INVESTIGATION OF SAWDUST AND GLYCEROL BLEND BIOFUEL BRIQUETTE PRODUCTION AND USAGE

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Abstract. Production and usage of sawdust fuel briquettes blend with glycerol additives were investigated. The environmental influence of wood fuel usage for heating is much less than the usage of fossil firing. While burning wood, it emits less CO_2, NO_x, sulphur compounds and other harmful gas emissions in comparison with burning of other oil products or carbon. While increasing the production of biodiesel in Lithuania, the glycerol usage problem becomes relevant. The market in the EU is full it, and to build a glycerol reprocessing factory would be no available. Consequently we used the mix of glycerol with sawdust and produced briquettes from this mix. It was experimentally determined, that the calorific value of the briquettes was 19.8 $MJ \cdot kg^{-1}$, and the efficiency of production and pressing equipment while using glycerol was increased. The working time between renovations was extended to 10-15 %, that could be explained by good lubrication features of glycerol. The research results of harmful gas emission measurement showed that while burning the sawdust briquettes with 5-10 % glycerol additives CO_2 emission increased to 40-50 %. However, it is bio-based gas, which takes part in the natural circuit of rape existence. The increase of NO_x emission could be named as negative influence.

Keywords: briquettes, glycerol, production technology, biofuel, burning, emission.

Introduction

Together with positive effects (reduction of the thermal gas emission effect, increase in employment in the agricultural sector, etc.), rapid development of biofuel (RME) production in the EU Member States raises new requirements for by-products, including glycerol market development [1-3]. With the abundant offer of raw glycerol in the EU states, its price reduces and its realization problems arise. The commercial requirements for raw glycerol determine its concentration not less than 80 %, and the price of such a product differs from 310 to 470 $EUR \cdot t^{-1}$ [4]. In the biofuel production phase, there is only 62-69 % of glycerol. Everything else is made of acids, $CaCl_2$, water and methanol remains.

After production of 1t RME, we receive 106 g of raw glycerol. This product does not meet the above-mentioned commercial requirements; it should be cleaned more or its application area should be found. Since little amount of biofuel (RME) is produced in Lithuania, it is economically purposeless to build a special glycerol purification plant. The most attractive is mixing of non-separated glycerol phase with liquid fuel, *e.g.,* oil fuel and burning in boiler-stations. However, glycerol and its other components do not mix or hardly mix with petroleum and break down. Thus, it is quite problematic to burn them.

According to our research results [5-7], it is purposeful to use raw glycerol in production of sawdust briquettes. However, it is important to explore the composition of its oxide emission, since, in high temperature, acroleine may compose and it is very toxic [8]. In briquette production, glycerol phase from which methanol is extracted should be used. It is quite easy to solve this problem when preparing the briquette production technology.

Sawdust is the main component of briquettes. Their size may vary 1-5 mm. Their caloricity, if the moisture content is 30 %, is about 17.0-18.1 $MJ \cdot kg^{-1}$ [6]. With the increase of the moisture content in fuel, its caloricity reduces, transportation, storage and burning costs increase.

Usage of wood for heat production affects environment less than usage of excavated fuel. Less CO_2 and NO_x emissions get composed when burning wood than burning oil products or coal. It should also be noted that such pollutants like SO_2, HCL and hard metals are composed less [9].

The aim of this work is to determine a possibility to use glycerol in sawdust briquette production. Also, our aim is to offer the production technology and equipment, to determine regimes and the environmental effect of burning briquettes with glycerol.

Materials and methods

In the Agricultural Cooperative *Telšiai bioenergija* that produces approx. 1000 t of biofuel (RME) per year, according to the technology prepared by the Institute of Agricultural Engineering, production equipment of sawdust briquettes in which raw glycerol (remains of RME production) is added (Fig. 1.) is equipped.

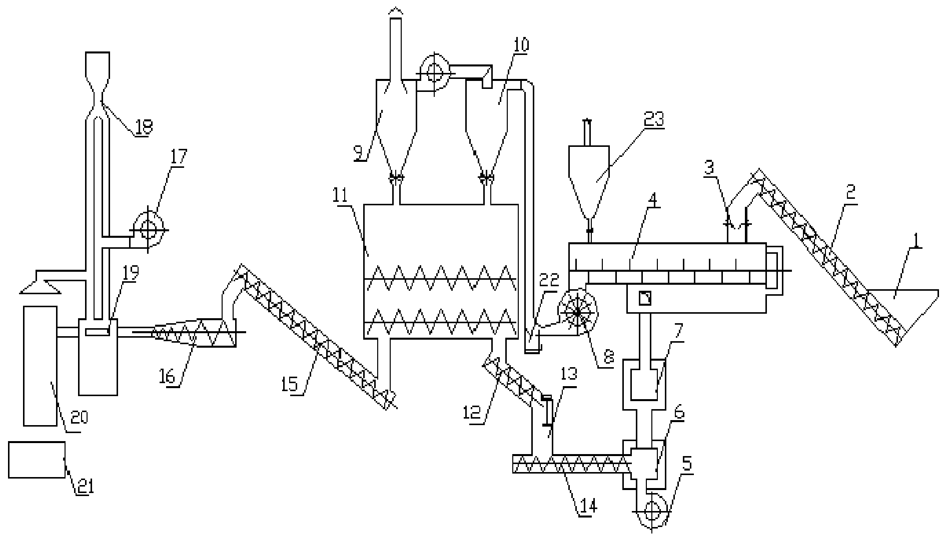

Fig. 1. **Technological scheme of sawdust briquette production:** 1 – sawdust hopper; 2 – auger conveyor; 3 – valve; 4 – drier; 5 – fan of the burner; 6 – chamber of primary combustion; 7 – chamber of secondary combustion; 8 – chopper; 9 – cyclone; 10 – dust separator; 11 – distribution hopper; 12 – batcher; 13 – oven hopper with level sensor; 14 – auger-batcher; 15 – press batcher; 16 – press; 17 – fan; 18 – ejector; 19 – briquette cutter; 20 – briquette transporter; 21 – packing table; 22 – separator; 23 – glycerol tank with batcher

Sawdust is loaded into the sawdust hopper 1, from which the auger conveyor 2 supplies it to the drier. Supply of sawdust is regulated by the valve 3. For production of briquettes, dampness of sawdust should be from 6 to 10 %; so, before pressing it is dried in a drier 4. Positions 5, 6 and 7 are named as the fan of the burner, the chamber of primary combustion and the chamber of secondary combustion accordingly. The burner is used for supply of hot air to the drier. Dry sawdust gets from the drier to the chopper 8 and after chopping it is lifted to the dust separator 10. The harder fraction of sawdust is poured through a doser in the distribution hopper 11. By a fan of the cyclone 9, the dust is separated from sawdust. Sawdust is poured through a cyclone doser to the distribution hopper. From the distribution hopper the part of sawdust gets into a batcher and fills into the oven hopper with the level sensor 13. Sawdust is supplied to the oven by an auger-batcher 14. The press batcher 15 is meant for directing sawdust into the press 16. The pressed sawdust is cut into briquettes by a device 19 to the desired length.

During briquette production smoke and heat extract, so the technology line foresees the aspiration system which is made of a fan 17 and ejector 18. The steam collector is equipped above the briquette transporter 20 and packing table 21. The separator 22 is meant for harder elements that got together with sawdust mass and which could disturb the briquetting process. During briquette production raw glycerol is added into sawdust during the drying process since water and methanol remains should be removed from glycerol. The glycerol tank with the batcher is marked as position 23 in the scheme.

Technical indices of the technological line:

- productivity 250 kg·h^{-1};
- briquette pressing channel temperature up to 350 ºC;
- moisture content of the pressed mass 10 %;
- briquette measurements 50x50x400 mm;
- briquette density 1100-1300 kg·m^{-3};
- amount of glycerol added to sawdust 50 and 100 kg·t^{-1}.

Sawdust briquettes were tested according to four parameters: average density, moisture content, ash content and caloricity. The briquette density and moisture content were determined in the

Chemistry laboratory of the Institute, and the ash content was researched when burning a pack of briquettes (12 pcs.) in a central heating boiler. The research was performed according to the standardized methodologies [5; 6].

Briquette burning tests were performed in the Laboratory of Energetics of the Institute. During the tests the amount of the air supplied to the oven mouth varied from 30 $dm^3 \cdot s^{-1}$ to 120 $dm^3 \cdot s^{-1}$. For analysis of fuel burning, an experimental burning device with a fire-place burner was used [10].

Fuel mass is determined by a balance RP-50Š11 with deviation ± 0.01 kg. Quantity of the supplied for burning air is measured by a rotameter. The rotameter is checked by measuring the air movement speed in the fire-place with a deviation ± 0.1 $m \cdot s^{-1}$ by a flow sensor FVA915-S120 and a device ALMEMO-2290-8. Burning temperature in the fire-place is measured by a NiCroSil-NiSil (N) thermo-element and registered by a device ALMEMO-2290-8, with 1 ºC precision. Duration of the tests is determined according to the time limits of the mentioned device. Burning quality is determined by a burning analyser PCA-65 produced by the company BACHARACH when measuring the quantity of oxide, carbon monoxide, nitrogene oxide in smoke and smoke temperature. Measurement precision: oxide – 0.3 %; CO_2 – 10 ppm; NO – 5 ppm; smoke temperature 1 ºC.

In the Laboratory of Agrotechnological Research of ASU the chemical composition of raw glycerol was determined, and in the Quality laboratory of fuel and peat (UAB *Durpa*) caloricity of sawdust briquettes was determined.

Results and discussion

Physical-chemical characteristics of glycerol obtained during biofuel production are presented in Table 1.

Table 1

Composition of glycerol phase and crude glycerol

Parameters	Glycerol fraction	Crude glycerol
Water, %	26.8 ± 1.6	12.5 ± 0.6
Glycerol, %	69.3 ± 2.3	86.8 ± 3.6
Methanol, %	3.2 ± 1.7	0.3 ± 0.03
RME residues, %	0.7 ± 0.08	0.4 ± 0.08
Density at 20 ºC, $g \cdot cm^{-3}$	1.12 ± 0.09	1.18 ± 0.11

As it may be seen from the presented data, glycerol phase contains 26.8 % of water and 3.2 % of methanol. Crude glycerol contains a small amount of methanol and water which should be removed by steaming before adding it to sawdust since this component may arise danger to human health. This is foreseen in the presented technological line of fuel briquette production. The amount of methanol in glycerol which we added to sawdust during briquette production has not exceeded 0.04 %, and water – 1.1 %.

The physical parameters of the obtained fuel briquettes with glycerol additive are presented in Table 2. 12 briquettes in one example were used and the glycerol proportion in the mixture was 10 %.

Table 2

Physical parameters of fuel briquettes with glycerol additive

Density, $kg \cdot m^{-3}$	Moisture content, %	Ash content, %	Calorific value of absolutely dry weight, $MJ \cdot kg^{-1}$
1120 ± 36	8.28	1.13	20.3
1080 ± 52	8.33	1.20	19.4
1280 ± 62	8.48	1.13	19.7
1160 ± 50	8.36 ± 0.15	1.15 ± 0.05	19.8 ± 0.31

The main operational part of the briquette forming press is a screw. During operation it is worn out intensively due to abrasive, chemical and electro-chemical effect. Only the screw and its covering parts that are alloyed work properly. Wearing out of the press screw is determined when it starts to “shoot” because, due to the increased friction, heat is generated in the pressure zone, and gas starts to break form the appeared clefts. It indicates that the screw should be restored. Glycerol mixed with the sawdust mass reduces friction of the mechanism elements, and, at the same time, it reduces wearing out of screw transporters and the press. It has been determined by tests that operational time of the press screw till restoration is prolonged by 10-15 %.

It has also been determined by tests that, when burning briquettes with 10 % of glycerol addition (mass of the example was 10 kg), temperature inside the oven was on the average 15 % higher than burning briquettes without glycerol (if the quantity of the supplied air is 60 $dm^3 \cdot s^{-1}$) (Fig. 2).

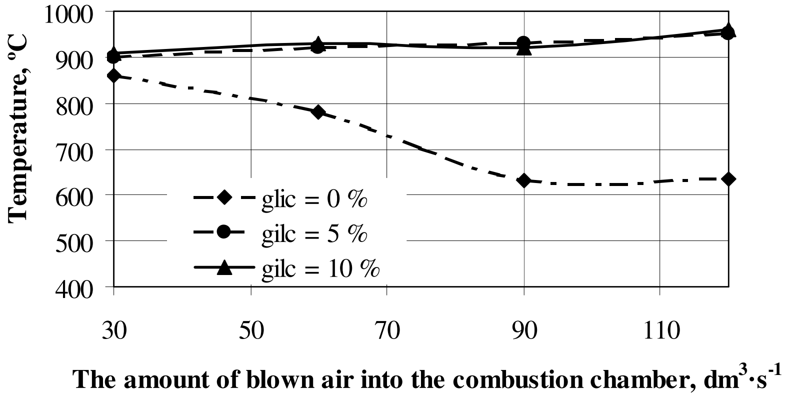

Fig. 2. **Temperature in burning chamber**

It is worth noticing that, when burning briquettes without glycerol additive, a quick temperature reduction in the oven was noticed (from 815 ºC to 630 ºC) after we increased the amount of the supplied air from 50 to 90 $dm^3 \cdot s^{-1}$. Increasing the amount of the supplied to the oven air till 120 $dm^3 \cdot s^{-1}$, temperature regime of the oven got stable (Fig. 2). When burning briquettes with 5 and 10 % glycerol additive, a stable oven temperature regime is noticed in the entire air amount range (from 30 to 120 $dm^3 \cdot s^{-1}$) (Fig. 2). Usage of glycerol additives predetermines better caloricity characteristics of briquettes.

Information about the quantity of carbon dioxide in oxides (depending on the blown to the oven air amount) is presented in Fig. 3. As it may be seen from the presented curves, with the increase of the air amount in the briquettes with glycerol, the quantity of carbon dioxide also increases (25-30 %). However, it should not be attributed to a negative environmental glycerol burning effect since the extracted quantity of CO_2 is of biological origin; it was accumulated at the end of the vegetation cycle-years.

Increase of NO_x amount in oxides while burning briquettes with glycerol additive should be attributed to a negative environmental effect (Fig. 4). However, this phenomenon is characteristic not only for glycerol burning but also for usage of biofuel in internal-combustion engines [11].

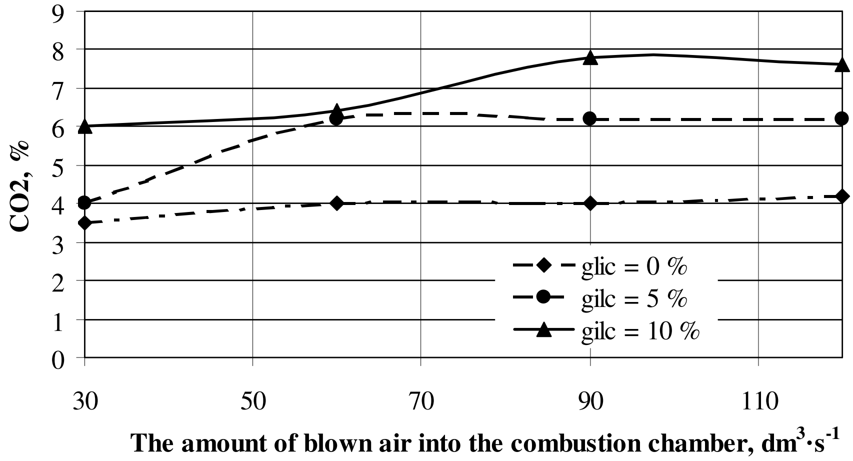

Fig. 3. **Carbon dioxide in the burning gases**

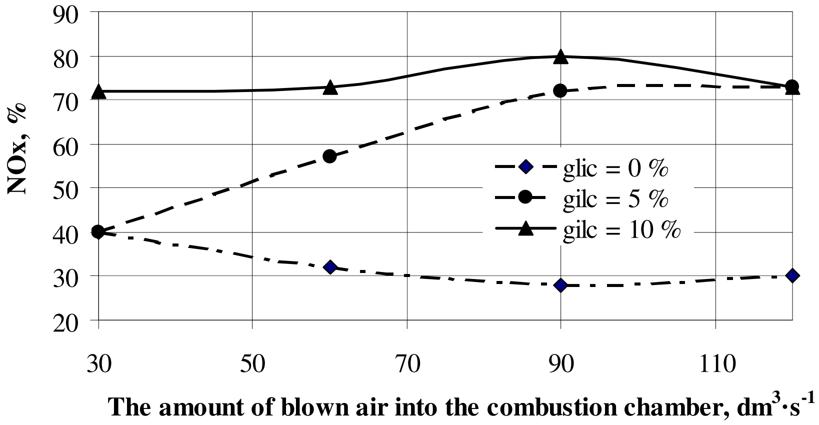

Fig. 4. **Amount of NO_x in the burning gases**

However, it is worth noting that with the increase of the glycerol amount from 5 to 10 % with the supplied to burning furnace 30 $dm^3 \cdot s^{-1}$ air amount, the amount of NO_x is about 40 % higher. So, form the environmental point of view, the recommended glycerol additive should not exceed 5 %, and, while burning briquettes with glycerol additive, it is necessary to keep to smaller amount regimes of the air supplied to the burning furnace (30-40 $dm^3 \cdot s^{-1}$).

Conclusions

1. Usage of glycerol in production of sawdust briquettes not only enables to rationally use RME production remains, but also reduces worn out of the press screw by 10-15 %.
2. Before adding glycerol to fuel briquettes, it is necessary to steam out water and methanol from it. The latter should not exceed 0.05 % in the composition of glycerol.
3. Having added glycerol additive into sawdust (5-10 %), the calorific value of the obtained briquettes increases from 8 to 10 % if compared to sawdust briquettes without glycerol.
4. From the environmental point of view, having evaluated CO_2 and NO_x emissions, the amount of glycerol in sawdust briquettes should not exceed 5 %.

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