CHARACTERISTICS OF BIOCHAR FROM MISCANTHUS STEMS OBTAINED AT DIFFERENT PROCESS PARAMETERS

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Abstract. In recent years, in the context of sustainable agriculture and the circular economy, the use of plant biomass as a renewable energy source has increased. Biochar is used not only as a new generation fuel but also in agriculture, construction, wastewater treatment, medicine or various industries such as food, textiles, cosmetics. It has great potential in reducing climate change and improving the quality of the environment, bringing a positive impact on the ecological balance at global level. It works through several non-aggressive methods, contributing both to the soil water retention, the removal of heavy metals and to the atmosphere, by reducing greenhouse gas emissions, waste management, and increasing the capacity to store carbon. The properties of biochar are influenced by the raw material used and the parameters of the production process. The paper presents the characteristics of biochar obtained from miscanthus strains such as moisture, ash content, density, water retention capacity at different process parameters. Two-degree fragmentation was used to obtain the biochar, namely 7cm and 15cm, different temperatures between 250 °C and 450 °C and three time intervals: 30 minutes, 60 minutes and 90 minutes. The results obtained showed that miscanthus strains are suitable for obtaining biochar with good characteristics that can be safely used in agriculture. The moisture of the biochar ranged from 2.98% to 7.61%, the density ranged from 90 $kg \cdot m^{-3}$ to 164 $kg \cdot m^{-3}$, the ash content ranged from 0.88% to 6.34%. In terms of water retention capacity, the values were up to 323.24%. These results support farmers who are looking for soil amendments that have a low environmental impact, which can be easily obtained from plant biomass or even agricultural waste and at low production costs.

Keywords: characteristics, biochar, climate change mitigation, sustainable agriculture, circular economy.

Introduction

Agricultural biomass, forest residues, energy crops and invasive plants, along with food waste, manure and municipal solid waste, are abundant resources. This residual organic biomass can be used for the production of biochar used either as a biofuel or as soil amendment [1; 2].

Biochar is a product obtained by carbonizing either biomass or biodegradable waste, having fine grain. It is distinguished by its high organic carbon content and high resistance to degradation. It can be produced by several thermochemical methods, such as pyrolysis, gasification, roasting, and hydrothermal carbonization [3-8].

Biochar, like charcoal, is a sustainable solution for agriculture and the environment, known for its increased academic interest in the 1990s. Researchers are currently looking at the potential of biochar to improve the soil quality while reducing greenhouse gas emissions. Interest in biochar has grown steadily since then, and studies on how to make it are constantly being conducted. Currently, biochar is used for various purposes, including soil improvement, energy production, and carbon capture from the atmosphere. It is also an alternative to chemical fertilizers, being both environmentally friendly and sustainable [9-11].

In sustainable agriculture, especially as part of the climate change mitigation strategy, biochar has received increasing attention due to its physical and chemical properties [12], as well as due to various additional uses [13; 14].

A plant can be considered an energy crop if it has certain characteristics: low cultivation costs, faster growth rate, short-rotation harvest, high yield, non-seasonal availability, less intensive agricultural practices such as demand for fertilizers and irrigation, less or no competition with agricultural crops for nutrients and sunlight, ability to cultivate degraded land, and resistance to extreme weather conditions. Because miscanthus exhibits these characteristics, it has recently gained attention as an emerging energy crop. Miscanthus is an invasive plant that originates from East Asian countries and is typically perennial in North America [15; 16].

Miscanthus is a promising crop for energy, due to its high lignocellulose content, but it is less studied for its thermochemical transformation to produce valuable fuels and materials [17; 18]. The physicochemical characteristics of biochar and its biooil are still largely unexplored, in addition to the limited amount of research on miscanthus pyrolysis [15; 19].

Some studies show that miscanthus can be used as fuel for combustion plants, but research is currently being done for the production of biochar from miscanthus used in different fields [20; 21]. However, in a recent study, it was found that combustion is the best way to produce energy from miscanthus biomass [22; 23].

Materials and methods

The miscanthus strains were harvested from experimental batches within the National Institute for Research and Development for Machinery and Installations for Agriculture and Food Industry – INMA Bucharest (Romania). After harvesting, they were dried at room temperature and then cut to the sizes of 7cm and 15cm, as can be seen in Fig. 1.

Fig. 1. **Preparation of miscanthus strains**

The reactor used was an experimental equipment (Fig. 2) designed and produced at the same institute, equipment that benefits from intelligent control for monitoring and adjusting critical parameters.

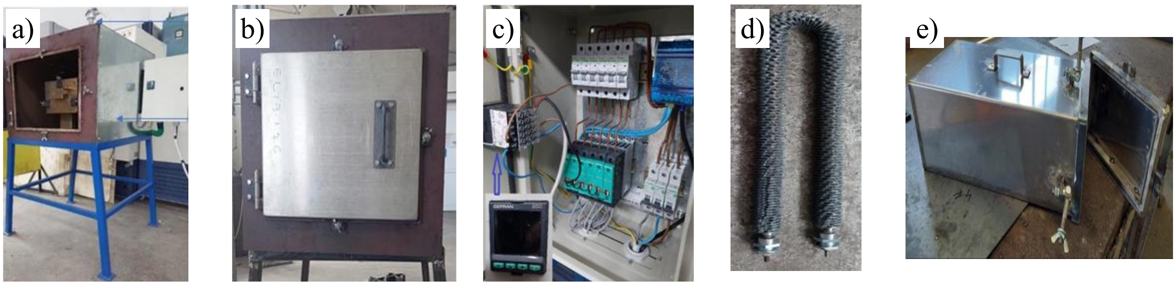

Fig. 2. **Experimental model for biochar production**

The experimental model is geared towards processing vegetable waste and has a housing support that contains actuation and control components. This equipment has an automated system that can control the thermal process under low oxygen conditions. It also has an advanced electrical control panel included in the system that allows precise control of the combustion process and significantly reduces the time required for biochar production. To improve efficiency, the design allows the retort to be replaced after each batch quickly.

The housing (Fig. 2b) and the control panel (Fig. 2c) are installed side by side and are separated with a ceramic fibre that withstands extremely high temperatures (up to 1260 °C) to prevent heat loss. On the bottom and ceiling of the housing are six electric resistors (Fig. 2d) around the retort (each having 2000 W). Also mounted on the housing there is an overpressure valve and a thermocouple capable of measuring high temperatures. Operating temperatures are between 300-500 °C for straw and other plant residues and 600 °C for forest residues. The retort (Fig.2e) is made of high-temperature resistant stainless steel [24].

Four temperatures between 250 °C and 450 °C were used to obtain the biochar and three time intervals: 30 minutes, 60 minutes and 90 minutes. The first stage of the process was setting the temperature, after the equipment reached the temperature, the sample was introduced and return to the set temperature was expected. After the time interval had elapsed, the sample was removed and left to cool for 30 minutes, then weighed and hermetically stored for analysis.

The analyses carried out for the biochar obtained were: moisture, density, ash content, variation in the mass of the raw material subjected to the biochar production process and water retention capacity.

Results and discussion

The determination of the biochar moisture was carried out using the method adapted according to [24], and the equipment used was the UFE 500 Model 100–800 thermostatically controlled oven – Memmert, Germany and the analytical balance Model: ATX 224 – Shimadzu, Japan.

The results obtained showed an average humidity of 5.25%, values that are within the accepted values [25-27]. The values obtained are presented in Fig. 3. Gm1, Gm2 are the dimensions of the material; T1, T2, T3, are the working temperatures; and t1, t2, t3, t4 are the working temperatures.

Determination of bulk density. It was made using the analytical balance and a 2000 ml dish. From the shredded raw material, 100g were weighed, then placed in a 2000 ml bowl. This process was repeated 10 times to ensure accuracy and to account for potential variations in the particle arrangement and compaction. The density of biochar varies significantly based on the temperature used during pyrolysis, the size of the particles, and the type of raw material employed [28]. The values obtained are shown in Fig. 4.

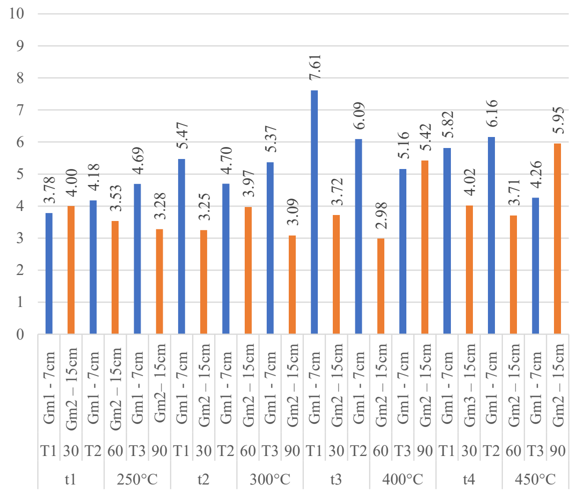

Fig. 3. **Moisture content of biochar, %**

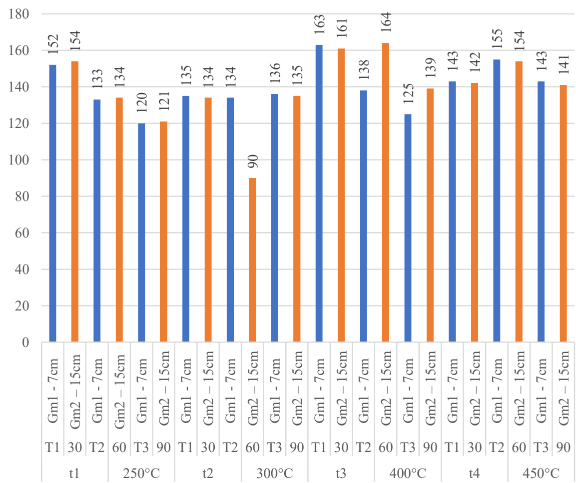

Fig. 4. **Density of biochar obtained, kg·m^{-3}**

Determination of ash content by calcination in a furnace was carried out using the method adapted according to [29] and was carried out by help of the calcination furnace Naberterm L Series, GmbH, Germany, with temperature control, analytical balance Model: ATX 224- Shimadzu, Japan, high-temperature resistant porcelain crucibles, exicator and desiccant for cooling the sample in dry environment, gloves and spatula, heat-resistant pliers. The results obtained for the ash content for biochar from miscanthus stems are shown in Fig. 5.

Variation in the mass of the raw material subjected to the biochar production process. All plant biomass samples initially had a mass of 1000g. Following the combustion process, the values obtained were those shown in Fig. 6.

The water retention capacity in relation to its own mass is one of the important characteristics of biochar, especially when it is intended to use it in the soil to improve moisture. To track the water holding capacity, the biochar was first weighed and then immersed in water at first for 10 minutes then an hour, and at the end 24 hours, after these intervals, the excess water was drained and the samples weighed again. Table 1 illustrates the variations in water absorption capacity.

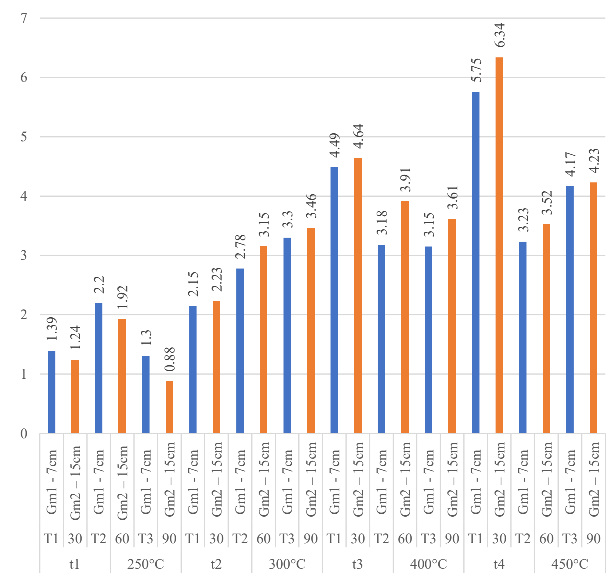

Fig. 5. **Ash content of biochar, %**

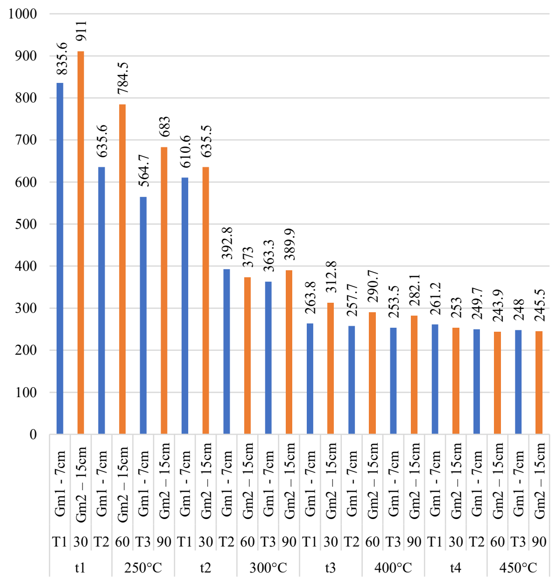

Fig.6. **Variation in the mass of the raw material subjected to the biochar production process, g**

Table 1

Variations in water absorption capacity

Biochar Production Temperature, °C	Biochar Yield Time, min	Degree of shredding of the material	Initial Weight	T1 Water retention after 10 min, %	T2 Water retention after 1 hour, %	T3 Water retention after 24 hours, %
t1 250 °C	T1	Gm1 – 7cm	13.90	16.00	16.60	20.30
	30	Gm2 – 15cm	17.50	6.64	13.44	45.92
	T2	Gm1 – 7cm	12.20	3.56	9.53	34.00
	60	Gm2– 15cm	13.93	3.66	9.56	32.00
	T3	Gm1 – 7cm	11.30	3.13	8.37	31.20
	90	Gm2 – 15cm	12.00	3.00	8.00	30.72
t2 300 °C	T1	Gm1 – 7cm	8.10	23.46	32.10	50.62
	30	Gm2 – 15cm	11.43	16.75	24.64	48.46
	T2	Gm1 – 7cm	5.70	28.07	43.86	43.86
	60	Gm2 – 15cm	5.97	30.56	39.58	294.00
	T3	Gm1 – 7cm	6.10	29.51	42.62	95.08
	90	Gm2 – 15cm	6.40	21.66	29.04	52.82
t3 400 °C	T1	Gm1 – 7cm	7.23	27.43	35.13	102.5
	30	Gm2 – 15cm	6.23	26.33	34.33	103.33
	T2	Gm1 – 7cm	6.40	41.10	62.20	163.5
	60	Gm2 – 15cm	16.40	40.33	62.38	164.33
	T3	Gm1 – 7cm	5.60	94.10	135.15	215.27
	90	Gm2 – 15cm	6.03	93.03	127.67	214.72
t4 450 °C	T1	Gm1 – 7cm	6.00	111.79	176.80	284.40
	30	Gm2 – 15cm	4.50	79.00	136	240.52
	T2	Gm1 – 7cm	5.40	14.00	183.00	275.93
	60	Gm2 – 15cm	5.00	115.67	168.33	260.56
	T3	Gm1 – 7cm	3.80	139.00	231.00	316.60
	90	Gm2 – 15cm	4.10	119.67	199.67	323.24

Note: GM1, GM2 are the dimensions of the material; T1, T2, T3, are the working temperatures; and t1, t2, t3, t4 are the working temperatures

Regarding the water retention capacity in relation to the correct mass of miscanthus biochar, the literature provides insufficient data. But, unlike biochar obtained from other materials, biochar from miscanthus showed a significantly higher retention capacity. The reported data show, for example, that bamboo biochar has a water retention capacity of 150%, and for hemp biochar 47% (Vlăduțoiu et al. 2025).

Conclusions

1. It is known that the quality and properties of the biochar obtained are directly related to the type of raw material and the process parameters used. As each type of biomass has its own characteristics and process parameters, they must be adapted for them.
2. Regarding the loss of the mass of the raw material following the biochar process, the values obtained showed that the degree of shredding of the material had very little influence, the values obtained being similar. The variations were given by temperature and time.
3. The moisture of the biochar was between 2.98% and 7.61%.
4. The density of the biochar ranged from 90 kg/m3 to 164 kg/m3.
5. The ash content decreased with the increase in temperature and varied between 0.88% and 6.34%, the highest value being obtained at a temperature of 450 °C for 30 minutes for the size of 15 cm.
6. The size of the raw material did not significantly influence the water retention capacity. But the lowest values were recorded in the biochar obtained at the lowest temperature (250 °C).
7. For the most part, the results obtained fall within the values expressed in the specialized literature and show that the biochar obtained is of high quality and can be successfully used as soil amendment.

   Following the conclusions drawn from this research regarding the characterization of biochar obtained from miscanthus, in order to continue research in the future, we are considering testing it in soil.

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Author contributions

Conceptualization. N.A.V; methodology. N.V.V. investigation. N.A.V., A-M.T., A.M..; data curation. N.A.V., A. M. and A-M. T..; writing–original draft preparation. N.A.V.; writing–review and editing. N.A.V. and A.M.; visualization. N.A.V. and A.M.; Project Administration. N.V.V.; funding acquisition. N.V.V. All authors have read and agreed to the published version of the manuscript.

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