Technology for obtaining high-quality fuel briquette based on petroleum and vegetable oil residues

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Abstract. This paper discusses methods of obtaining fuel briquettes from hydrocarbon-containing waste of oil refineries as a binder, as well as conducts a comparative analysis of the operational characteristics of the obtained products and previously known fuel briquettes. To improve the operational properties of oil sludge briquettes, research is conducted and an optimal composition of the fuel briquette based on licorice root waste in combination with a binder mixture based on oil and fat residues is proposed. The paper provides a technology for obtaining a binder mixture based on oil and fat residues. Six types of alternative road bitumen samples based on the developed composition have been obtained, and research has been conducted on the following indicators: water absorption of the fuel briquette, total moisture in the fuel briquette, degree of ash content, and the amount of total sulfur in the fuel briquette. The article also presents a recommended technological scheme for the production of fuel briquettes using licorice root waste as a binder mixture.

1 Introduction

Currently in Uzbekistan, the majority of fuel briquettes are produced from coal and wood, as they are very economical and environmentally friendly. In Uzbekistan, about 5 thousand tons of oil sludge are formed annually at refineries, and about 20 thousand tons of cottonseed resin are produced at oil and fat plants, which are used as a by-product.

In Karakalpakstan, five production facilities were established for the production of medicine from licorice root, with an investment of 2.3 million US dollars, with over 2 million tons exported to China [1].

Today, after processing licorice root, a large amount of waste is generated, namely licorice roots. Used licorice roots are currently used as firewood or fertilizer for poorly enriched soil. Many scientists are working on rational ways to use used licorice roots for the benefit of humanity.

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2 Materials and methods

The stated technical solution aims to develop a technology for obtaining a binder mixture based on oil and fat residues, the composition of which enhances the quality characteristics and assortment of fuel briquettes, as well as the utilization of waste from oil refining and oil and fat industries.

The technical result is high-quality fuel briquettes that expand the range of their composition.

To achieve this result, the following research methods were conducted: determination of water absorption of the fuel briquette (according to State Standard 21290), determination of total moisture (according to State Standard 52911), determination of ash content (according to State Standard 11022), and determination of total sulfur (according to State Standard 8606) [2].

2.1 The method of determining water absorption

The essence of the method of determining water absorption lies in determining the percentage of water absorption, calculated based on the difference in weights of the samples before and after saturation with water.

The test briquettes are weighed, placed on a mesh stand, and immersed in a vessel with water, and a timer is started [3].

The briquettes should be immersed in the liquid without touching each other or the walls of the vessel, and should be covered with a layer of liquid at least 30 mm thick.

The briquettes are left in the water for:

Briquettes made from stone coal, anthracite, coke, semicoke - 24 hours;

Briquettes made from brown coal and lignite - 2 hours.

Then, the stand with the briquettes is removed from the vessel, allowed to drain for 2 minutes, and the briquettes are reweighed.

The water absorption of briquettes X, in percentage, is calculated using the formula

$$x = \frac{m_1 - m}{m} \cdot 100 \quad (1)$$

where m — is the mass of the briquettes before the test, in kilograms.

m_1 — is the mass of the briquettes after the test, in kilograms.

Calculations are carried out with an accuracy to the hundredths of a percent, rounding the final result to the tenths of a percent [4].

The method of determining total moisture:

The essence of the method of determining total moisture lies in drying the sample with a particle size of less than 11.2 mm in air at 105 - 110 °C.

All weighings are carried out on scales with a permissible error limit of ± 0.01 g. The initial sample is ground to a maximum particle size of 11.2 mm and reduced to a mass of not less than 2.5 kg. Alternatively, it is acceptable to grind the sample to a particle size of no more than 10 mm and reduce it to a mass of 2 kg. At least two portions of 600 g each are taken from the ground sample.

Dry empty trays are weighed. Portions of the fuel are placed in the trays, distributing them evenly so that the loading density does not exceed 1 g/cm2. If one tray is insufficient for the fuel portion, it is permissible to use two or more trays.

The trays with the sample are weighed and placed in a drying cabinet preheated to 105°C - 110°C. Drying is carried out at 105°C - 110°C, passing a stream of nitrogen through the drying cabinet at a rate of about 15 volumes of the drying chamber per hour [5].

The sample is dried to constant weight. After the main drying is complete, the trays with the sample are removed from the cabinet and weighed in a hot state as quickly as possible (within 5 minutes) to avoid moisture absorption during cooling.

Then the trays with the sample are placed back in the drying cabinet for a control drying. The time for control drying at 105°C - 110°C is not less than 25% of the duration of the main drying, but not less than 30 minutes.

Drying is considered complete if the sample mass loss during the control drying does not exceed 0.2% of the total mass loss.

The mass fraction of total moistureW_t, %, determined by the one-stage method, is calculated using the formula:

$$\mathrm{Wt} = \frac{m_2 - m_3}{m_2 - m_1} 100 \quad (2)$$

Where:

m_1 — is the mass of the empty tray (trays), in grams;

m_2 — is the mass of the tray (trays) with the sample before drying, in grams;

m_3 — is the mass of the tray (trays) with the sample after drying, in grams..

The result of determining the total moisture, which is the arithmetic mean of two parallel determinations, is calculated with an accuracy of 0.01% and rounded to 0.1%. The test report indicates that the determination of total moisture was carried out according to the method of this standard (one-stage method) [6].

Method for determining ash content.

The essence of the method of determining ash content lies in burning the sample in a muffle furnace, heated at a specified rate to a temperature of (815 ± 10) °C, and holding it at this temperature until a constant mass is achieved.

The essence of the method is that the analytical sample of solid fuel is ashed with a mixture of magnesium oxide and anhydrous sodium carbonate (Eschka mixture) in an oxidizing atmosphere (with free access to air) at a temperature of (800 ± 25) °C. Under these conditions, the organic mass of the fuel is burned, and all forms of sulfur are converted into sodium and magnesium sulfates.

The formed sodium and magnesium sulfates are dissolved in hot water or hydrochloric acid (alternative methods). In the solution, sulfate ions are determined by the gravimetric method, precipitating them in a chloric acid environment with barium chloride as barium sulfate.

The mass fraction of total sulfur in the analytical sample of solid fuel is calculated based on the mass of the precipitated barium sulfate [7].

If blank tests are conducted with the addition of potassium sulfate solution, then the mass fraction of total sulfur in the analytical sample of fuel S_t^a, expressed in percentages, is calculated using the formula:

$$S_t^a = \frac{(13.74(m_2 - m_3 + 0.03348 \cdot c)}{m_1} \quad (3)$$

where m_2 — The mass of barium sulfate obtained during the analysis of fuel, in grams.;

m_3 — The mass of barium sulfate obtained in the blank test, in grams.;

c— The concentration of potassium sulfate solution is 5.10 grams per decimeter cubed (or per liter);

If blank tests are conducted without the addition of potassium sulfate solution, then the mass fraction of total sulfur in the analytical sample of fuel S_t^a , expressed in percentages, is calculated using the formula:

$$S_t^a = \frac{(13.74(m_2 - m_3)}{m_1} \quad (4)$$

Where m_1- mass of barium sulfate obtained from fuel analysis, g

m_2- mass of barium sulfate obtained in a blank experiment, g;

c—concentration of potassium sulfate solution (5.10), g/dm3;

m_3 - mass of the fuel sample taken for analysis, g.

Refer to the explanations for formula (1).

$$S_t^a = \frac{(13.74(m_2 - m_3)}{m_1} \quad (5)$$

where m1, m2, m3 - see explanations to formula (1).

The result calculation is carried out with accuracy to the third decimal place, rounding the final result to the second decimal place [8].

The arithmetic mean of the results of two parallel determinations is taken as the final result.

The conversion of analysis results to dry and working conditions of fuel is carried out according to State Standard 27313.

The following recommended technological scheme is provided for obtaining the binder mixture.

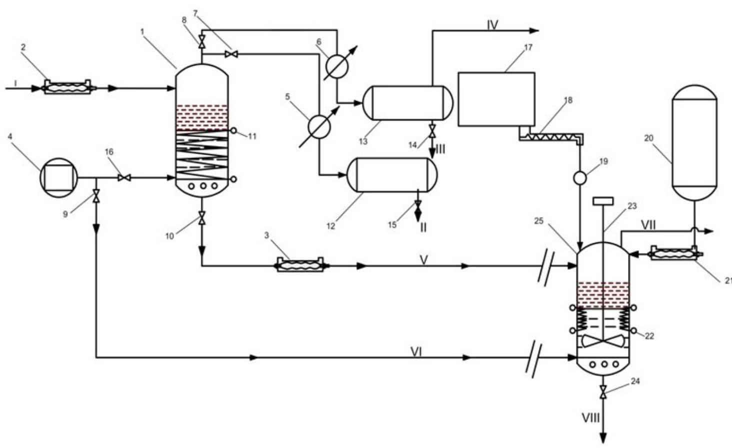

Fig. 1. Technology for obtaining the binder mixture.

3 Results and discussions

To obtain the binder mixture, an optimal composition was developed, the quantity of substances of which is presented in Table 1.

Table 1. Amount of substances in the binder mixture.

Samples	Amount of substances to obtain 100% finished binder mixture, wt.%		
	Gossypol resin	Oil sludge	Quicklime
SS-1	50	70	0.5
SS -2	50	70	1
SS -3	50	70	1.5
SS -4	50	70	2
SS 5	50	70	3

Additionally, samples for obtaining fuel briquettes were obtained, which are presented in Table 2.

Table 2. Ratio of dried spent licorice root to binder mixture for obtaining fuel briquettes.

Samples	The ratio of substances to obtain the finished fuel briquette	
	Spent licorice root	Binder mixture
*FB-1	9	
FB-2	10	
FB-3	11	
FB-4	12	1
FB-5	13	
FB-6	14	
FB-7	15	

Remark: * FB – Fuel Briquet.

As seen in table 1, fuel briquette samples were obtained based on spent licorice root and binder mixture in the following ratios: 9:1 (FB--1); 10:1 (FB -2); 11:1 (FB -3); 12:1 (FB -4); 13:1 (FB -5); 14:1 (FB -6); and 15:1 (FB -7). Subsequently, to determine which of these samples will yield the highest-quality fuel briquette, a series of analyses will be required, such as determining the adhesive properties of the binder mixture, as well as the strength and water absorption characteristics of the briquettes.

As evident from Table 3, the lower the mass fraction of total moisture in the briquette composition, the better its quality for use as a fuel briquette [9].

The mass fraction of total moisture in the fuel briquette is provided in table 3.

Table 3. Mass fraction of total moisture of the fuel briquette.

Indicator	**Samples of fuel briquettes**						
	FB -1	**FB -2**	**FB -3**	**FB -4**	**FB -5**	**FB -6**	**FB -7**
Mass fraction of total moisture, %	0.06	0.09	0.14	0.19	0.29	0.36	0.48

Based on the obtained indicators presented in Fig. 2, it can be concluded that water penetration into the fuel briquette depends on the quantity of the binder mixture.

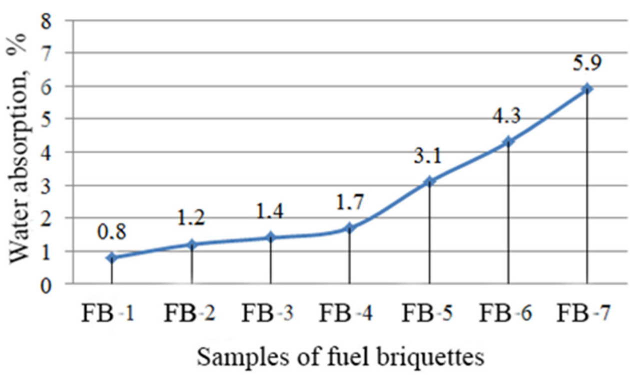

Fig. 2. Dependence of water absorption of the fuel briquette on its composition.

Thus, from the graph, it can be seen that the water absorption of the fuel briquette samples FB -1, FB-2, FB -3, and FB -4 exhibited the lowest values compared to the other fuel briquette samples.

Research on determining the ash content of the fuel briquette plays a significant role, as ash formation affects the environment [10].

The formation of ash for each briquette sample with increasing temperature can be observed in Fig. 3.

The next investigation involved determining the mass fraction of total sulfur in the fuel briquette using the gravimetric method. Based on the amount of barium sulfate, the mass fraction of total sulfur in each fuel briquette sample was calculated, and the results obtained are presented in Table 4

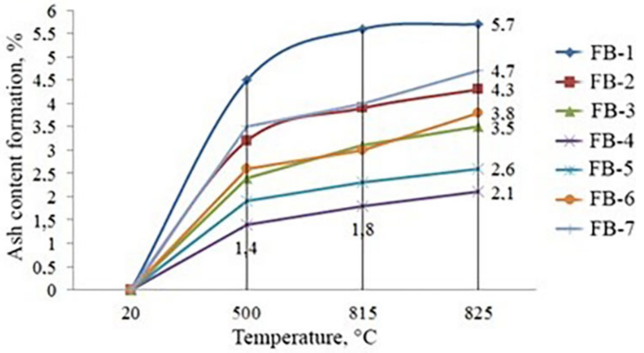

Fig. 3. Dependence of ash content of the fuel briquette on the quantity of binder mixture in the composition.

Table 4. Mass fraction of total sulfur in the fuel briquette.

Index	**Samples of fuel briquettes**						
	FB -1	**FB -2**	**FB -3**	**FB -4**	**FB -5**	**FB -6**	**FB -7**
Mass fraction of total sulfur, %	0.49	0.38	0.23	0.16	0.12	0.09	0.07

4 Conclusion

Based on the obtained results and analyses, it can be concluded that to produce a fuel briquette, a composition consisting of dried spent licorice root sized 3-7 mm and a binder mixture at a temperature of 70°C was determined.

Since not only quality but also cost-effectiveness plays a significant role in fuel briquette production, it can be concluded that sample FB-4 proved to be the most acceptable for production and meets the requirements of GOST R 52911-08.

As evident from Fig. 4, the ash content of fuel briquette FB-4 at a temperature of 500°C is 1.4%, at 815°C it is 1.8%, and at 825°C the ash content of the analytical sample is 2.1%. The ash content formation of other fuel briquette samples was higher than that of fuel briquette FB-4.

Based on the above, it can be concluded that after conducting all the tests, fuel briquette sample FB-4 is the most acceptable and meets the standards requirements.

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