

## Volatile combustible release in biofuels

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**Abstract.** Plant biomass consists of varied materials. Biomass is used for different purposes, but it is most frequently burnt in modern combustion devices for heat production. The quality of solid biofuels depends on the total content of combustibles while the volatile combustible content affects the combustion process. The aim of the paper is to determine the exact content of the biofuel components by the means of the gravimetric method – namely volatile combustible, ash and moisture content – and to evaluate the process of volatile combustible release as a function of temperature during the experiment. The device Nabertherm L9/11/SW/P330 type with accessory was used to carry out the experiments. Various biofuel samples were examined, namely wood (9 kinds), wood cuttings and wood chips (2 kinds), pellets (4 kinds), sawdust (1 kind), compared to less traditional fuels (DDGS and RME – 2 kinds) and wood coal (1 kind). The tables and graphs present the experimental results, which allow evaluation of the components content in different biofuels and provide characteristics of the process of volatile combustible release in analysed fuels. Spruce wood without bark showed the highest content of combustible (99.89%). Sawdust of fruit trees contains the highest proportion of volatile combustible (93.978%) and releases the combustible at the highest rate (15.25 mg h<sup>-1</sup>).

**Key words:** ash content, wood, pellets, combustible content, Scheffé test.

### INTRODUCTION

Biomass as a source of heat energy is nowadays gaining in importance. Biomass is organic matter, which arose from photosynthesis, or material of animal origin. The plant biomass used for energy purposes represents a renewable source of energy. From the available alternative resources (wind, water, solar power etc.), meant to reduce greenhouse emissions, biomass is the only carbon-based sustainable option (Khan et al., 2009). Demirbas (2004) claims that the biomass energy is one of the earliest sources of energy for humankind, particularly in rural areas, where it is often the only available and affordable source of energy. Globally, biomass ranks fourth among energy resources, providing approximately 14% of the world's energy demand. All human and industrial processes produce waste – normally unused and undesirable products of a specific process. Liquid biofuels are also a common type of alternative fuels. These types of fuels are made from renewable sources and their combustion process produces low emissions, mainly particulate matter (Uhrinová et al., 2012). The third group of alternative fuels includes gaseous biofuels. Gaduš & Giertl (2016) carried out research focused on the gaseous biofuels.

Akhmedov et al. (2017) states that the use of solid biofuels made of different types of biomass became a viable alternative to conventional fuels in many countries. Numerous benefits, such as low cost of the final product that meets the standards of quality, financially undemanding production, possibility of producing briquettes or pellets from almost any agricultural waste or combination of raw materials speak in favour of biomass-based fuels.

Solid, liquid and gaseous biofuels can be classified according to chemical composition. The quality of solid biofuels depends on moisture and volatile combustible content as a portion of total combustible content (Mikulová et al., 2014). Obernberger et al. (2006) presents that the chemical properties of the different types of solid biofuels affect their thermal utilization and thus combustion and flue gas cleaning technologies. Coniferous and deciduous woods contain relatively low amounts of N, S and Cl. Straw, cereals, grasses, grains and fruit residues may contain relatively high levels of N, Cl and S, which is of special relevance in respect to NO<sub>x</sub>, HC, PCDD/F and SO<sub>x</sub> emissions as well as corrosion.

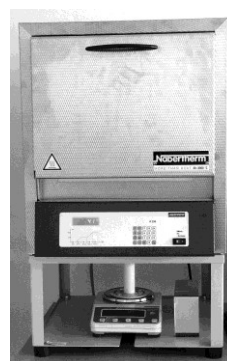
Combustion process is an oxidizing process resulting in conversion of energy content to heat due to oxidation of combustible in fuel with atmospheric oxygen. The quality of biofuel depends on the quantity and quality of combustible and ballast content (moisture and ash content). Biomass contains higher portion of volatile combustible compared to fossil fuel (Vitázek et al., 2014; Nosek & Holubčík, 2016). Biomass combustion does not pollute the environment by the excessive production of CO<sub>2</sub>. Biomass offers a wide variety of raw materials and is universally used in energetics (Jandačka et al., 2015). The modern combustible devices use biomass for heat and electricity production. The different properties of raw materials result in varied properties of the biofuels. Holubčík et al. (2015) discussed the composition of solid raw materials (straw, wood, corn) in terms of combustion.

This paper deals with the determination of the exact proportion of biofuel components by means of the gravimetric method. Volatile combustible content and volatile combustible release rate (milligram per minute) were calculated within the given time interval. The paper presents the comparison of different biofuels. The five tested groups contained wood, pellets, sawdust, alternative biofuel based on distillery waste and wood coal. In addition, comparison of these biofuel types in terms of statistical significance is also provided. The research papers previously published in this field deal solely with the composition of biofuels, namely with the proportion of combustible, moisture and ash (Jandačka et al., 2012 and Kantová et al., 2017) and non-volatile combustible release rate. We focused on this issue to present new findings in the field.

## **MATERIAL AND METHODS**

The total content of combustible, volatile combustible content and the volatile combustible release rate during the combustion are the most important factors affecting the combustion of biofuels. The ash is the residual after the fuel combustion. The examined samples were classified into groups as follows: wood (9 kinds), wood cuttings and wood chips (2 kinds), pellets (4 kinds), sawdust (1 kind). They were compared with less traditional fuels (DDGS – distiller's dried grain with solubles and RME – pressing refuse of rapeseed methyl ester – 2 kinds) and wood coal (1 kind).

The samples of solid biofuels were combusted in a Nabertherm L9/11/SW/P330 furnace (Fig. 1). Data of weight loss rates during the time intervals were measured by Kern digital scales with the accuracy 0.1 mg and recorded in a personal computer. This measurement equipment enables determination of moisture, combustibles and ash content in the tested biofuel samples. The individual components of biofuel samples were identified according to the weight changes during the process.

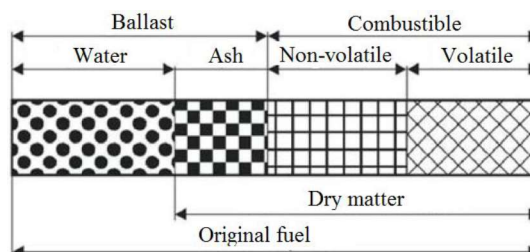


**Figure 1.** Measurement equipment consisting of furnace Nabertherm L9/11/SW/P330 type and laboratory scales Kern.

Proportions of particular components of biofuel samples were calculated as follows: ash content (A') according to standard STN ISO 1171, ash content without the moisture (pps) according to standard STN EN 14775, moisture content (w) and combustible content (h') according to standard STN EN ISO 18134-2.

The standard STN EN 14774-2 prescribes the heating of analysed sample to 105 °C ± 2 °C and drying for 120 minutes. Weight loss in an interval of 0–180 minutes was accounted for by the removed moisture.

The mass residue at the end of the experiment was made up of ash. The residual amount of dry matter was the combustible ( $p_{hs}$ ). The volatile combustible released until the time interval of 240 min, i.e., until the temperature reached 500 °C. The solid biofuel composition is schematically shown in Fig. 2.



**Figure 2.** The scheme of solid biofuel composition.

## RESULTS AND DISCUSSION

The fuel was dried at 105 °C during 180 minutes (the time interval consisted of 60 minutes of the heating starting from ambient temperature to 105 °C and 120 minutes of drying process). At temperatures above 150°, volatile matter began to release. After exceeding temperatures from 260 °C to 410 °C, the release of volatile matter was significantly accelerated. The weight loss in the interval of 180–500 °C was accounted for by the volatile combustible (the third interval). The solid portion of combustible began to oxidize at a temperature of about 500 °C. Temperature of 815 °C led to a complete oxidation of the solid residue (Mikulová & Vitázek, 2016).

The results of gravimetric measurements of analysed samples are shown in Table 1. The highest moisture content was recorded in case of wood chips, which were combusted immediately after processing in a forest and therefore water did not have time to evaporate from this biofuel type. On the other hand, the lowest moisture content was observed in black locust wood, because this biofuel type was stored in dry conditions and therefore water was released before the combustion process. Brunerová et al. (2017)

carried out research on moisture content of tropical waste biomass. This work confirms the observation that the moisture content also depends on the biofuel type.

**Table 1.** The values of moisture content, ash content and combustible content in analysed samples

Biofuels	Parameter				
	w, %	A', %	h', %	$p_{ps}$ , %	$p_{hs}$ , %
Black locust wood (C1)	6.20	0.24	93.56	0.24	99.76
Apricot wood (C2)	7.32	1.63	91.05	1.76	98.24
Plum wood (with bark) (C3)	8.44	0.68	90.88	0.74	99.26
Cherry wood (C4)	11.91	0.45	87.64	0.51	99.49
Walnut wood (C5)	24.87	2.35	72.78	3.16	96.84
Spruce wood (without bark) (C6)	8.32	0.10	91.59	0.10	99.90
Apple tree wood (C7)	11.40	1.06	87.54	1.13	98.87
Hardwood (C8)	7.89	0.11	92.00	0.12	99.88
Maple wood (C9)	6.90	0.24	92.86	0.27	99.73
Cuttings from coniferous trees (C10)	41.67	6.17	52.16	11.30	88.70
Wood chips (C11)	58.19	0.68	41.13	1.61	98.39
Sunflower pellets (C12)	9.84	3.59	86.58	3.96	96.04
Spruce pellets (90% spruce wood, 10% fir) (C13)	10.33	0.55	89.12	0.62	99.38
Spruce wood pellets (C14)	7.53	0.38	92.09	0.38	99.62
Pellets from waste – Agrobio (C15)	7.35	5.12	87.53	5.65	94.35
Sawdust (fruit trees) (C16)	9.21	2.40	88.39	2.65	97.35
DDGS (C17)	10.43	4.32	85.25	4.64	95.36
RME (C18)	11.29	6.33	82.37	7.13	92.87
Wood coal (C19)	4.49	18.21	77.30	19.08	80.92

The content of combustible in dry matter ( $p_{hs}$ ) was calculated from the measured values obtained from three repetitions of the experiment (Table 2). One measurement lasted 7 hours. Average value and standard deviation for each biofuel were calculated from three measured values.

**Table 2.** Measurement repetition, average value and standard deviation of combustible in different biofuels

Biofuels	Value, %	Average value of $p_{hs}$ , %	Standard deviation, %	Biofuels	Value, %	Average value of $p_{hs}$ , %	Standard deviation, %
C1	99.745	99.76	0.032	C11	98.368	98.39	0.019
	99.796				98.407		
	99.737				98.389		
C2	98.243	98.24	0.039	C12	96.021	96.04	0.039
	98.197				96.013		
	98.274				96.085		
C3	99.259	99.26	0.019	C13	99.388	99.38	0.013
	99.284				99.367		
	99.246				99.391		
C4	99.508	99.49	0.014	C14	99.631	99.62	0.029
	99.480				99.592		
	99.488				99.649		
C5	96.869	96.84	0.166	C15	94.473	94.35	0.494

Table 2 (continued)

	96.656				93.801		
	96.984				94.764		
C6	99.893	99.90	0.007	C16	97.357	97.35	0.094
	99.889				97.246		
	99.902				97.433		
C7	98.808	98.87	0.168	C17	95.173	95.36	0.188
	99.061				95.349		
	98.744				95.548		
C8	99.877	99.88	0.010		92.862	92.87	0.071
	99.869			C18	92.939		
	99.889				92.798		
C9	99.743	99.73	0.074		80.931	80.92	0.078
	99.651			C19	80.842		
	99.797				80.998		
C10	89.421	88.70	0.627				
	88.402						
	88.278						

Tables 3–5 show the comparison of all biofuels to state the differences in combustible content in terms of statistical significance according to the Scheffe test. Number 0 means the highest statistical significance of difference, whereas 1 indicates the lowest. Grey cells mark the statistical significance of differences in average values of combustible content at significance level lower than 0.05.

Table 3. The comparison of biofuels C1 – C6 to state the statistical significance of differences in combustible content ( $p_{hs}$ )

Biofuels	C1	C2	C3	C4	C5	C6
C1		0.000023	0.934768	0.999963	0.000000	1.000000
C2	0.000023		0.020988	0.001028	0.000127	0.000003
C3	0.934768	0.020988		0.999996	0.000000	0.655365
C4	0.999963	0.001028	0.999996		0.000000	0.991950
C5	0.000000	0.000127	0.000000	0.000000		0.000000
C6	1.000000	0.000003	0.655365	0.991950	0.000000	
C7	0.097610	0.651644	0.994074	0.684774	0.000000	0.021331
C8	1.000000	0.000004	0.700090	0.994998	0.000000	1.000000
C9	1.000000	0.000034	0.962187	0.999994	0.000000	1.000000
C10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C11	0.000196	1.000000	0.111633	0.007769	0.000015	0.000028
C12	0.000000	0.000000	0.000000	0.000000	0.229158	0.000000
C13	0.996216	0.004597	1.000000	1.000000	0.000000	0.914314
C14	1.000000	0.000159	0.997792	1.000000	0.000000	0.999956
C15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C16	0.000000	0.093379	0.000000	0.000000	0.919239	0.000000
C17	0.000000	0.000000	0.000000	0.000000	0.000041	0.000000
C18	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C19	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

**Table 4.** The comparison of biofuels C7 – C12 with all biofuels to state the statistical significance of differences in combustible content ( $p_{hs}$ )

Biofuels	C7	C8	C9	C10	C11	C12
C1	0.097610	1.000000	1.000000	0.00	0.000196	0.000000
C2	0.651644	0.000004	0.000034	0.00	1.000000	0.000000
C3	0.994074	0.700090	0.962187	0.00	0.111633	0.000000
C4	0.684774	0.994998	0.999994	0.00	0.007769	0.000000
C5	0.000000	0.000000	0.000000	0.00	0.000015	0.229158
C6	0.021331	1.000000	1.000000	0.00	0.000028	0.000000
C7		0.025973	0.130163	0.00	0.948717	0.000000
C8	0.025973		1.000000	0.00	0.000035	0.000000
C9	0.130163	1.000000		0.00	0.000296	0.000000
C10	0.000000	0.000000	0.000000		0.000000	0.000000
C11	0.948717	0.000035	0.000296	0.00		0.000000
C12	0.000000	0.000000	0.000000	0.00	0.000000	
C13	0.916577	0.934768	0.998591	0.00	0.030428	0.000000
C14	0.323113	0.999983	1.000000	0.00	0.001319	0.000000
C15	0.000000	0.000000	0.000000	0.00	0.000000	0.000002
C16	0.000021	0.000000	0.000000	0.00	0.016899	0.000498
C17	0.000000	0.000000	0.000000	0.00	0.000000	0.508932
C18	0.000000	0.000000	0.000000	0.00	0.000000	0.000000
C19	0.000000	0.000000	0.000000	0.00	0.000000	0.000000

**Table 5.** The comparison of biofuels C13 – C19 to state the statistical significance of differences in combustible content ( $p_{hs}$ )

Biofuels	C13	C14	C15	C16	C17	C18	C19
C1	0.996216	1.000000	0.000000	0.000000	0.000000	0.000000	0.00
C2	0.004597	0.000159	0.000000	0.093379	0.000000	0.000000	0.00
C3	1.000000	0.997792	0.000000	0.000000	0.000000	0.000000	0.00
C4	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.00
C5	0.000000	0.000000	0.000000	0.919239	0.000041	0.000000	0.00
C6	0.914314	0.999956	0.000000	0.000000	0.000000	0.000000	0.00
C7	0.916577	0.323113	0.000000	0.000021	0.000000	0.000000	0.00
C8	0.934768	0.999983	0.000000	0.000000	0.000000	0.000000	0.00
C9	0.998591	1.000000	0.000000	0.000000	0.000000	0.000000	0.00
C10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
C11	0.030428	0.001319	0.000000	0.016899	0.000000	0.000000	0.00
C12	0.000000	0.000000	0.000002	0.000498	0.508932	0.000000	0.00
C13		0.999992	0.000000	0.000000	0.000000	0.000000	0.00
C14	0.999992		0.000000	0.000000	0.000000	0.000000	0.00
C15	0.000000	0.000000		0.000000	0.025057	0.000041	0.00
C16	0.000000	0.000000	0.000000		0.000000	0.000000	0.00
C17	0.000000	0.000000	0.025057	0.000000		0.000000	0.00
C18	0.000000	0.000000	0.000041	0.000000	0.000000		0.00
C19	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	

According to the experimental results, the following values were calculated: the content of the volatile combustible from the total amount of combustible in dry matter during the time interval from 180 to 240 minutes, total amount of oxidized combustible to 300 minutes of experiment duration and the volatile combustible release rate

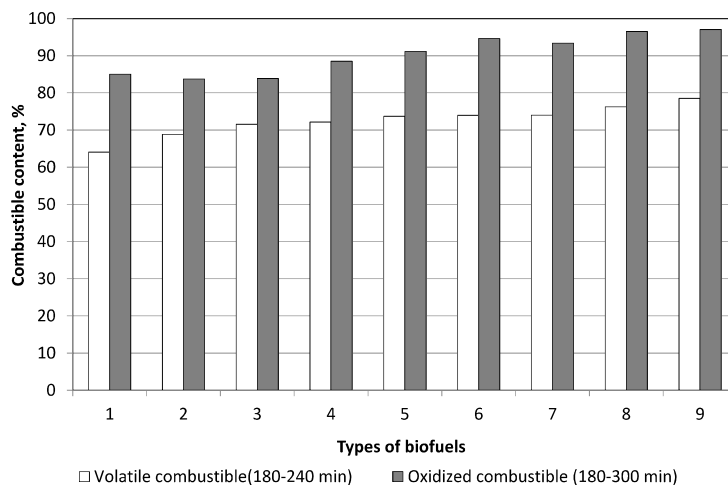
expressed in milligrams per minute of 1 gram of dry matter of the sample. The results are listed in Table 6. Graphical representations of the released combustible content are shown in Figs 3 and 4. Considering the wood biomass (Table 3, column 2), the black locust wood (C1) is related to spruce wood without bark (C6), hardwood (C8), maple wood (C9) and spruce wood pellets (C14). On the other hand, less traditional fuels (DDGS and RME) and pellets from waste (C15) show the significant differences with all researched biofuels. These facts are important for replacement of biofuels by each other. Besides the combustible and ash content, the moisture content is also very important factor affecting the combustion process in boiler with specific burner type.

**Table 6.** The content of volatile combustible and the volatile combustible release rate

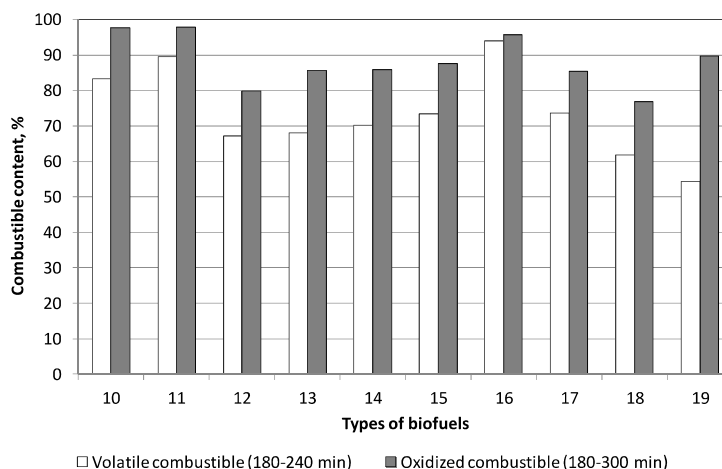
Biofuels	Volatile combustible (180–240 min), %	Oxidized combustible (180–300 min), %	Volatile combustible release rate, mg min <sup>-1</sup>
Black locust wood (1)	64.08	85.08	10.65
Apricot wood (2)	68.85	83.74	11.27
Plum wood (with bark) (3)	71.55	83.87	11.84
Cherry wood (4)	72.17	88.54	11.97
Walnut wood (5)	73.70	91.18	11.90
Spruce wood (without bark) (6)	73.97	94.61	12.32
Apple tree wood (7)	74.05	93.40	12.19
Hardwood (8)	76.25	96.52	12.69
Maple wood (9)	78.51	97.06	13.05
Cuttings from coniferous trees (10)	83.35	97.59	12.28
Wood chips (Vrable) (11)	89.58	97.84	14.69
Sunflower pellets (12)	67.17	79.89	10.75
Pellets (mix) (13)	68.02	85.74	11.27
Spruce wood pellets (14)	70.18	85.87	11.65
Pellets from waste – Agrobio (15)	73.48	87.67	11.57
Sawdust (fruit trees) (16)	93.98	95.76	15.25
DDGS (17)	73.55	85.52	11.67
RME (18)	61.85	76.77	9.57
Wood coal (19)	54.25	89.79	7.32

The overall proportion of combustibles in the tested samples is presented in Table 1. Proportion of volatile matter in dry matter at the interval from 180 minute to 240. minute is shown in Table 6, column 2 (the heating from 105 °C to 500 °C). Values are ascending from the lowest to the highest (54.25% – 93.98%) in case of all groups, therefore indicating a high content of the volatile combustible in solid biofuels. The heating endurance at 500 °C was during the next time interval (from 240 minute to 300 minute). In Table 6 (column 3), the time interval from 180 minutes to 300 minutes presents the portion of released combustible. It was no longer regarded as volatile matter, but as a proportion of total oxidized combustibles. The course of the experiment for wood coal also confirmed this fact, because the content of the total and the volatile combustible was significantly lower than in case of another (raw) fuels. The biofuels contained a high content of total and also volatile combustible. Table 6 shows that 97.6%

of total combustible was released at 500 °C. The biofuels with the highest content of total combustible may not contain the highest portion of the volatile combustible.



**Figure 3.** The content of released combustible in biofuels no. 1–9.



**Figure 4.** The content of released combustible in biofuels no. 10–19.

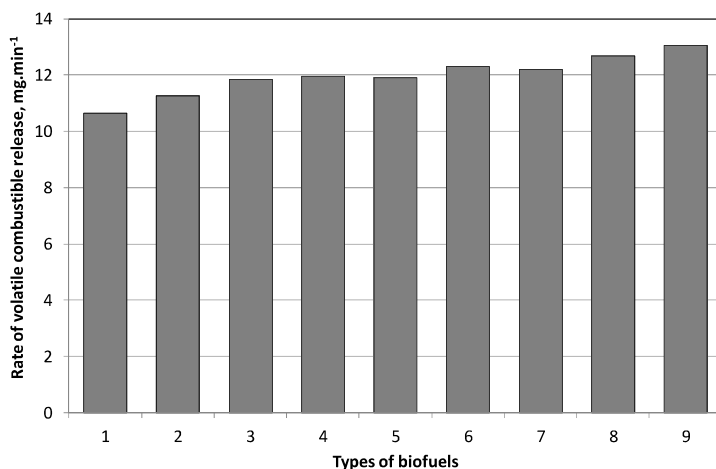
The highest content of combustible in dry matter was present in the sample of spruce wood without bark (99.90%, Table 1). On the other hand, the lowest was found in the cuttings from coniferous trees (88.70%) with the ash content of 11.30%, apart from the wood coal with the content of combustible in dry matter of 80.92%. The data presented in Table 6 shows that the highest content of volatile matter was present in the sawdust (fruit trees) sample (93.98%). The case of cuttings from coniferous trees is particularly interesting, because it indicated the highest ash content and the total content of oxidized combustible reached 97.59% (Table 6, column 3). The rate of volatile combustible release is calculated per 1 gram of the sample dry matter (Table 5,



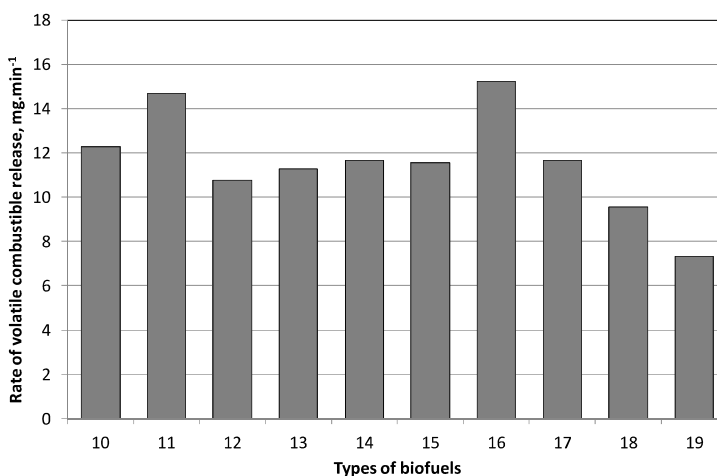
column 4) and expressed by mg per minute. The sawdust (fruit trees) reached the highest value  $15.25 \text{ mg min}^{-1}$ .

The values of total combustible content are listed in Table 1. However, these results did not allow determination of the volatile part. Therefore we analysed the weight loss of biofuel samples during given time intervals. The results are presented in Table 6. The data shows that biofuels with the highest content of combustible in dry matter ( $p_{hs}$ ) do not also contain the highest proportion of volatile combustible, which is being released at the highest rate. Comparison of the data of Table 6 indicated that the smallest difference between the intervals is found in biofuel sawdust (fruit trees). In the case of wood, this difference was more apparent and stable.

Graphical views of volatile combustible release rate are shown in Figs 5 and 6.



**Figure 5.** The volatile combustible release rate in biofuels no. 1–9.



**Figure 6.** The volatile combustible release rate in biofuels no. 10–19.

The content of combustible in biomass depends on the fuel type. The moisture content of 14÷15% is common value required for safe long-term storage. The combustion process does not yield the maximum amount of biomass energy. Conversion of biomass to another fuel type which allows yielding the maximum energy is much more effective. Technical conversion is the most widespread type of various conversion processes (Gaduš & Giertl, 2016). It enables to produce liquid, gas or solid fuels of higher quality from the biomass. The converted fuel properties allow for reaching a high amount of biofuel energy and increasing the combustible content in biofuel. Biomass processed this way is characterised by low moisture with an impact on caloric value and the combustion process (Beláková et al., 2017). The thermal decomposition of spruce wood was studied using the thermogravimetric analysis in air atmosphere and the dependence of the apparent activation energy on the degree of conversion was determined (Ondro et al., 2018).

Ash content is affected by various additives – our results indicated that the bark content is an important factor. The influence of bark on the properties of biofuels was examined by Nosek et al. (2016). The ash content of spruce wood is presented by Radačovská et al. (2017) – this fuel has ash content of 0.26%, while our results indicated 0.1%. In general, spruce wood contains very low proportion of ash. Radačovská et al. (2017) examined also spruce wood with bark where the ash content reached the value of 0.55%. This result confirmed the statement that bark affects the ash content. Difference in our results was presumably caused by the bark removal in case of the biofuel sample tested by Radačovská et al. (2017). The differences in values found in all tested biofuels may be influenced by the composition of the fuels. These differences were the most apparent in pellets, because they did not in many cases contain raw wood.

The lowest content of released combustible in observed intervals was found in RME (61.85% and 76.77%). DDGS and RME samples confirmed that waste from processing is suitable for use as an alternative fuel. Our results supported the findings obtained by Dand et al. (2014).

The paper of Mikulová & Vitázek (2016) showed the graphic representations of combustible release rates in equal time intervals. The highest content of released combustible was found in the cherry wood sample (88.32%). In our experiment, cherry wood sample yielded 88.54%.

The influence of moisture content on the heat value is dealt with by Nosek & Holubčík (2016) and Vitázek et al. (2013). The examined samples indicated that biomass in a boiler room in Vráble was combusted even at an initial moisture content of 58.2%. The particular boiler enabled this process. The obtained results confirmed the high combustible content in pure wood (only slight differences were observed). In the case of cuttings from coniferous trees the combustible content in dry matter was lower than 90% (content of various additives). The course of combustion is, naturally, influenced by the initial moisture content, which in one case reached 58.19%. The highest content of released combustible in the interval up to 240 min. was found in sawdust (93.98%), the lowest in black locust wood (64.08%). The highest content of released combustible in the interval up to 300 min was found in wood chips (97.84%), the lowest in RME (76.77%). Hard wood yielded lower values; therefore the content of non-volatile combustible is higher. Rate of combustible release is average during the

entire time interval. This rate is initially higher in fuels with a higher volatile combustible content. Wood coal is presented just for comparison, it is thermally processed biomass.

The quality of solid biofuels depends on physical properties, too (Križan et al., 2017). Basic physical properties include form of fuel, particle size distribution of fuel, etc. These properties influence the proper design of combustion devices. The usage of additives has a significant impact on the properties of wood pellets, which include combustion and production of emissions (Jandačka et al., 2012; Kantová et al., 2017).

Unsuitable temperature in combustion chamber and high content of combustible in solid biofuel can cause ash sintering, even when using the new boilers equipped with innovative technologies. It can cause permanent damage of combustion devices (Radačovská et al., 2017). Therefore, the knowledge of the combustible content in biofuel, combustible release rate and other thermophysical properties is of significant importance. The presented findings are a follow-up to the results published in (Vitázek et al., 2018).

## CONCLUSION

The different materials under different conditions (moisture content) were processed in different shapes and forms (pellets, wood chips, brown coal). These materials have different physical properties, which determine the method of possible next processing and the suitable combustion device. Wood cuttings and wood chips from coniferous trees were burned in a suitable boiler even at the high initial moisture of 58.2%. The presented gravimetric method is suitable for the research of combustible content and combustible release rate in selected solid biofuels. Graphic presentation of weight loss rate in temperature intervals of preheating and holding time at 500 °C enables to observe the volatile combustible release rate as well as oxidation rate. The volatile combustible release rate was calculated per 1 gram of dry matter and weight loss was observed in the time interval from 180 to 240 minutes i. e. the expected interval of the volatile combustible release.

Evaluating the research results, the following hypothesis was confirmed: the biomass contains high proportion of volatile combustible which was released in time interval from 260 °C to 410 °C. The rate of volatile combustible release related with the total combustible content. This fact is very important for boiler construction, because the biofuels burn with long flame and require secondary or alternatively tertiary air. Therefore the boilers for standard solid fuels (for example coal) are not suitable for biofuels in most cases.

Nineteen samples of various biofuels were examined. Statistically processed results show the differences in average values of combustible content in biofuel samples at statistical significance 0.05. Using the Scheffe test, the results were compared to each other in terms of combustible content. It allows evaluating the replacement possibility of single biofuels in practice if a particular biofuel is not available for given boiler. The research will continue to further examine the biofuels from different sources.

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