

The results of the study of obtaining alternative fuels from biowaste in the experimental pyrolysis device

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Abstract. The research presents the thermal processing of agricultural biowaste based on the pyrolysis device and the process of obtaining energy fuels. These energy fuels can be effectively used in the energy system of households, industry and greenhouses. The resulting fuels are considered environmentally friendly and help to solve problems such as environmental pollution, CO₂ emissions, and dependence on oil and natural resources. In the study, the results of pyrolysis of different types of biowaste at a temperature of up to 400 °C were obtained. The quantity, characteristics and factors affecting gas, bio-oil, and bio-coal fuel released from biomass were carried out on the basis of scientific and theoretical analyses.

1 Introduction

In the period of development, the depletion of natural resources and their extraction, transportation, and delivery to consumers is one of the global problems. The main part of electricity produced in our country is made by burning natural resources. The issues of saving these fuels and delivering them to the next generation are the cause of debate among many scientists. Cheap and safe production of energetic fuels is one of the priority directions in the energy industry. Therefore, the production of energy fuels from agricultural and industrial wastes is in line with the current demand [1]. Because there are areas in Uzbekistan Republic that are not fully and reliably supplied with energy. The type and amount of waste is increasing year by year. A large number of scientific monographs and articles are devoted to various theoretical and practical issues in this field. Such as scientists of different countries, including A.B. Bridgwater, D. Mohan, Ch.U. Pittman, R.B. Bayramov, A.M. Pendjiev, R.A. Zakhidov, A.B. Vardiyashvili, N.R. Avezova, G.N. Uzakov, X.A. Davlonov, and others, have made great contributions to the biomass energy system.

2 Materials and methods

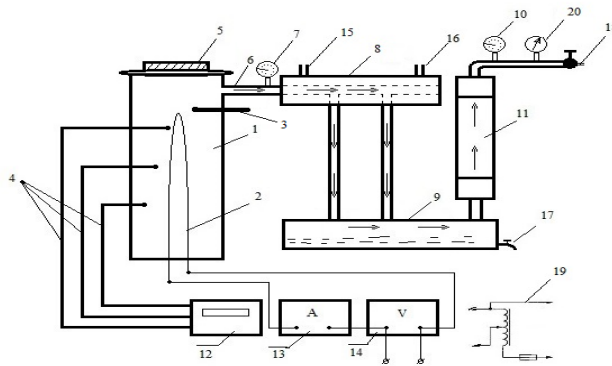
There are a number of problems with the direct burning and use of natural solid biomass as a fuel. One of the main problems is the low energy efficiency of biomass as fuel raw material

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and environmental damage caused by its direct burning. It is known from research conducted in the world that obtaining liquid and gaseous fuels through thermal processing of biomass is one of the effective methods. Liquid and gaseous fuels obtained from bio-waste are considered the most optimal in terms of use, and it has been determined that they have high energy efficiency [2].

The thermochemical technology of obtaining gaseous, liquid and solid fuel from biomass of different composition consists of the following processes: direct burning, pyrolysis, gasification, synthesis [3].

The main purpose of the research is to study the influence of the temperature of the raw material (biomass) loaded into the reactor of the device on the parameters of the pyrolysis process and to determine the amount of liquid fuel, synthesis gas, and solid fuel released from the process. A pyrolysis laboratory device which is shown in (Figure 1) was created to conduct the experimental study. The device consists of a pyrolysis reactor, a condenser-cooler, a liquid fuel collection tank, and a gas holder. With the help of this laboratory device, pyrolysis experiments of different types of waste biomass can be carried out. The pyrolysis laboratory is equipped with modern electrical and thermal measuring tools.



1 - reactor; 2 - electric heater; 3 - thermometer; 4 – thermocouple; 5 – raw material loading cover; 6 – steam-gas pipeline; 7, 10 – manometer; 8 – condenser – cooler; 9 – liquid fuel tank; 11 – gas holder; 12 – potentiometer; 13 – ammeter; 14 – voltmeter; 15, 16 – condenser-refrigerator liquid pipe; 17 – liquid fuel tap; 18 – pyrolysis gas pipeline; 19 – laboratory autotransformer; 20 – gas consumption meter.

Fig. 1. Schematic of the pilot-laboratory device for pyrolysis of biomass waste.

Biomass pyrolysis experiments were carried out in the laboratory device according to the following methodology. Before starting the experiment, biomass (poplar sawdust) with a temperature of 29 °C and a moisture content of 21% was taken. The mass of the biomass loaded into the reactor was measured with an electronic scale, temperature with an electronic thermometer, and humidity with a digital МГ-4Д moisture meter with an accuracy of $\pm 1.5\%$. Biomass was loaded into the reactor 1 and electric heaters 2 were connected to the network to create the desired temperature regime. The steam-gas mixture formed as a result of the heating of the biomass inside the reactor goes out of the reactor 1 to the condenser-cooler 8 and is condensed. Condensed liquid tar passes through the condenser and remains in the liquid fuel tank 9. Uncondensed gas moves to the gas holder 11 and the gas pressure was monitored by 10 manometers and the amount of gas was measured by 20 gas consumption meters. The combustion of the gas released from the pyrolysis process was monitored.

Characteristic temperature points at different points of the cylindrical reactor were recorded by XK type 4 thermocouples and КСН-4 potentiometer. The temperature in the bioreactor was controlled using a 19 - laboratory autotransformer. According to the potentiometer data, the average temperature in the reactor was calculated as follows:

$$t_{av} = \frac{t_1+t_2+t_3+t_4}{4}, \quad (1)$$

Here, t_1 , t_2 , t_3 and t_4 are temperatures at the characteristic points of the reactor, °C. Electric power in the pyrolysis process was determined by the following formula:

$$P = U \cdot I, Vt \quad (2)$$

Here, U - electric voltage, V; I - current, A. Voltage and current were determined measured indicators of voltmeter and ampermetre. The total energy used for the pyrolysis process was calculated as follows:

$$Q_{\tau} = U \cdot I \cdot \tau \cdot 10^{-3}, kVt \cdot h \quad (3)$$

Here, τ is the duration of the pyrolysis process, hours. After determining Q and τ , the amount of specific energy spent for the pyrolysis process is calculated based on the following formula:

$$Q_{s.e.c} \frac{Q_{\tau}}{G}, \frac{kVt \cdot h}{kg} \quad (4)$$

Here, G is the loaded biomass mass, kg.

3 Results and discussion

Based on the results of the biomass pyrolysis experiment, the release of pyrolysis products from biomass and the effect on temperature and parameters were determined. The results of the pilot study on biomass are presented in Table 1.

Table 1. Experimental results of biomass pyrolysis process.

Raw material (biomass) type	Poplar tree's sawdust							
Loaded biomass mass, kg	1.35							
Biomass moisture, %	21							
Loaded biomass temperature, °C	29							
Working pressure	0.1							
Voltage, V	220							
Current, A	2.1							
Process temperature, °C	100	205	290	365	400	400	400	
Procedure duration (minutes)	15	30	45	60	75	90	105	
Pyrolysis products	Gas	1.9	6.1	11.9	16.1	20.8	27.2	32.8 %
	Liquid	-	3.8	8.7	12.3	16.6	19.4	21.2 %
	Solid fuel	46%						

The results of the biomass pyrolysis experiment were summarized and it was determined that the amount of release of pyrolysis products depends on the temperature in the reactor, heating rate, biomass, and thermal physical properties of the environment where the process takes place. The duration of the process was recorded every 15 minutes, and a graph of temperature dependence of the release of gaseous and liquid fuel products formed as a result of the pyrolysis process was constructed Figure 2.

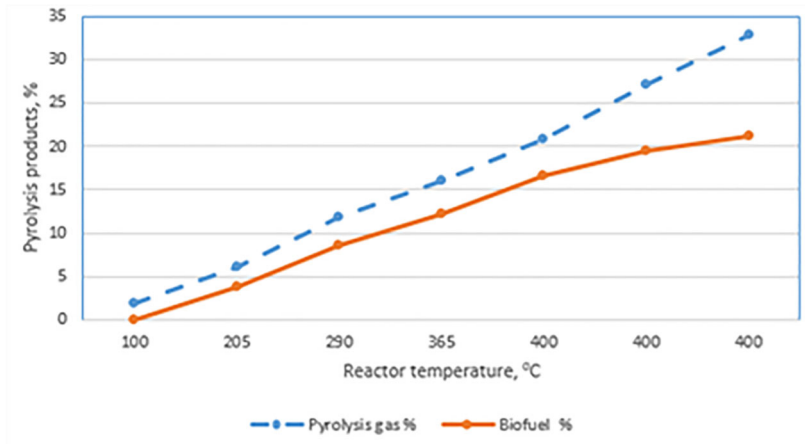


Fig. 2. Temperature dependence graph of pyrolysis product yield.

In general, the pyrolysis reaction can be expressed as follows: $BM \text{ (biomass)} + \text{HEAT} = C \text{ (carbonaceous material)} + \text{tar} + C_nH_m + CH_4 + CO_2 + CO + H_2$. Gaseous products of pyrolysis are considered to be medium calorific gas. The composition of the chemical group of gas depends on raw materials and process parameters.[5]

After the completion of the experimental study, it was found that the heat of combustion of pyrolysis fuels is equal to 18-25 MJ/kg [4]. It is possible to effectively use these energy fuels in the energy system of households, industry and greenhouses, as well as in the electricity industry. The resulting energy fuels are considered environmentally friendly and help to solve problems such as environmental pollution, CO₂ emissions, and dependence on oil and natural resources [6]. It is also possible to provide cheap, reliable electricity and thermal energy to remote areas without energy supply and improve their lifestyle.



Fig. 3. Fuels from biowaste.

Modern pyrolysis technologies available today can classify biomass according to the following technological parameters:

- heating rate (fast, slow pyrolysis);
- environment in which the pyrolysis process takes place (vacuum, hydrolysis, methanopyrolysis).

Today, the most well-known method is the process of pyrolysis of plant raw materials according to the heating rate.

Slow pyrolysis is the most efficient method of biomass conversion. Therefore, biochar and biochar production are cited as the most promising technologies in many literatures. Slow pyrolysis requires low to moderate (400-700°C) temperatures and can typically last from 1-2 hours to 24 hours.[7]

Thus, 46% (621 g) of biochar, 21.2% (286 g) of liquid and 32.8% (0.56 m³) of gas were obtained as a result of thermal processing of 1.35 kg of biomass (poplar sawdust) loaded into the experimental device by pyrolysis method fuels were taken. After that, different biomasses and coal pyrolysis experiments were conducted through the same methodology and included in the table below. Table 2 presents the results of pyrolysis of different types of biowaste.

Table 2. Results of pyrolysis of different types of biowaste.

	Type of raw material loaded	Loaded raw material mass (kg)	The operating temperature of the reactor is °C	The start time of the experiment	Time for the experiment to end	Derived fuel products		
						Liquid %	Gas %	Solid %
1	Poplar sawdust	1.35	350÷400	08 : 00	11 : 00	21.2	32.8	46
2	Pine needle leaf	0.75	350÷400	18:00	21 : 00	24	30	45
3	Tomato stalk waste	2.4	350÷400	09 : 00	12 : 00	14.5	35.5	50
4	Coal	4	300÷400	10 : 00	14 : 00	7.6	11.4	81

As we can see from the table below, the amount of fuels produced from different types of biomass is different, and it must be concluded that the fuel produced depends on the composition of the biowaste. It was also determined based on experiments and analyzes that the amount of residual biochar in the bioreactor during pyrolysis of biomass raw materials can be up to 50% [8]. The results of the conducted experimental research were summarized and a diagram of the balance of fuels that can be obtained from different types of biowaste was drawn up Figure 4.

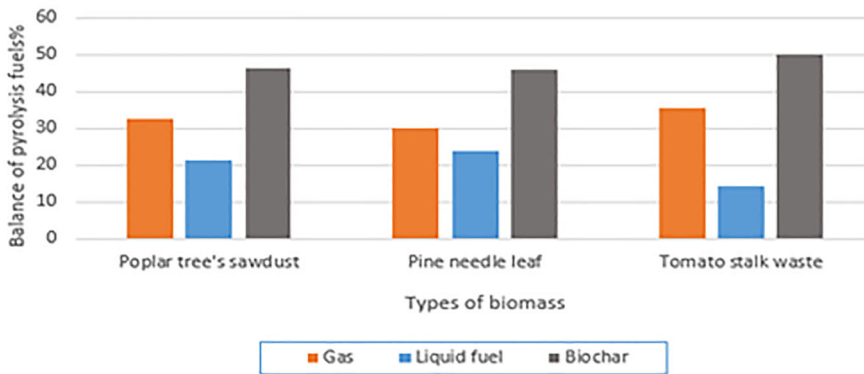


Fig. 4. Fuel quantity balance diagram in pyrolysis of different biowastes.

It is possible to obtain not only heat energy but also electricity from biomass. Of course, the use of cogeneration devices is a promising solution. Because of this, burning pyrolysis gas in an engine is more efficient than biogas in the electricity industry[9]. According to the sources of world scientists, 0.29-0.31 m³ of pyrolysis gas or 0.36-0.38 m³ of biogas is used to produce 1 kW of electricity [8,10].

4 Conclusion

The research conducted on obtaining fuel from local biowaste by pyrolysis method showed that the fuel obtained during pyrolysis depends on reactor temperature, type, size and moisture content of biowaste. Biomass can also be used as a valuable renewable energy source. Because 3 types of gas, liquid fuel and bio-charcoal fuel can be obtained from biowaste by pyrolysis and used for energy purposes. It was found that these fuels obtained from biomass are effective in the use of greenhouses, housing, industry and in various directions for various purposes of the energy system of the Republic of Uzbekistan. It serves to provide uninterrupted energy to consumers in the country, effective use of non-traditional renewable energy sources, development of the country and improvement of people's lifestyle.

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