EVALUATION OF WOOD AND PEAT MIXTURE BIOFUEL CHARACTERISTICS

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Abstract. Wooden fuel is one of the most widely used fuel sorts in Lithuania. Peat resources in Lithuania make more than 500 million tons, but in the recent years, peat has not been widely used as fuel due to comparatively high emissions and the ash content (4-6 %). It is purposeful to expand the volumes of peat usage for fuel preparing mixtures of peat with wood chip. As the practice shows, when using the mixture of peat and wood chip, boilers do not wear out so quickly, their exploitation time increases since the burning process gets better quality. Many boilers for burning of chip wood may be effectively used for burning the mixture of peat and wood chip. The physical characteristics of peat, wood chip and their mixtures have been determined by experiments. Increasing the moisture of peat and wood chip from 20 to 40 %, their filled density increases accordingly 11-12 % and 14-15 %. Fall and natural pour angles of the mixture components (peat and wood chip) have been researched. The results of the experiments showed that moisture has bigger effect on the peat fall angle, which changed from 71.0 ± 0.6 to 90.3 ± 0.6 degrees, than on thewood chip angle, which changed from 84.0 ± 0.9 to 88.0 ± 0.8 degrees. The natural slope angle of wood chip changed from 39.3 ± 1.0 to 41.0 ± 1.0 degrees. Moisture of peat does not have big effect on the natural pour angle. Fractional composition of the components has been determined by the research. Based on the results, it may be stated that the biggest part of peat (about 50 %) is of 0-1 mm fraction. About 50 % of wood chip make fractional composition of 8 mm, the smallest fraction of wood chip is 0-1 mm. The calorific value of peat and wood chip is similar (18.7-20.1 $MJ \cdot kg^{-1}$); so, it may be supposed that when preparing mixtures, the quality of component mixing (evenness of mixture components) does not influence the fuel calorific value. As it may be seen from the obtained results, it is purposeful to prepare peat and wood chip mixtures since the ash quantity after burning the mixture is 45 % smaller than burning only peat. The recommended mixture composition is 50 % peat and 50 % wood chip.

Key words: biofuel, crumbly peat, wood chips, fuel mixture, uniformity, calorific value.

Introduction

Apart the most widely used in the country wood biofuel, other local resources that may be used for energetics are present: straw, waste products, peat. If we used about 40 % of straw (this quantity is used in Denmark) in Lithuania for fuel, we would receive about 1.2 million tons of biofuel; it is about 440 thousand tons of oil equivalent [1].

It is projected that in 2020-2025, the accumulated quantity of waste products would be about 1.4 million tons. Projecting that in Lithuania primary (performed by citizens) and secondary (performed centralised in special companies) sorting shall take place, about 730 thousand tons of sorted waste should be obtained in Lithuania. It is about 200 thousand tons of oil equivalent [2].

Peat is not considered a renewable resource and biofuel. However, it is a local resource. In Lithuanian peat-bogs, light and dark peat is excavated. Light peat is usually sold as a raw-material for plant-growing and flower-growing. Meanwhile, dark peat which could be used as fuel is simply left in peat-bogs. Presently, peat is considered as little used fuel; only 80 thousand tons are used in the country. According to evaluation of the scientists of the Kaunas University of Technology, presently in the exploited peat-bogs of Lithuania about 16.7 million tons of dark peat are accumulated. Scientists offer using 300-340 thousand tons of peat per year for energy production [2].

Talking about processed peat fuel, the most wide-spread are briquettes and granules produced from crumbly peat; chunk peat is rarer used. Peat pressing to granules or briquettes is a rather energy consuming process; it increases the prime-costs of the obtained fuel [3; 4]. Limited usage of crumbly peat for biofuel depends on high quantity of ash (4-6 %) and high quantity of harmful emissions [5; 6]. Aiming to expand peat usage for fuel volumes, it is purposeful to prepare a mixture of peat with other types of biofuel, firstly, with wood chip. It has been determined that using a wood chip and peat mixture, boilers do not wear out so quickly, their exploitation time prolongs since the burning process gets better quality [7]. Mostly boilers adapted to use wood chip may effectively operate with peat and wood mixture.

Preparing qualitative mixtures and projecting fuel transportation equipment to stoves, dispenser and accumulative bunkers, determining their constructive parameters, it is important to determine by experiments the physical characteristics of crumbly peat, wood chip and their mixtures which affect the characteristics of the obtained fuel: filled density, fractional composition, fall angle, natural slope angle. Presently, in practice peat and wood chip mixtures content of peat in which makes 30-40 %; however, we could not find grounds of the optimal composition of mixture based on scientific research in the literature sources. To ground optimal relation of mixture composition, it is necessary to research the calorific values, ash content of the mixtures and their components.

The aim of the research work was to evaluate the peat and wood biofuel characteristics and, based on the physical characteristics of these components to justify the composition of peat and wood mixture.

Materials and methods

The research has been performed in laboratories of the Aleksandras Stulginskis University (ASU) and UAB *Klasmann-Deilmann Ežerėlis* and Lithuanian Energy Institute. Crumbly peat produced by UAB *Klasmann-Deilmann Ežerėlis* in Kaunas district and wood chips of various sorts for biofuel were used for the research investigations.

Wood was chopped by the drum chopper Pezzolato 700/660 productivity of which reaches 40-50 $m^3 \cdot h^{-1}$. Moisture of wood chip and peat was determined in ASU laboratory: five samples were taken; they were weighted and dried in a cabinet drier for 24 hrs, in the temperature 105 ºC. The dried samples were weighted by a scale METTLER TOLEDO SB 16001, with precision 0.01 g; after that, the empty vessel wasweighted.

Poured density was determined after filling peat, wood chip and mixtures to a cylindrical plate the measured volume (V) of which was equal 0.0119 m^3 and not pressing weighted by the scale METTLER TOLEDO SB 16001 to determine their mass (m), the poured density was calculated by this formula: $\rho = m/V$ [8].

Fractional composition of peat and wood chip was determined using a set of sieves in which the sieves are located one on another in this order: 63 mm, 45 mm, 16 mm, 8 mm, 3.15 mm and 1 mm diameter. 0.5 kg of sample mass was sieved by a special sieve shaker Haver EML Digital plus. Operational parameters of the sieve shaker: vibration duration 1min, vibration interval 10 s, vibration amplitude 1 mm [9].

A stand produced in the Agriculture Engineering and Safety Institute is used to determine dry angles. The natural slope angle α_n and fall angle α_{gr} were determined by the special stand [10]. Calorific values of peat, wood chip and their compositions were determined according to the presented methodology [11]. Electronic scale Electronics Balance TYP AY220 was used to perform the measurements, a calorimeter V08MA with the temperature registrar ABL 646.00.00 (Fig. 1), dry-cabinet, heating boiler. The upper calorific value of dry fuel Q_v was found; further, we calculated the lower calorific value Q_a according to the presented in literature formula [12] (1):

$$Q_a = Q_v \cdot (1 - A / 100) \cdot (1 - W / 100) - C_s \cdot W / 100), \tag{1}$$

where Q_v – upper calorific value of a sample (absolutely dry material, without ash), $kJ \cdot kg^{-1}$;
W – moisture of sample mass, %;
A – ash content of sample mass, %;
C_s – water secret evaporating heat, $kJ \cdot kg^{-1}$.

Ash content of wood chips, peat and their mixtures was determined according to the methodology set in the standard [13]. Ash content of dry mass is expressed by dry mass percent and calculated according to the formula (2):

$$A_s = (M3 - M1) / (M2 - M1) \cdot 100 / (100 - W_n) \cdot 100 \%, \tag{2}$$

where $M1$ – mass of empty plate, g;
$M2$ – mass of plate with sample, g;
$M3$ – mass of plate with ash, g;
W_n – moisture of sample used for analysis, %.

Fig. 1. **General view of calorimeter V-08 MA with temperature registrar ABL 646.00.00**

The results of the performed research are presented in the form of graphs. Experimental value was used to receive separate points; it is obtained from 3-5 parallel experiments. The experiment data were processed according to methodologies calculating the average value of measuring series and average square deviation of separate measuring.

Results and discussion

Moisture of peat samples changed from 19.9 % to 41.7 %; moisture of wood chips changed from 15.1 % to 38.8 %. The upper limits of sample moisture correspond to moistures of wood chip and crumbly peat supplied to the boilers which are used in practice. From the results presented in Table 1, it may be stated that if the moisture of peat and wood chips increases from 20 % to 40 %, their filled density corresponds accordingly to 11-12 % and 14-15 %.

Table 1

Indices of wood chips and crumbly peat density ρ, fall α_{gr} and natural slope α_n angles

Samples	Moisture w, %	Filled density ρ, kg·m^{-3}	Natural slope angle α_n, degrees	Fall angle α_{gr}, degrees
Wood chips	15.1 ± 0.2	185.1 ± 0.9	39.7 ± 1.1	84.0 ± 0.9
Wood chips	19.7 ± 0.5	210.1 ± 1.2	39.3 ± 1.0	86.0 ± 1.0
Wood chips	24.8 ± 0.4	220.4 ± 1.0	40.0 ± 0.9	87.2 ± 0.8
Wood chips	38.8 ± 0.5	249.5 ± 1.1	41.0 ± 1.0	88.0 ± 0.8
Crumbly peat	19,9 ± 0.9	297.2 ± 0.8	37.1 ± 1.0	71.0 ± 0.6
Crumbly peat	29.7 ± 1.0	299.7 ± 1.1	36.7 ± 1.1	73.0 ± 1.0
Crumbly peat	31.5 ± 0.3	309.4 ± 0.7	36.8 ± 1.1	77.0 ± 0.8
Crumbly peat	41.7 ± 1.0	340.9 ± 0.4	36.7 ± 0.6	90.3 ± 0.6

Fall angles of the mixture components (peat and wood chips) have been determined (Table 1). The experiment results show that moisture has bigger impact on the peat fall angle, which varied from 71.0 ± 0.6 to 90.3 ± 0.6 degrees, than wood chips, which varied from 84.0 ± 0.9 to 88.0 ± 0.8 degrees. Considering the fall angles, the constructive parameters of storage places (bunkers), walls of mechanisms of supply to the boilers (leaning angles of the walls should be higher than the determined) are set.

Moisture did not have influence on the natural slope angles. The natural slope angle of wood chips varied insignificantly from 39.3 ± 1.0 to 41.0 ± 1.0 degrees. The natural slope angle of peat with increase of moisture also varied insignificantly in the error limits (from 36.7 ± 1.1 to 37.0 ± 2.0 degrees). Based on these results, it is possible to calculate the sizes of the spreading areas of wood chips and their mixtures if pouring components before mixing.

Fractional composition of the components has been determined by results to ground qualitative preparation of peat and wood chip and qualitative mixing. As it may be seen from the research results, the bigger part of peat (about 50 %) is of 0-1 mm fraction. The biggest fraction of peat does not exceed the size of 16 mm. Fractional composition of wood chips varies more differently. Mostly, about 50 % is made of 8 mm diameter fractional composition; the smallest is of 0-1 mm fractional composition. Moisture does not influence the fractional composition.

Researching biofuel mixtures from wood chips and peat, mixtures of various proportions were chosen, starting from 15 % peat and 85 % wood chip and finishing 65 % peat and 35 % wood chips. Pouring density was determined for various variants. The obtained results are presented in Fig. 2. As it may be seen from the results, the smallest density is in the mixture of 15 % peat and 85 % wood chips, and the biggest is in the mixture of 65 % peat and 35 % wood chips. In this variation interval of mixture components, the density increased 13 %, on the average. Based on the research results, we may state that with increase of peat quantity in mixture, its density also increases.

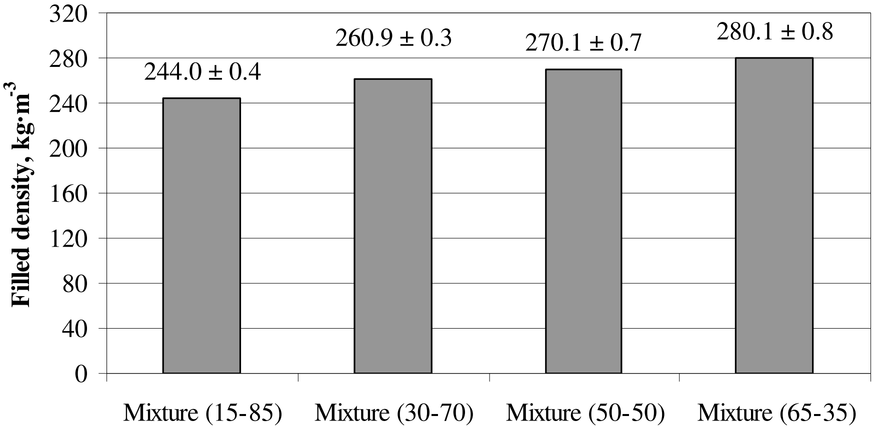

Fig. 2. **Filled density of mixtures if peat moisture is 41.7 %; moisture of wood chips is 38.8 %**

Calorific values (Q_a – the lower calorific value of dry mass, MJ·kg^{-1}) and ash content (A_s – ash content of dry mass, %) of peat, wood chips and their mixture ratio (50-50), 50 % of peat and 50 % of wood chips, have been determined by experiments. The research results are presented in Fig. 3 and Fig. 4.

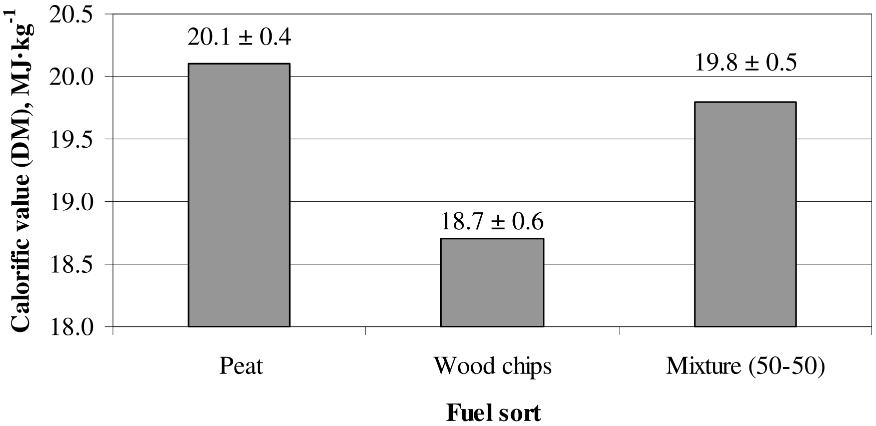

Fig. 3. **Calorific value of components and their mixture, MJ·kg^{-1}**

As we may see, in our case the peat calorific value was 7 % higher than that of wood chips. It depends on the sort of peat and wood; however, in practical calculations, it is considered that the calorific value of peat and wood is similar. It allows us conditioning that, when preparing mixtures, the quality of component mixing (evenness of mixture component distribution) does not have much influence on the fuel calorific value.

Little quantity of ash in fuel conditions – better fuel quality. As it may be seen from the research results, it is purposeful to prepare peat and wood chip mixtures since the ash quantity after burning such mixture is 45 % lower than burning only peat. Thus, the mixture ratio (50-50) preparing peat and wood chip biofuel would be the most acceptable. Increasing the quantity of wood in the mixture, a lower ash content is obtained. Also, we reduce volumes of usage peat in biofuel production. Increasing the peat quantity in the mixture, the ash content of biofuel increases, and this worsens the quality of biofuel. It is also worth noting that under production conditions, similar quantity of mixture components eases the technological process of preparation of this biofuel.

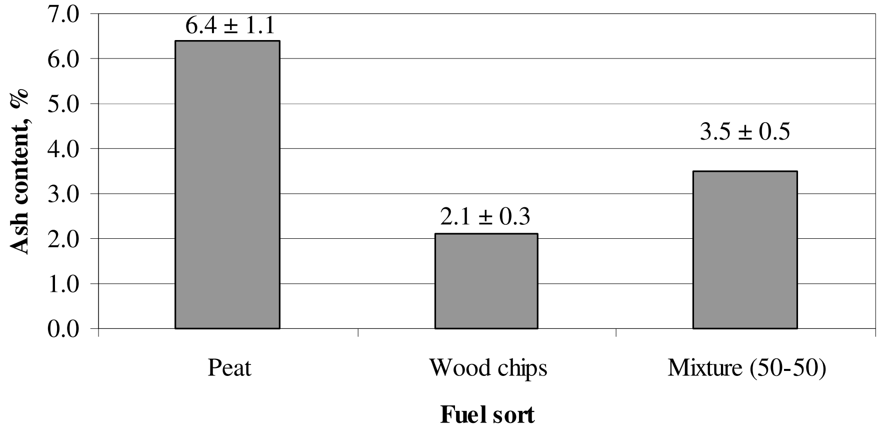

Fig. 4. **Ash content of components and their mixture, %**

Conclusions

1. Dependency of the density on moisture of peat, wood chips and their mixtures has been determined. When the moisture of peat and wood chips increases from 20 % to 40 %, their filled density increases accordingly 11-12 % and 14-15 %. According to the research results, we may state that if the quantity of peat in a mixture increases, its density in a mixture increases as well.
2. Fall and natural slope angles of the mixture components (peat and wood chips) have been determined. The research results show that moisture has the biggest effect on the peat fall angle, which varied from 71.0 ± 0.6 to 90.3 ± 0.6 degrees.
3. Fractional composition of the components has been determined by experiments. Based on the results, we may state that the biggest part of peat (about 50 %) is of 0-1 mm fraction, about 50 % of wood chips are of 8-16 mm fractional composition; the smallest fractional composition of wood chips is 0-1 mm.
4. Calorific values of peat, wood chips and their mixtures have been determined. The research results allow stating that when preparing mixtures, the quality of component mixture (evenness of mixture component dispersion) does not influence the calorific values of fuel.
5. Ash content indices of the mixtures and their components show that it is purposeful to prepare peat and wood chip mixtures since the quantity of ash after burning the prepared mixture (made of 50 % peat and 50 % of chopped wood) is 45 % smaller than burning only peat.

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