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# QUALITATIVE CHARACTERISTICS OF A FUEL BRIQUETTE OBTAINED BASED ON LICORICE ROOT AND A BINDING MIXTURE

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**Abstract**

Based on dried spent licorice roots (length 10–15 mm and thickness 3–7 mm) and a ready-made binder mixture (gossypol resin 50%, oil sludge 70% and quicklime 1.5%), a fuel briquette was obtained in a ratio of 12:1. The qualitative characteristics of the fuel briquette were determined in the following order: water absorption of the fuel briquette, total moisture of the fuel briquette, ash content, mass fraction of total sulfur in the fuel briquette and the release of volatile substances. Based on the results obtained, the fuel briquette FB-4 turned out to be the best briquette.

**Keywords:** *Licorice root, binder mixture, fuel briquette, water absorption, sulfur, ash content, volatile substances*

## Introduction

Currently, in Uzbekistan, most fuel briquettes are made from coal and wood, as they are very economical and environmentally friendly. Analyzing information, articles, patents, dissertations and other data on the production of fuel briquettes, we can conclude that raw materials have a very important aspect for the quality of the product.

In Uzbekistan, about 5 thousand tons of oil sludge are generated annually at refineries, and in oil and fat plants about 20 thousand tons of gossypol resin are used as a by-product.

In recent years, in Karakalpakstan, the production of medicines from licorice roots has increased many times and a huge amount of waste from spent licorice roots has accumulated, since in most cases they are not used and sometimes are not disposed of. The problem of recycling spent licorice roots in our country is one of the most pressing, since currently, with existing processing methods, almost half of the biomass of licorice roots is lost. This indicates a low level of woodworking technological processes. The most significant results in the use of spent licorice roots have been achieved by countries with a highly developed sawmill and woodworking industry, which is the main supplier of waste.

Today, after processing licorice, waste is generated in large quantities, that is, licorice roots. Spent licorice roots are used as combustion wood or fertilizer for poorly enriched soil. Many scientists are working on how to rationally use waste licorice roots for the needs of humanity.

The binder mixture was prepared from gossypol resin, oil sludge and quicklime. During the experiments, the composition of the sample of the finished binder mixture was selected: gossypol resin 50%, oil sludge 70% and quicklime 1.5%. Then, in order to obtain a high-quality fuel briquette, you first need to dry the spent licorice roots to ensure adhesion to the binder mixture.

High-quality drying of spent licorice roots was carried out in an ABM-065 drum dryer. After conducting experiments, a fraction of licorice root with a length of 10–15 mm and a thickness of 3–7 mm was selected, which was dried at a temperature of 70 °C. Based on dried spent licorice roots (length 10–15 mm and thickness 3–7 mm) and a ready-made binder mixture (gossypol resin 50%, oil sludge 70% and quicklime 1.5%), a fuel briquette was obtained in a ratio of 12:1.

## Methods

The qualitative characteristics of the fuel briquette were determined in the following order: water absorption of the fuel briquette, total moisture of the fuel briquette, ash content, mass fraction of total sulfur in the fuel briquette and the release of volatile substances.

***Determination of water absorption of fuel briquettes.*** The water absorption of fuel briquettes (GOST 21289–75) was determined by keeping them in water at room temperature for 2 hours. Seven whole briquettes were weighed and immersed on a metal mesh in water to a depth of 30 mm from the surface. After being under water, the grid with briquettes was taken out, the water was allowed to drain for 2 minutes, then the briquettes were weighed on technical scales.

The water absorption of the fuel briquette (W), in percent, was calculated using the formula

$$W = \frac{m_1 - m}{m}$$

where m -mass of briquettes before testing, g; $m_1$ – mass of briquettes after testing, g.

***Determination of total moisture.*** The determination of total moisture was carried out according to GOST R 52911–2008 using a one-step method.

The initial fuel briquette sample was crushed to a maximum piece size of 11.2 mm and reduced to a minimum weight of 2.5 kg. The tray with the briquette was placed in a drying cabinet at 105–110 °C in air. Air exchange rate – up to 5 times per hour. Drying was considered complete if the weight loss of the sample during the time between two dryings did not exceed 0.2% of the total weight loss.

The mass fraction of total moisture Wt, in percent, was determined by the formula

$$W_t = \frac{m_2 - m_3}{m_2 - m_1} \cdot 100$$

where $m_2$ -mass of the tray with the sample before drying, g; $m_3$ – mass of the tray with the sample after drying, g; $m_1$ – mass of an empty tray, g.

The arithmetic mean value of the results of two parallel determinations was taken as the result of determining the mass fraction of total moisture. Calculations were carried out with an accuracy of 0.01% and rounded to 0.1%.

***Determination of ash content.*** To determine the ash content of a fuel briquette (GOST 11022–95) (Konyukhov, V.Yu., Kerban, N.V., 2015), an analytical sample was used, crushed to the size of particles passing through a sieve with a mesh size of 0.2 mm. Before starting the determination, the analytical sample was thoroughly mixed for 1 min mechanically.

The pre-heated crucible was weighed, 1–2 g of sample was evenly distributed and weighed again. Weighing error is no more than 0.1 mg. The crucible with the sample was placed in a muffle furnace at room temperature. Over 60 minutes, the oven temperature was increased to 500 °C and this temperature was maintained for 30 minutes. Next, heating was continued to (815 ± 10) °C in the same oven and maintained at this temperature for at least 60 minutes.

After calcination, the crucible was removed from the furnace and cooled on a thick metal plate for 10 min, and then placed in a desiccator without a drying agent. After cooling, the crucible with the ash residue was weighed.

Then control calcinations were carried out at (815 ± 10) °C for several 15-minute periods until the subsequent mass change was no more than 1 mg.

The ash content of analytical sample A, %, by weight, was calculated using the formula

$$A = \frac{m_3 - m_1}{m_2 - m_1} \cdot 100$$

where is the $m_1$ -mass of the crucible, g; $m_2$– mass of crucible with sample, g; $m_3$– mass of crucible with ash, g.

The arithmetic mean of the two closest definitions was taken as the test result.

***Determination of total sulfur.*** Determination of the mass fraction of total sulfur in the fuel briquette was carried out according to GOST 8606–93 using the gravimetric method. This method is based on the absorption of sulfur oxides formed during the combustion of a sample of fuel by an Eschka mixture consisting of magnesium oxide and anhydrous sodium carbonate with the formation of magnesium and sodium sulfates. The resulting salts were dissolved in hot water and precipitated with barium chloride in a solution acidified with hydrochloric acid. Based on the amount of barium sulfate, the mass fraction of total sulfur, %, was calculated using the formula

$$S = \frac{13{,}74\left(m_2 - m_3 + 0{,}03348\rho_{K_2SO_4}\right)}{m_1}$$

where is the $m_1$– mass of the sample, g; $m_2$– mass of barium sulfate obtained during determination, g; $m_3$– mass of barium sulfate obtained during control determination, g; $\rho_{K_2SO_4}$ – mass concentration of potassium sulfate solution, g/dm$^3$.

The result was taken as the arithmetic mean of two parallel determinations with an accuracy of ± 0.1%.

**Determination of the yield of volatile substances.** The yield of volatile substances was determined according to GOST 6382–2001 (Rasskazova, A.V., Alexandrova, T.N., 2013) by heating a sample sample without access to air at a temperature of 900 °C for 7 minutes and calculated by the weight loss of the sample minus the weight loss due to the humidity of the sample.

The yield of volatile substances from the analytical sample of the tested fuel $V^a$,%, was calculated using the formula

$$V^a = \frac{100(m_2 - m_3)}{m_2 - m_1} - W^a$$

where is the $m_1$ -mass of an empty crucible with a lid, g; $m_2$– mass of the crucible with lid and sample before testing, g; $m_3$– mass of the crucible with a lid and non-volatile residue after testing, g; $W^a$ – mass fraction of moisture in the analytical sample, %.

The yield of non-volatile residue from the analytical sample of the tested fuel $(NV)^a$, %, was calculated using the formula

$$(NV)^a = \frac{100(m_3 - m_1)}{m_2 - m_1}$$

If the mass fraction of carbon dioxide from carbonates in the fuel sample is more than 2%, the yield of volatile substances corrected for carbon dioxide from carbonates $V^a_{CO_2}$, %, was calculated using the formula

$$V^a_{CO_2} = V^a - \left[(CO_2)^a - (CO_2)^a_{NV} \cdot \frac{(NV)^a}{100}\right]$$

where $(CO_2)^a$ is the mass fraction of carbon dioxide from carbonates in the analytical sample; $(CO_2)^a_{NV}$ – mass fraction of carbon dioxide from carbonates in the non-volatile residue.

The result was taken as the arithmetic mean of two determinations that were within the acceptable discrepancies.

## Results and discussion

To conduct research on the water absorption of fuel briquettes, we obtained samples based on dried spent licorice root (fraction size 10–15 mm long and 3–7 mm thick) and a binder mixture (Table 1).

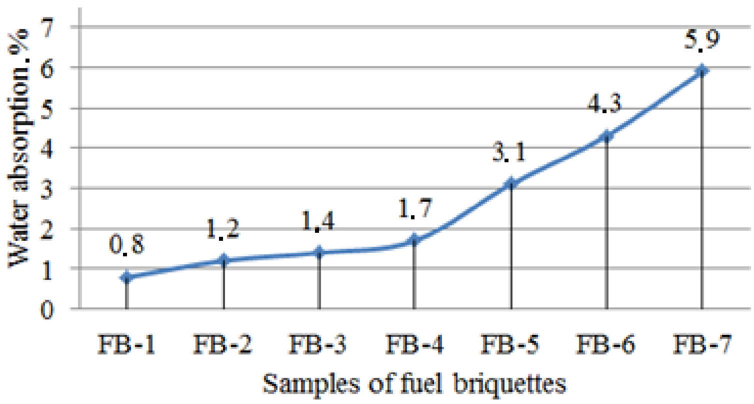
**Table 1.** – *Ratio of dried spent licorice root (DSLR) and binder mixture (BM) for obtaining fuel briquettes*

| Samples FB | DSLR: BM |
|---|---|
| Fuel briquette –1 | 9:1 |
| Fuel briquette –2 | 10:1 |
| Fuel briquette –3 | 11:1 |
| Fuel briquette –4 | 12:1 |
| Fuel briquette –5 | 13:1 |
| Fuel briquette –6 | 14:1 |
| Fuel briquette –7 | 15:1 |

*Note: FB – fuel briquette, DSLR – dried spent licorice root, BM – binder mixture.*

The final results of water absorption of fuel briquettes can be seen in Figure1.

**Figure 1.** *Dependence of water absorption of a fuel briquette on its composition*




As can be seen from Figure 1, fuel briquettes FB-1, FB-2, FB-3 and FB-4 have the lowest water absorption rate than others, because this aspect is influenced by the adhesive strength of the composition of the fuel briquette.

Each sample of fuel briquette was examined to determine the mass fraction of total moisture, which is shown in Table 2.

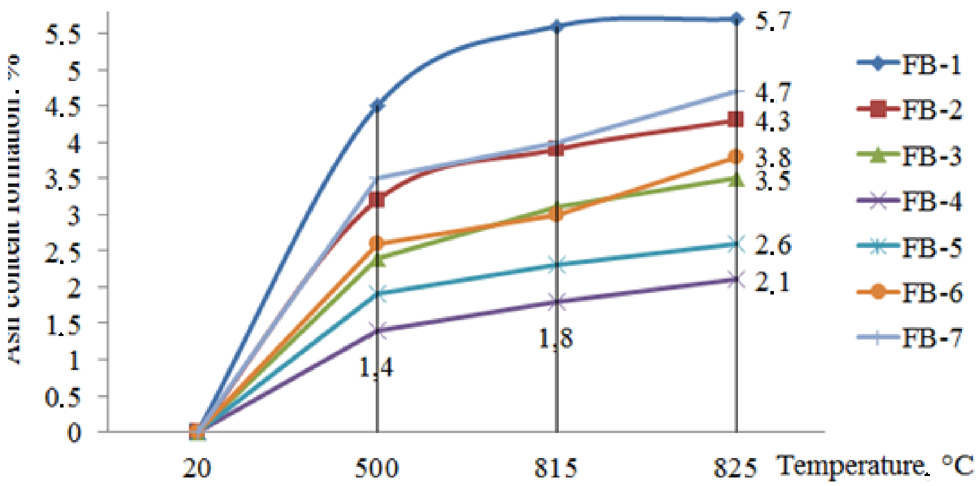
**Table 2.** *Mass fraction of total moisture of the fuel briquette*

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

As can be seen from Table 2, the lower the mass fraction of total moisture in the briquette, the better its quality for use as a fuel briquette. But since not only quality, but also efficiency also plays an important role in the production of fuel briquettes. Based on the GOST requirements, the most acceptable sample turned out to be FB-4 for production.

Research to determine the ash content of a fuel briquette plays a very important role, since the formation of ash affects the environment. The formation of ash for each briquette sample with increasing temperature can be seen in Figure 2.

**Figure 2.** *Dependence of the ash content of a fuel briquette on the amount of binder mixture in the composition*



As can be seen from Figure 2, the formation of ash content of the FB-4 fuel briquette at a temperature of 500 °C is 1.4%, at a temperature of 815 °C it is 1.8%, and at a temperature of 825 °C the ash content of the analytical sample is 2.1%. The formation of ash content in other fuel briquette samples was higher than in the FB-4 fuel briquette.

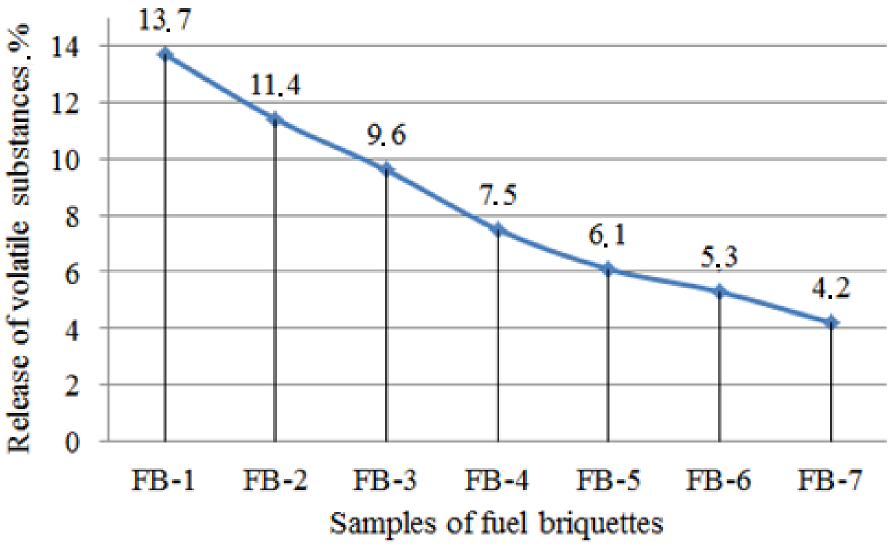
The following study to determine the mass fraction of total sulfur in a fuel briquette was carried out according to the gravimetric method. Based on the amount of barium sulfate, the mass fraction of total sulfur in each sample of fuel briquette was calculated; the results obtained are shown in Table 3.

**Table 3.** *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 |

The following study to determine the yield of volatile substances from a fuel briquette was carried out in accordance with GOST 6382–2001. The results of the data on the release of volatile substances from each sample of the fuel briquette can be seen in Figure 3.

**Figure 3.** *Dependence of the yield of volatile substances from a fuel briquette on its composition*




As can be seen from Figure 3, the yield of volatile substances from a fuel briquette will directly depend on the amount of binder mixture used. Since the ratio of licorice root and binder mixture in each briquette is different and the amount of binder mixture decreases, the yield of volatile substances in the samples also decreased from 13.7 to 4.2%.

## Conclusion

In this work, samples of fuel briquettes were obtained based on dried spent licorice root (fraction size 10–15 mm long and 3–7 mm thick) and a binder mixture in a ratio of 12:1. After all tests have been carried out, namely, the water absorption of the TB-4 fuel briquette meets the requirements of the standard, the mass fraction of the total moisture of the TB-4 fuel briquette is less than 0.2%, the formation of ash when heating the TB-4 fuel briquette has the lowest indicator. The mass fraction of total sulfur in the TB-4 fuel briquette complies with GOST requirements, and the yield of volatile substances from the TB-4 fuel briquette directly depends on the amount of binder mixture used in the briquette.

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