DETERMINATION OF THE QUALITATIVE CHARACTERISTICS OF COFFEE GROUNDS FOR ENERGY PURPOSES: A CASE STUDY FOR 100% ROBUSTA COFFEE

Daraduda Nicolae[1], Banari Alexandru[2*], Lupescu Ștefan Constantin[3]

[1]Technical University of Moldova, Faculty of Industrial Mechanical and Transport Engineering, Department of Transport, Chisinau, Republic of Moldova
[2]Technical University of Moldova, Solid Biofuels Scientific Laboratory, Chisinau, Republic of Moldova
[3]Department of Mechanics and Technologies, Stefan cel Mare University of Suceava, 13 University Street, 720229 Suceava, Romania
**Corresponding author e-mail: alexandru.banari@sfc.utm.md, tel. +373 69386587*

Abstract: *This study investigated the feasibility of using spent coffee grounds for energy purposes. Coffee grounds are a lignocellulosic residual by-product of the coffee industry, present in every city worldwide. The purpose of this research is to determine the qualitative characteristics of experimental coffee grounds in the Scientific Laboratory of Solid Biofuels at the Technical University of Moldova, with the subsequent potential to be used as raw material in the production of densified solid biofuels. The data obtained in the laboratory, correlated with information available in the literature, indicate an ash content of 2.31% and a net calorific value at 10% moisture of 19,06 MJ/kg. This demonstrates that coffee residues have significant energy potential and can be used as raw material for pellet production, as well as a component in various raw material blends employed in the manufacturing of solid biofuels.*

Keywords: *Biomass, used coffee grounds, residues, solid biofuels*.

1. Introduction

Biomass biofuels, which come from various sources of organic waste, can be converted by several methods to produce energy, thus reducing dependence on fossil sources. The depletion of classical fuel reserves, the need to reduce global warming on the one hand and the increase in the production of solid biofuels from renewable resources on the other hand emphasize the need to use all types of residues for energy purposes [1] . So this is becoming an increasingly widespread practice that boosts the local economy by creating jobs in the agriculture, forestry and waste processing sectors.

Worldwide, coffee is one of the most important agricultural commodities whose global production potential fluctuates from year to year, influenced by global climate change and changes in the use of agricultural land. Coffee grounds are a suitable resource for garden fertilizer, raw material for bioethanol , biogas, bio -oil production or densified solid biofuels in the form of pellets and briquettes [2] .

Thus, the use of solid biofuels densified from coffee residues as renewable energy for the conditions of the Republic of Moldova, could have a role in diversifying sources in providing sustainable fuel alternatives [3].

According to a UNDP article in collaboration with a chain of cafes in Chisinau alone, between 2000 and 3000 kg of coffee waste end up in the trash each month without sustainable and efficient use [4] .

Globally, coffee consumption is in continuous growth, such as in the European Union and the United States, coffee remains a basic product. EU coffee imports are estimated at 47.5 million 60kg bags, and those from the US at 24.5 million bags in 2024, so the hypothesis of the study focuses on exploring the possibility of producing densified solid biofuels with properties compatible with the standard ENplus , using coffee residues as a raw material or to be used as a mixture in the production of densified solid biofuels.

The present study aims to analyse the qualitative characteristics of coffee grounds for energy purposes, by analysing the main biomass characteristics such as moisture content, ash content, calorific value.

The transformation of coffee residues into biofuels is an effective method for reducing waste, preventing harmful effects on health and reducing environmental pollution. This approach promotes sustainability, utilizing waste for energy purposes thus contributing to reducing the negative impact on the environment.

2. MATERIALS AND METHOD

Conducting experiments. The research was carried out within the Solid Biofuels Scientific Laboratory of the Technical University of Moldova (LȘBCS UTM). Standard methods validated and applied in the laboratory were applied to determine the qualitative indicators of the selected biomass, namely the 100% Robusta Coffee grounds. The experimental residue samples were collected from the coffee machine that invigorates the scientific collaborators with energy drink.

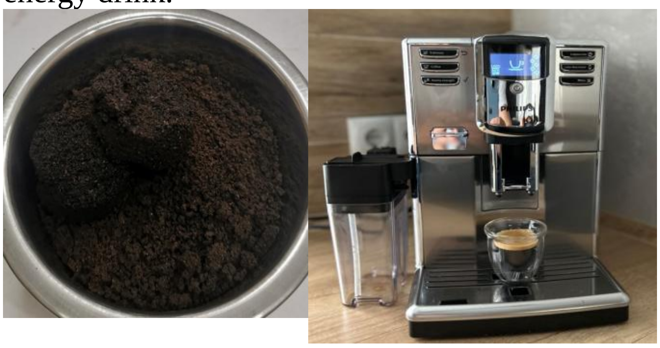

Figure 1. *Coffee grounds obtained from the automatic coffee machine in the laboratory*

As previously mentioned, the main characteristics of biomass, which subsequently influence the finished products, are the content of moisture, ash, volatile materials and calorific value.

Estimation of ash content.

Ash content is an essential indicator of biofuel quality. A high level of ash adversely affects fuel performance, reducing calorific value and combustion efficiency [3] . The ash content of the samples was estimated according to Standard SM EN ISO 18122:2023. The mass of the sample should be approximately equal to 1 gram. The heating of the crucibles with the test samples was carried out up to (250±10) o C at the rate of +5 o C /min for 50 minutes. At this temperature maintained for 60 minutes, followed by further heating of the oven to the threshold of (550±10) o C for 60 minutes. Keeping the temperature constant at this level is carried out for 120 minutes, followed by cooling the samples to ambient temperature.

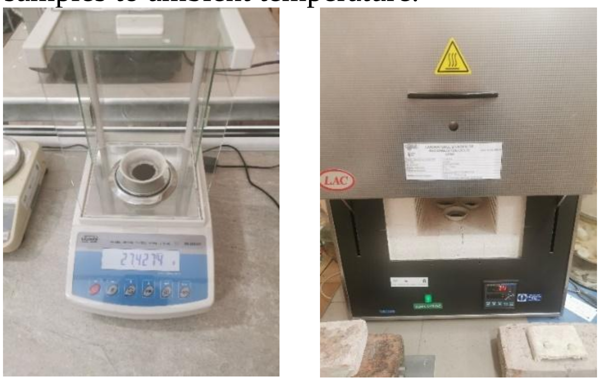

Figure 2. *Sequences relating to the determination of ash content*

Volatile matter content.

In biofuels, volatile matter represents approximately 70-80% of the total composition and favors a rapid and complete combustion, ensuring the efficient conversion of energy stored in biomass. The content of volatile matter was estimated according to SMV Standard EN 15148:2012 by incinerating (1± 0.1) g of an analytical sample with particles of maximum 1 mm, inserted in special crucibles in which contact with oxygen is limited during testing, where it is maintained for 7 minutes in a calcination socket, preheated to a temperature of (900±10) o C.

Calorific power

The calorific value defines the amount of heat released by the complete and perfect combustion of a unit mass of fuel, followed by the cooling of the combustion gases to the temperature of 25°C (298 K). This is a key indicator for evaluating the energy efficiency of solid biofuels.

The calorific value was determined with the IKA C6000 isoperibolic calorimeter . The measurement procedures were carried out according to Standard SM EN ISO 18125:2017.

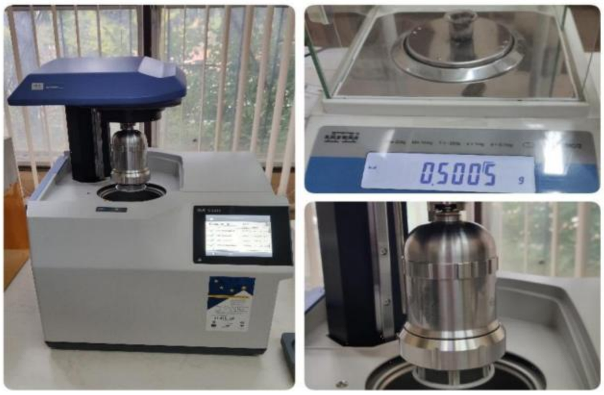

Figure 3. *Sequences related to the determination of calorific value with the IKA C6000 calorimeter*

Another primary indicator that characterizes the quality characteristic is the moisture content, which in turn is between 20 and 40%, varies depending on the coffee machine. Therefore, drying was carried out using a Memmert UNB 500 thermally regulated electric oven at a temperature of (105 ±2) o C.

A very important aspect that must be mentioned at this stage is that before being subjected to the tests, the dimensions of the biomass samples are comminuted by comminution in a Retsch SM 100 hammer mill with passage through a sieve with a mesh size of 1 mm, but in the case of coffee grounds grinding procedure is performed before coffee preparation.

Each trial was performed in three repetitions to guarantee the accuracy of the results obtained. Finally, the standard deviation and confidence interval were calculated to assess the accuracy of the data collected in each series of tests.

Analysis of published research indicates the need to use coffee grounds for the production of biodiesel , bioethanol , bio -oil and biochar [5] [2].

Among the main operating properties of fuels are also those that describe their behavior at low temperatures, being particularly determined by the cloudiness temperature and the freezing temperature. The properties of fuels at low temperatures indicate a reduced ability to pump them through pipelines and operate (supply, drain) in winter. It should also be emphasized that petroleum products do not have a fixed transition temperature between different states of aggregation. As the temperature decreases, certain components gradually become more viscous and less mobile, and some of them separate as precipitates or crystals.

The freezing point determination method involves cooling the tested fuels until they lose their mobility (Fig. 2). The freezing temperature is considered the maximum temperature indicated by the thermometer when the first visible crystals appear in the fuel (according to GOST 5066-91, ISO 3013-74).

3. Results and discussion

The moisture content of coffee residues is in accordance with the parameters required for densification in the form of pellets or briquettes are between 8 and 12% moisture, because a high water content in lignocellulosic waste reduces the calorific value, preventing combustion [6]. That is why we recommend prior natural drying.

The table below presents the characteristics of the coffee residues obtained in the LȘBCS laboratory, necessary to evaluate the possibility of using them as a raw material for the manufacture of densified solid biofuels.

Analyzing the information presented in the table by evaluating the qualitative parameters of the coffee residues suitable for use as raw material in the manufacture of BCSD, we find the calorific value of 21.5 MJ/kg, which corresponds to the ENplus quality classes.

Table1. *Results of qualitative characteristics of coffee grounds*

The name of the sample	Ad, %	Ar = 10. %	MV	qVd , J/g	qVnet d, J/g	qPnet r, J/g
ROBUST COFFEE 100%	**2.31**	**3.08**	**80.08**	**21517**	**21438**	**19060**
Standard deviation	**0.010**	**0.013**	**030**			
Trust domain	**0.011**	**0.014**	**034**			

Ad *– ash content on a dry basis;* ***Ar*** *– ash content at 10% moisture;* ***MV*** *– volatile materials;* ***q Vd , J/g*** *– higher calorific value measured at constant volume;* ***qVnet d, J/g*** *– lower calorific value at constant pressure;* ***qPnet r, J/g*** *– lower calorific value at constant pressure calculated for 10% moisture content*

We also see an ash content of 2.31% and a net calorific value at 10% moisture of 19.06 MJ/kg. Thus, it has been demonstrated that coffee residues have a significant energy potential and can be used as a raw material for the production of pellets , as well as as a component in various mixtures of raw materials used in the manufacture of densified solid biofuels.

The results of the study contributed to the strengthening of the knowledge base on the use of indigenous biomass for the production of solid biofuels. The detailed analysis of the specialized literature and the comparison of the biomass potential evaluation methods allowed the selection of innovative and efficient approaches to determine the available resources.

The results obtained in the laboratory and correlated with those available in the specialized literature [7] , regarding the utilization of coffee residues for energy purposes, we observe that they fully meet the strict requirements of the values recommended by the ENplus norms . Moreover, they can be used in mixtures with components whose energy characteristics are lower, so that the final product meets the requirements of the ENplus standard.

4. Conclusion

As a consequence of this large market, the coffee industry is responsible for generating large amounts of residues, and finding alternative uses for these residues through careful and innovative management can play a crucial role in the transition to a more sustainable energy future.

Dry coffee grounds have a significant calorific value of 21 MJ/kg placing it close to hardwood and other solid fuels with high efficiency. This makes it a viable alternative for use in biomass power plants or for the production of solid biofuels.

The results obtained in this case study demonstrate that coffee residues have an energy potential and can be used to produce solid biofuels with qualitative characteristics in accordance with European ENPlus norms .

The use of coffee grounds as biomass can contribute to the reduction of food waste and the recovery of a common by-product, which brings economic and ecological benefits.

THANKS

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