (0.4%), coming to conclusion that these values can represent a limiting factor to proper operation of these types of boilers. Nevertheless, according to Spinelli et al. (2012), these materials can still be exploited under industrial conditions despite their high ash contents.

The aim of this study is to determine the contents of ash, moisture, and volatiles. These results, especially the ash content result, can be used in further development of the efficient technology for the purposes of combustion.

Material and methods

For this study, the samples of vineyard pruning residues from Rakvice Stand in the Moravian viticultural region were used.

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Fig. 1 Apparatus for thermogravimetric experiments

Four different vine varieties were utilized for this experiment: Welschreisling, Grüner Veltliner, Gewürztraminer, Palava; these samples were collected in area with average annual temperature of 9–10 °C. These samples were ground in the cutting mill Retsch SM 100 in order to obtain the sample particle size less than 1 mm.

For the purposes of thermogravimetric experiments, furnace Nabertherm L9/11/SW/P330 with Kern digital scales were used (Fig. 1). The measurements were carried out under the static air atmosphere conditions using the samples with mass ~10 g. For each sample, three or more experiments were performed, according to the reproducibility of the obtained results.

The experiments were performed in accordance with the STN ISO 1171. Table 1 shows the parameters during thermogravimetric measurement. These intervals allow the determination of moisture content, combustibility, and ash content.

Firstly, the samples were heated to 105 °C and dried for 120 min. in order to remove the moisture. Subsequently, the samples were heated to 500 °C, where the mass loss contributes to combustible volatiles. The last step was to heat the samples to 815 °C – after subjection to this

temperature for 60 min., the residues correspond to ash content. The proportions of particular components are calculated according to the following equations:

$$w = \frac{m_1 - m_2}{m_1} \cdot 100 \quad (1)$$

where:

w – moisture content

m_1 – original sample weight

m_2 – dry matter weight

$$A' = \frac{m_3}{m_1} \cdot 100 \quad (2)$$

where:

A' – sample ash content

m_3 – ash weight

$$p_{ps} = \frac{m_3}{m_2} \cdot 100 \quad (3)$$

where:

p_{ps} – ash content in dry matter

$$h' = \frac{m_4}{m_1} \cdot 100 \quad (4)$$

where:

h' – combustible content in the sample

m_4 – weight of combustible content

$$p_{hs} = \frac{m_4}{m_2} \cdot 100 \quad (5)$$

where:

p_{hs} – weight of combustible content in dry matter

In order to determine these variables, the following standards were utilized: STN EN 15148; STN EN 14775; and STN ISO 1171.

Results and discussion

The thermogravimetric analysis results (Fig. 2) show different behaviour of used biomasses from vineyards during heating, especially in the first phase, which corresponds to the release of moisture and adsorbed water. The mass loss during 175 and 250 minute of measurement corresponds to the main phase of decomposition (Ondro et al., 2018; Vitázek et al., 2019).

In certain cases, the main phase of decomposition is shifted to lower temperatures. This can be caused by the

Table 1 Parameters obtained in thermogravimetric measurement

Interval	1	2	3	4	5	6
Time (min)	60	120	60	60	60	60
Temperature (°C)	20–105	105	105–500	500	500–815	815

Fig. 2 Thermogravimetric curves (solid lines) of used different grape varieties a) Palava, b) Welschreisling, c) Gewürztraminer, d) Grüner Veltliner (dashed lines characterize the temperature program)

weakest bond sites of hemicelluloses, since bond power and degradation rate may vary (Melcer et al., 1990). Considering the Grüner Veltliner sample, the concentration of weaker bonds was probably higher, which led to occurrence of thermal decomposition at lower temperatures in contrast to the other vineyard pruning residue samples. After the isotherm at 500 °C, there was no other process phase that could cause another mass loss of the sample.

On the basis of these thermogravimetric measurements, the moisture, combustible, and ash

contents were calculated according to Eqs 1–5, and the obtained values are listed in Table 2.

Table 2 provides the basic characteristics of pruning residues from vineyards. The moisture content ranged from 27.84% to 37.48%, the ash content ranged from 1.80% to 2.61%, the combustible matter content ranged from 60.25% to 69.55%, the ash content in the dry matter ranged from 2.76% to 3.62%, and the content of combustible matter in dry matter ranged from 96.37% to 97.24%.

Calorific value types of woody biomass have been studied often,

e.g. the articles by Burg et al. (2017) and Manzone et al. (2016), who presented 14 years of observational data, report the calorific values (Lower Heating Values, LHVs) of various samples of vineyard pruning residue of 18.2 MJ·kg⁻¹ and 17.96 MJ·kg⁻¹, respectively. However, the ash content is also important due to the well-known fact that the energy content is inversely proportional to ash content (Picchi et al., 2018).

This value is important, because the EN ISO 17225 divides the solid fuels (wood chips) into various groups on the basis of this data. Parameters determined in thermogravimetric measurements (Table 1) show that there is no significant difference between the ash contents of individual samples. However, the Palava sample was the only sample that met prerequisites for inclusion to the B category. On the other hand, based on the measurements, the ash content in the rest of samples was higher than the limit for this category. Therefore, it can be concluded that the samples of Welschreisling, Grüner Veltliner, and Gewürztraminer can be mixed with other types of woody biomass in order to achieve the lower ash content in dry matter. On the contrary, Giorio et al. (2019) reported the ash content of 3.07–3.10%; however, this value strictly depends on grape variety. Consequently, for the technological purposes, it is better to combust the mixtures of different types of wood biomass.

It is well-known that the methods of processing vineyard pruning residues include composting and thermal composition. If the material is to be for combustion (e.g. as a mixture with another wood biomass), it is better to dry it before storage, since it was observed that it takes approx. two

Table 2 Thermogravimetric measurement results

Biofuel	Parameter				
	<i>W</i>	<i>A'</i>	<i>h'</i>	<i>p_{ps}</i>	<i>p_{hs}</i>
Welschreisling	33.27 ± 1.40	2.045 ± 0.073	64.70 ± 1.47	3.0502 ± 0.18	96.95 ± 0.18
Grüner Veltliner	27.84 ± 1.49	2.61 ± 0.084	69.55 ± 1.41	3.62 ± 0.044	96.38 ± 0.044
Gewürztraminer	37.48 ± 1.76	2.27 ± 0.0012	60.25 ± 1.76	3.63 ± 0.11	96.37 ± 0.11
Palava	35.012 ± 0.12	1.80 ± 0.10	63.19 ± 0.24	2.76 ± 0.14	97.24 ± 0.14

Palava

Welschreisling

Gewürztraminer

Grüner Veltliner

Fig. 3 Mould on the ground samples of Palava, Welschreisling, Gewürztraminer and Grüner Veltliner after two weeks

weeks to form the mould on ground samples of vineyard pruning residues (Fig. 3).

Conclusion

Majority of scientific studies are aimed to determine the calorific value of different types of vineyard pruning residues. However, considering the technological point of view, the ash content also represents a significant factor and it is important to take into account its potential negative impacts on small boilers. For this very reason, this study observes ash content and the parameters associated with it of various vineyard pruning residues by means of thermogravimetric analysis under static air atmosphere condition. The main results can be summarized as follows:

- The main thermal decomposition of samples occurs approximately in the same temperature range. However, this range was markedly shifted to the lower temperature in case of Grüner Veltliner sample, which is caused by the weaker bond sites of hemicelluloses.
- Considering all the samples of vineyard pruning residues from Rakvice Stand in the Moravian viticultural region, the lowest ash content in dry matter was observed in the Palava sample.
- The other samples did not meet the requirements for the B category determined by the EN ISO 17225.
- Based on the results, it can be concluded that it is better to combust the mixtures of different types of wood biomass for technological applications.

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