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Environmentally friendly technologies for obtaining fuels for agricultural energy

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Abstract. The paper describes some ways of greening the agricultural energy industry, in particular, methods of utilizing industrial waste to produce fuel briquettes using pig manure as a binder and creating a biogas plant in the climatic conditions of Siberia, which allows organic waste (manure, bird droppings, household waste) to be recycled etc. The optimal ratios of the initial components in the briquette mixture are revealed. It is established that the best compositions, taking into account the strength of the briquettes obtained, are briquettes with coal of grade D - up to 10%: grade B2 - from 60%: manure with moisture content 72% - not more than 30%. It was determined that reducing the proportion of binder (manure) to 15% leads to the need to increase the pressure of the press to 300 kgf / cm². Adding manure in the briquette changes the burning characteristics, the briquette burns longer, and it becomes possible to reduce the pressure. The data on the kinetics of drying the prepared briquettes with the determination of the optimal mode providing explosion-fire safety and the absence of volatile substances were obtained. The possibility of introducing biogas technologies into the agricultural sector of the Krasnoyarsk Territory economy has been considered.

1. Introduction

The rational nature management consists in the fact that a person treats the environment reasonably and in the process of developing natural resources prevents the negative consequences of his activity. An example of rational nature management is the use of low-waste technologies that ensure the fullest use of the processed raw materials and the resulting waste. At the same time, substances in relatively harmless quantities are returned to the environment. The rational nature management can also be considered the creation of environmentally friendly fuels, the improvement of technologies for the extraction and transportation of natural raw materials, etc. [1, 2].

In this paper, some ways of greening the energy of agriculture are considered, in particular, methods of utilizing coal preparation and coal processing waste to produce fuel briquettes using pig manure as a binder and creating a biogas plant in Siberian climatic conditions that allows organic waste to be recycled (manure, poultry dung, household waste, etc.). After processing, biogas – gaseous fuel – is received. Thanks to biogas, the farm can completely abandon the heating of greenhouses in the winter period with expensive natural gas. In addition to biogas, environmentally friendly organic fertilizers are also produced from industrial waste. These fertilizers don't have pathogenic microflora, weed seeds, nitrites and nitrates [3].



Briquettes obtained with the use of manure, burn well, do not harm the environment and, most importantly, almost you do not have to pay for them. For those who do not have a main gas, it makes sense to think about the use of briquettes. Due to the low level of ash content and a small percentage of carbon dioxide emitted, the popularity of fuel briquettes is growing every year. In Siberia, as in all coal-mining areas, there is the problem of efficient use of substandard coal and coal processing waste. In addition, currently in the Krasnoyarsk Territory an average of 858 thousand tons of manure per year is accumulated per year, the disposal of which is a big problem [1-5]. Fuel briquettes can have different compositions - it can be manure mixed with coal of varying degrees of metamorphism, straw, wood waste, and grain waste. Perhaps such an alternative fuel will be for someone to fuel independence [6].

The purpose of this work was to establish the influence of the characteristics of the feedstock on the strength and heat and energy characteristics of fuel briquettes from plant waste and manure as a binder.

The tasks of the work were to determine the most effective percentage ratio of the solid phase and the binder and the effect of the quality of the feedstock on the characteristics of the fuel briquettes produced.

2. Coal briquettes

As raw materials were used: pork manure (LLC Yemelyanovskoe), coal of grade B2 from the Berezovsky deposit and grade D from the Balakhtinsky deposit, coarse-grained and fine-grained sludge (mine Polosukhinskaya, Kemerovo region), wheat straw, sawdust. Characteristics of the starting materials and particle size distribution are presented in table 1.

Table 1. Characteristics of raw materials.

Component	Humidity, %	Ash, %
Pig manure	80.2	5.8
Coal grade B2	21.9	8.7
Coal grade D	3.7	12.3
Coarse-grained sludge	14.5	14.7
Fine-grained sludge	34.6	27.8
Straw	20	-
Wood shredding	60	-
Wood shredding	30	-

During the experimental work, the composition of the mixture was calculated according to GOST 27313-95. Next, the original components were mixed in the mixer for 7 minutes.

The mixture was briquetted on screw auger installation with a BT.ShP 50.0 press (figure 1).



Figure 1. a) press BT.ShP 50.0; b) briquetting process.

Studies on the briquetting of the mixture, pre-dried in atmospheric air to optimum humidity, on an elevated piston press, have shown the possibility of preparing briquettes of the required quality.

The received briquettes were analyzed for humidity according to GOST 27314-91, ash content according to GOST 11022-95. The received briquettes were tested for resistance to dropping according to GOST 21289-75. Dried briquettes were burned in a laboratory setting [7].

The research has been conducted of the effect of the quantitative composition of the initial raw materials in briquettes on their quality. Based on this research, the optimal ratios of the starting components in the briquette mixture were revealed. Briquettes were obtained with the ratio of manure: coal in % - 5:95; 10:90; 15:85; 20:80; 25:75; 30:70. In the course of experimental work, it was found that briquettes from coal of grade D at all ratios do not retain their shape when processed in a press under pressure from 250 to 500 kgf / cm². Brown coal and sludge briquettes are more resistant when they are treated with pressures from 300 to 500 kgf / cm² and retain their shape after drying and drop resistance tests. The drop strength was mainly 80-90% at all the above ratios.

The compositions of coals of different stages of metamorphism and waste of coal processing in the process of briquette production are investigated. It is established that the best compositions, taking into account the strength of the briquettes obtained, are briquettes with a ratio of coal grade D - up to 10%: grade B2 - from 60%: manure with a moisture content of 72% - no more than 30%. It should be noted that the production of slime-based briquettes, i.e. coal mining waste practically does not cause technological and technical problems. Heating of the initial mixture to 50-60 ° C leads to an improvement in the strength characteristics of briquettes from all coals [8-10].

While getting briquettes using sawdust, the ratios of manure were analyzed: sawdust - 50:50; 25:75; 15: 85%. Getting fuel briquettes from sawdust and manure, as a binder, it was established that the quality of wood has a great influence, in this case. When using softwood sawdust, the quality of briquettes is improved both in strength and in terms of burning characteristics, which is explained by the increased content of resinous substances. It was determined that reducing the proportion of binder (manure) to 15% leads to the need to increase the pressure of the press to 300 kgf / cm².

The ratio of manure: straw 50:50; 25: 75% was studied. When receiving briquettes from straw and manure, devices are used for cleaning raw materials from soil and dust (when harvesting straw, soil and dust get into the raw materials, and at the first stage it is cleaned in a centrifuge), dryers (maximum moisture content is 16%), shredders (straw cutter) (the size of the stems is not more than 10 mm), stamp press or extruder (pressure more than 30 MPa). In principle, when receiving briquettes from one straw in stamp presses, the raw materials are compacted by simple squeezing, and no binder materials are added, because the lignin contained in biomass serves as a binder. Adding manure in the briquette changes the burning characteristics, the briquette burns longer, and it becomes possible to reduce the pressure.

One of the important indicators of fuel briquettes is its humidity. Accordingly, it is necessary to dry the briquettes. The final moisture content in the briquette should not exceed an average of 20-30%. Analysis of the data on the kinetics of drying of the obtained fuel briquettes from all types of raw materials showed that at a humidity of 31.2% and a drying agent temperature of 100 ° C, the drying time was from 50 to 80 minutes. The mass of briquettes is averaged 12-18 grams.

After determining the optimum moisture content of the briquette mixture and its pressing mode, the research of the drying kinetics of the obtained briquettes was carried out. Coal briquettes were dried at 110 °C, 130 °C and 160 °C on the MA-35 moisture analyzer and additionally at a temperature from 160 °C to 250 °C in a muffle furnace.

Raw briquette was exposed to drying (immediately after pressing). The change in the mass of the sample on the graph is presented in relative units. The relative mass of the original sample is taken as 100%. The relative mass of the dried sample on the graph corresponds to the value of M_{rel} [11].

$$M_{rel.} = \frac{m}{M} \times 100\%$$

where m is the mass of the sample at the current time, g; M – is the mass of the original sample, g.

The results of drying kinetics are presented in figure 2. As shown in the figure, after placing the sample in the heating medium, the relative weight of the sample gradually decreased to a constant value,

i.e. until complete drying of the briquette. An increase in the drying time of dry briquettes to 2 hours at the indicated temperatures did not lead to an additional weight loss due to the release of volatile substances. When the temperature rises to 220 °C, the sample showed a tendency to decrease in mass. The mass reduction in the temperature range of the heating medium from 160 °C to 220 °C is explained only by the process of drying the sample, the volatile matter does not occur at these temperatures, as indicated by the presence of a horizontal section on the graph of the sample mass.

In the course of the experiment, the dependence of the heating of the inner region of the briquette sample on the temperature of the heating medium was investigated. The temperature of the internal region of the sample was measured with a chromel-alumel thermocouple. The thermocouple thickness was 0.5 mm. The thermocouple junction was placed in an area close to the briquette axis at a distance from the ends exceeding the briquette diameter. Studies were subjected to briquettes with a diameter of 30 mm and a length of more than 60 mm. It is established that when the temperature of the heating medium is less than 180 °C, the drying time of the sample should be relatively long. Even after 30 minutes, the temperature in the middle of the sample did not reach 90 °C. The rise in temperature in the center to values exceeding 100 °C is observed only an hour after the sample is placed in the heating medium. This time practically coincides with the drying time of the samples (figure 2).

Thus, the expected drying time of the briquettes is about 1 hour. Depending on the adopted drying option (up to 10% or up to 15%), the required time will be determined during the commissioning works.

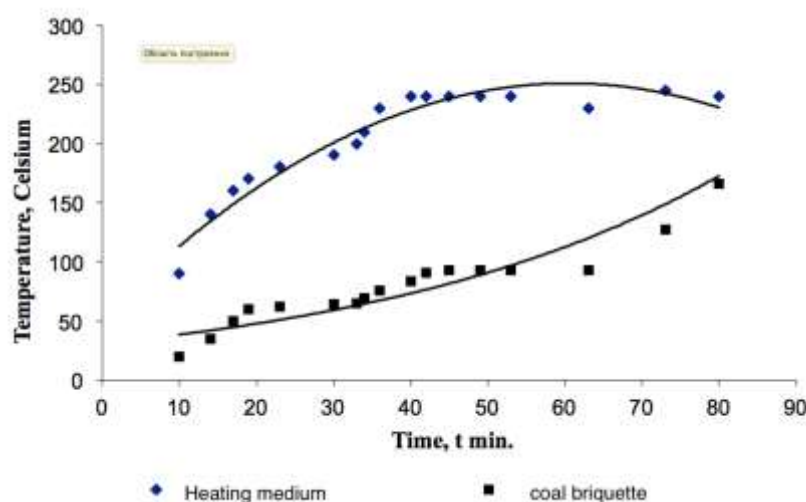


Figure 2. The dependence of the drying time of briquettes on the temperature of the heating medium.

3. Biogas

The purpose of the work phase was to adapt the technology and create an experimental plant for processing livestock wastes to produce biogas [11-16]. During this work, an inventory of livestock wastes in the territory of the Krasnoyarsk Region was carried out; the suggestions were worked out for the utilization of manure using BGI, which is the main waste of livestock production; areas of application of BGI with different productivity are investigated, with reference to the needs of consumers with the justification of the economic efficiency of the intensive technology of anaerobic digestion of pig manure.

At present, the amount of litter (with low humidity) pig manure in the Krasnoyarsk Region reaches approximately 900.000 tons, it is possible to obtain at least 15-20.000 m³ of biogas. It should be noted that the production of 1 kW of electricity requires 0.4-0.5 m³ of biogas. In order to maintain the biogas station in a harsh winter, it is necessary to design a station with an installed electric power of at least

0.45-1.1 MW. When determining the regime, it was found that the most effective is thermophilic. A modified composition of introduced biological strains was determined when applying the thermophilic regime. The use of this additive allows increasing the biogas yield from 20 to 40% without changing the design of the biogas installation, to increase the methane content in biogas, to extract all biogas in the main fermentation reactor without the pre-fermentation stage. Thus it is possible to build biogas stations 2 times cheaper or to extract additional energy from the raw material. The possibility of controlling the quality of fertilizers obtained and the scheme of their application depending on the quality of soils is established. The liquid phase after the separator (the so-called «ammonia water») needs to be processed with increasing and decreasing of nitrogen content, there are currently no such processing schemes. An effective system of technical support of the technological process has been developed. It is proposed to apply a reversible feedstock supply system and output of final products. It is proposed to use a bubbling mixing scheme with the introduction of a biological material into the gas phase.

Quantitative characteristics of the product - the capacity of the plant for the raw material - from 1/20 to 1/10 of the total volume of raw materials in the reactor; the amount of biogas produced (m^3 per 1 kg of dry matter) - from 0.250 to 0.620; the amount of solid fertilizers is up to 20%; the amount of liquid fertilizers is up to 80%. Qualitative characteristics of the product - the lower calorific value of biogas - up to 24-26 kJ / m^3 .

Technological solutions that are promising for use in the climatic conditions of the Krasnoyarsk Region were divided into three types, for:

- small farms and villagers with a personal subsidiary farm, which usually includes 2-3 cows, several pigs and several dozen chickens, when the technological equipment is installed directly in the premises for keeping animals, which will make it possible to use successfully the equipment in the winter conditions of the Krasnoyarsk Region;
- medium-sized farms, starting from 50 heads of cattle or 500 heads of pigs, or 5.000 birds;
- large agricultural enterprises (cattle farms, pig farms, poultry farms), when the technological equipment is additionally installed and upgraded in comparison with the standard equipment, so that it can be successfully used in winter conditions of the Krasnoyarsk Region.

The evaluation of the scope of BSU for various consumers was carried out on the basis of criteria of both comparative (commercial) efficiency and absolute economic efficiency.

4. Conclusion

Thus, the work revealed the optimal ratios of the starting components in the briquette mixture. It is established that the best compositions, taking into account the strength of the briquettes obtained, are briquettes with a ratio of coal grade D - up to 10%: grade B2 - from 60%: manure with a moisture content of 72% - no more than 30%. The briquettes with the ratio of manure: sawdust - 50:50; 25:75; 15: 85% were received. It was determined that reducing the proportion of binder (manure) to 15% leads to the need to increase the pressure of the press to 300 kgf / cm^2 . Studied the ratio of manure: straw 50:50; 25: 75%. Adding manure in the briquette changes the burning characteristics, the briquette burns longer, and it becomes possible to reduce the pressure. The data on the kinetics of drying prepared briquettes with the determination of the optimal mode providing explosion-fire safety and the absence of volatile matter were obtained.

The possibility of introducing biogas technologies into the agricultural sector of the economy of the Krasnoyarsk Territory has been considered, consumer groups have been identified for which 2 product promotion schemes have been developed - 1) project documentation developed for a particular farm, taking into account its features and with the author's supervision during the installation process; 2) direct production of a biogas plant.

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