ENERGY RECOVERY OF WASTE FROM THE VINEYARD AND WINERY

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Abstract
Viticulture and viniculture processes produce different organic waste, particularly grape marc (pomace), wood mass, to name but a few. Concerning the waste management, research finds out new, waste-free technologies and the use of waste as biofuel. The objective of this work is to determine the net calorific value of selected waste materials by the calorimetric method for its further use in solid biofuels production. Results show that comparable values of net calorific value are for the samples of wood cane, wood trunk, grape marc, grape stalks, cane pellets and ranged from 16.24 to 17.79 MJ·kg^{-1}. The higher net calorific value had grape seeds (21.14 MJ·kg^{-1}) and grape bagasse pellets (19.62 MJ·kg^{-1}) and the lowest net calorific value was determined for filter cellulose sheets (9.38 MJ·kg^{-1}). Based on data of the calorific values of tested samples, it is clear, that the majority of tested materials have very good calorific values.

Key words: *organic waste; solid biofuels; calorific values; pomace; wood mass.*

INTRODUCTION

Grapes are one of the most cultivated fruits worldwide (*FAO, 2017*). For this reason, it is important to think about produced waste and other secondary products. The waste management leads the research to new, waste-free technologies and the technologies where waste is used for biofuels (*Boulton et al., 2010*). A sizeable portion of wastes is from timber after the cut of vineyards (*Burg et al., 2017*), and also from the processing of grape and its processing during the production of wine (*Burg, Masan & Ludin, 2017*).

The production value from vineyards wood mass was evaluated by *Michálek, Burg, & Zemánek (2013), a*ccording to them this depends on the buckle in the planting and varies from 1,600 to 2,500 kg·ha^{-1}. Many other authors (*Rosúa & Pasadas, 2012; Boschiero et al., 2016*) agreed on the average production with value 1,000 kg·ha^{-1}. During compressing of 1,000 kg of grapes, the waste produced contains the amount of 40-60 kg of stems, 230-300 kg of pomace, with the part of seeds which is approximately from 50 till 100 kg and grape marc which amount is between 150 until 250 kg (*Baydar, Özkan & Çetin, 2007; Hugh, 2002; Muhlack, Potumarthi, & Jeffery, 2018; Rubio, Álvarez-Orti & Pardo, 2009; Schieber, Stintzing & Carle, 2001*). During winemaking, the other waste is produced as well such as used filter cellulose sheets.

This waste material has a large variation in its properties and produced amounts, but they represent an important amount of raw material that can be utilize as well. An interesting alternative is either technology that uses these wastes, as an input material for biogas plants, or the technology that uses grapeseed oil as a fuel substitute (*Chelladorai et al., 2018*), or the one which exploits the energy content of waste in technology of pyrolysis (*Zhang et al., 2017*). The easiest and most straightforward method of use applicable on a wide scale is the energetic combustion. These technologies are also established in practice, from wood shredding, or pelleting to combustion in the boiler and overall, financially accessible affordable too for smaller winery.

The objective of the work is to determine the net calorific value of selected waste materials by the calorimetric method for its further use in solid biofuels production.

MATERIALS AND METHODS

Waste mass

The subject of the research is wood mass produced from grape cane and trunk, grape pomace, grape marc without seeds, grape seeds, grape bagasse pellets (secondary product from grape seed oil pressing), grape stalks, filter cellulose sheets (type S 10) and commercial grape cane pellets used as a standard. The waste mass was produced and collected in South Moravia, Czech Republic in the year 2018. Samples of vines and old trunks were taken from the wine mill in Velké Žernoseky, the year of planting 1971, the wine type Pinot Blanc. The filter plates were used to filter Savilon 2018 in a volume of 2500 liters of wine. Grape marc in its original state, grape marc after seed separation, and in seeds themselves was from wine variety Sauvignon. Grape bagasse pellets were produced during the grape seed oil pressing on screw press and were from the wine variety Sauvignon too.

Laboratory methods

Determination of moisture content and dry mass was carried out accordingly to standard laboratory procedures ISO 18134-3 (total content of carbon, hydrogen and nitrogen), ISO 16948, ISO 16994 (total content of sulfur) and ISO 18122 (total content of ash). All procedures were evaluated in accredited laboratories TÜV NORD Czech, Ltd.

The Determination of the Energy Value

Determination of the gross calorific value was performed accordingly to the standard for solid biofuels ISO 1928. The obtained gross calorific values were converted into net calorific value according by equation (1)

$$Q^r{}_i = Q^r{}_s - \gamma \cdot (W_t^r + 8.94 \cdot H_t^r) \qquad (1)$$

where

$Q^r{}_i$ – net calorific value of the evaluated sample, $MJ \cdot kg^{-1}$;
$Q^r{}_s$ – gross calorific value of the original sample, $MJ \cdot kg^{-1}$;
γ – ratio of evaporation of 1% H_2O, $MJ \cdot kg^{-1}$, at temperature 25°C, $\gamma = 0{,}02442\ MJ \cdot kg^{-1}$;
8,94 – hydrogen to water conversion ratio of, –;
$W^r{}_t$ – total water content in the original sample, %;
$H^r{}_t$ – total hydrogen content in the original sample, %.

Statistic

Every sample and determinations were done in triplicate and the data were reported as means ± standard deviation. Analysis of variance was conducted and the results were tested and compared using Tukey's multiple range test (α=0.05). A statistical analysis was carried out using the software package "Statistica 12.0" (StatSoft Inc., Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSION

The basic precondition for using the solid biofuels is to reduce their humidity to a technologically acceptable value from the perspective of storage, but also to convert it into biofuel. From this point of view, the most problematic materials are filter cellulose sheets with wet basic moisture 67.61%, grape marc 63.47% and grape pomace 59.53%. Overall, the moisture samples fluctuated within a relatively wide range of values from 8.43 to 67.61%. Wood cane and wood trunk have low wet basic moisture, because they were harvested during the winter, when plants do not transplant.

The highest dry moisture content (set at the combustion tests) was then determined for the wood cane at 17.86% and the lowest at filter cellulose sheets at 3.54%. The highest moisture loss would be seen with filter cellulose sheets and grape pomace, which is logical in view of the production method, but may in practice represent increased drying costs. On the other hand, the change in humidity was the lowest in grape bagasse pellets, which, due to their compactness, do not have the prerequisite to attract more air humidity. Samples used in the tests met the basic processing condition, namely the content of dry moisture under 20%. In the content of elements, there was no significant difference between the samples. The hydrogen content required for calculating the calorific value according to equation (1), ranged from 4.14 to 6.49% in the measured samples. Overview of these average values for each samples are shown in Tab. 1.

The ash content samples fluctuated within a relatively narrow range of values from 2.63 to 8.83%, with exception of filter cellulose sheets where the value was 37.06%. This is caused by the material from which the sheets are made (in general, cellulose generates a significant amount of ash during combustion), but also by trapping sediments in the filtering of the wine, which are unburnable (mainly bentonite). For the same reason, their calorific value is also low compared to other samples. Overview of these average values for each samples are shown in Tab. 2.

Manzone et al. (2016) claims that the average ash content from pruning residue was 3.85% during a period of 15 years and average moisture content was 50%. *Burg & Souček (2008)* presents the average basic wet moisture at 40.70%. *Fernández-Puratich, Hernández & Tenreiro (2015)* discuss the average basic wet moisture 53.5% and average ash content 4.4%.

Tab. 1 Average values of moisture and composition of different organic waste

Samples	Wet basic moisture (%)	Dry moisture (%)	Composition (%)				
			H	C	N	H	S
Wood cane	36.29 ± 0.72^{d}	17.86 ± 0.10^{h}	5.10	50.40	0.85	40.22	0.02
Wood trunk	21.53 ± 1.59^{c}	7.62 ± 0.34^{a}	5.75	50.89	0.53	39.36	0.06
Grape pomace	59.53 ± 2.86^{e}	11.76 ± 0.33^{e}	6.07	54.01	2.84	29.73	0.15
Grape marc	63.47 ± 1.15^{f}	13.37 ± 0.23^{g}	6.16	55.72	2.46	30.07	0.13
Grape seeds	13.89 ± 0.22^{b}	7.45 ± 0.04^{a}	6.49	56.48	1.95	32.06	0.11
Grape bagasse pellets	8.43 ± 0.06^{a}	8.49 ± 0.02^{d}	5.78	53.42	2.12	34.89	0.13
Grape stalks	18.09 ± 0.40^{c}	12.50 ± 0.15^{f}	5.30	50,23	2.04	32.78	0.09
Filter cellulose sheets	67.61 ± 1.91^{g}	3.54 ± 0.09^{b}	4.14	29.08	0.49	28.96	0.01
Cane pellets	6.24 ± 0.10^{a}	6.23 ± 0.09^{c}	5.72	45.23	1.31	37.96	0.09

Tab. 2 Average values of ash content and calorific values of different organic waste

Samples	Ash (%)	Gross calorific value (MJ·kg^{-1})	Net calorific value (MJ·kg^{-1})
Wood cane	3.33 ± 0.08^{a}	18.7616 ± 0.06^{ab}	17.2070 ± 0.06^{ab}
Wood trunk	2.63 ± 0.06^{b}	18.5402 ± 0.75^{ab}	16.9856 ± 0.75^{ab}
Grape pomace	7.11 ± 0.04^{d}	20.9403 ± 0.33^{c}	19.3857 ± 0.33^{c}
Grape marc	6.47 ± 0.10^{c}	19.3467 ± 1.06^{b}	17.7921 ± 1.06^{b}
Grape seeds	3.39 ± 0.19^{a}	22.6945 ± 0.04^{e}	21.1399 ± 0.04^{e}
Grape bagasse pellets	3.18 ± 0.05^{a}	21.1788 ± 0.01^{c}	19.6242 ± 0.01^{c}
Grape stalks	8.83 ± 0.15^{e}	18.1606 ± 0.15^{ab}	16.6060 ± 0.15^{ab}
Filter cellulose sheets	37.06 ± 0.24^{g}	10.9387 ± 0.45^{d}	9.3841 ± 0.45^{d}
Cane pellets	9.25 ± 0.05^{f}	17.7900 ± 0.10^{a}	16.2354 ± 0.010^{a}

* Values are means±standard deviations of a triplicate measurements. Alphabetical superscripts indicate significant differences ($P<0.05$) among values in columns.

The statistical analysis (Tab. 2.) show that comparable values of net calorific value are for the samples wood cane, wood trunk, grape marc, grape stalks, cane pellets. The net calorific values for these samples ranged from 16.24 to 17.79 MJ·kg^{-1}. The higher net calorific value had grape seeds (21.14 MJ·kg^{-1}) and grape bagasse pellets (19.62 MJ·kg^{-1}). This is due to the fact that this material contains considerable amount of oils. On the other hand, the lowest net calorific value was determined for filter cellulose sheets (9.38 MJ·kg^{-1}), which is caused by the high content of ash.

For the evaluation of the energy potential of waste mass, the most important is net calorific value (NCV), even when some authors state their results in gross calorific value (GCV). *Annamalai, Sweeten & Ramalin-gam (1987)* set the GCV of grape pomace at the level of 20.34 MJ·kg^{-1}. *Burg, Masan & Ludin (2017)* report that grape pomace had gross calorific value from 16.07 till 18.97 MJ·kg^{-1}, grape marc of 14.60-17.75 MJ·kg^{-1} and grape seeds have the values of 19.78-21.13 MJ·kg^{-1}. *Manzone et al. (2016)* report the values of average higher heating value of vineyard pruning residue ranged from 17.92 to 18.02

MJ·kg^{-1}, whereas the lower calorific value ranged between 7.34 and 7.96 MJ·kg^{-1}. *Gligorević & Zlatanović (2013)* report the values of gross calorific value at 18,3 MJ·kg^{-1} and NCV at 11,82. *Walg (2007)* set the net calorific value of 12.6 MJ·kg^{-1} and *Burg & Souček (2008)* determined the net calorific value in the range between 14.39 to 16.66 MJ·kg^{-1}.

The main potential problem of grape pomace and filter cellulose sheets used in the production of solid biofuels can be high moisture. On the other hand, *Benetto et al. (2015)* state, that the marc is responsible for the better consistency of the pellets and also prevents the disintegration of the material in the pressing process due to the pulp content of the peel. *Miranda et al. (2012)* reports that as the proportion of marc in the pellets increases, the proportion of ash decreases. On the other hand, pellets with higher marc content show higher values of fixed carbon (*Balaman & Selim, 2015*).

CONCLUSIONS

This thesis brings the results of complexed experiment that was concerned with the possibility of energy utilization of various wastes that arise in the viticulture and viniculture processes. Not just pruning residues but others waste materials have energetic potential too and can be a significant biofuels. This waste material has a large variation in its properties and produced amounts, but they repre-sent an important amount of raw material that can be utilize as well. From the data of the calorific values of tested samples, it is clear, that it is mostly materials with a very good calorific values, which is comparable with the calorific values of e.g. brown coal (18.10 MJ·kg^{-1}). The results show that comparable values of net calorific value are for the samples wood cane, wood trunk, grape marc, grape stalks, cane pellets and ranged from 16.24 to 17.79 MJ·kg^{-1}. The higher net calorific value had grape seeds (21.14 MJ·kg^{-1}) and grape bagasse pellets (19.62 MJ·kg^{-1}) and the lowest net calorific value was determined for filter cellulose sheets (9.38 MJ·kg^{-1}). The results obtained suggest that the waste mass and their use may have an economic and ecological benefit. For greater use, it is necessary to find optimal technological and technical solutions with the aim to obtain energy. From this point of view, filter cellulose sheets with wet basic moisture 67.61%, grape marc 63.47% and grape pomace 59.53% are the most problematic materials, which may in practice represent increased drying costs. Another problem of filter cellulose sheets is the ash content, where the value was 37.06%.

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