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RESULTS OF HARDNESS RESEARCH AND ENERGY REQUIRED FOR DESTRUCTION OF THE RESIDUES FROM OIL-BEARING ROSE PRODUCTION IN REPUBLIC OF BULGARIA

Ivan ZAHARIEV, Dimitar KEHAYOV

Agricultural University of Plovdiv, 12 Mendeleev Blvd., Plovdiv, Bulgaria

Corresponding author email: zaharievbgr@abv.bg

Abstract

About 4000 hectares of oil-bearing rose are grown in Bulgaria, of which approximately 20000 tons of residual biomass is harvested annually. For now, there is no unilateral decision on how it can be used. The purpose of this study is to establish: what kind of wood (soft or hard) is the residuals of contour pruning of oil-bearing roses and what are the hardness and energy required to destroy these residues. From the research it was found that a sheet of rosewood mass can be processed with machines for crushing and pelleting/briquetting of softwood and the energy needed to destroy 1 g of these residues with a humidity of about 14% is 16.56 J, which is equal to 46 kWh/t.

Key words*: energy required for destruction, hardness, sticks of oil-bearing roses.*

INTRODUCTION

The need to generate heat and electricity, global warming caused by increased greenhouse gas emissions, rising fossil fuel prices and the demand for energy independence have created a new industry focusing on the production of energy through the use of renewable sources.

In accordance with European Parliament Directive 2009/28, in 2010, our country adopted a National Renewable Energy Action Plan (NREAP), which corresponds to the "20-20-20" EU energy policy objective Marinov K. (2013). The aim of the plan is to ensure a sustainable transition to a low-carbon economy based on modern technologies and the widespread use of renewable energy sources. It establishes a framework to promote the development of renewable energy, with the aim of reaching a minimum of 16% of total energy production, including the biomass share of 36%. In line with this plan, the new Forest Law (Article 88 (5)) provides for energy crops from fast growing wood species for accelerated biomass production falling within forest areas (point 2) and agricultural land or urbanized areas 4), not to be managed as a forest. This act allows the production of biomass as a priority of energy crops.

Among the different options, biomass is the third most important source of electricity generation and is the main source of heat generation Nunes L. et al. (2014). Usually, biomass is processed into solid (pellets, briquettes) or liquid (biodiesel) fuel.

Since the global pellet market is developing rapidly, the use of wood remains is no longer sufficient to meet its needs. Pellet standards provide limits for both physical and mechanical characteristics. They depend mainly on the characteristics of the raw material, such as particle size and moisture content, and operating conditions such as the applied pressure and the temperature of the matrix Mohamed M. et al. (2019)

Biofuel production uses various agricultural products such as cane, hemp, straw, rape meal, sludge and rape residue Nilsson D. et al. (2011), compost from municipal waste Mavaddati S. et al. (2010), cork products Nunes L. et al. (2013). Pellets from garden waste have been found to be conveniently used in residential cooking stoves (Pradhan P. et al., 2018).

Maize cobs have some characteristics that make it possible to use them in industrial plants. However, these properties are not sufficient for use in domestic stoves and boilers where higher fuel quality is required. For this reason, briquetting and pelleting are used Miranda M. et al. (2018).

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The main quantities of biomass waste in Bulgaria are obtained from the maize stalk mass of the maize and the sunflower stems, after the harvesting of the main production, as well as the vine rods, after the cutting of the vine massifs Enakiev Y. et al. (2016). It has been found that when granulating sunflower stems and vine rods, the energy consumption is 129 kWh/t, and in the case of maize leaf-stalk mass - 149 kWh/t obtained at a matrix speed of 220 min^{-1} and humidity of the materials respectively 18% for maize, 20% for vine rods and 20.3% for sunflower.

Many attempts have been made in our country and around the world to pelletize livestock waste Mohov V. (2008); Yanakiev J. et al. (2016) and to use the obtained materials as solid fuel or fertilizer.

In the practice of processing waste biomass from logging and wood processing, many machines are separated. Typical of them is that they are designed for different types of wood - soft, hard Peichev K. et al. (2006).

In their study, the authors Nielsen N. et al. (2009), comparing the energy required to pelletize pine and beech wood, conclude that it is much higher in 'solid' beech wood. Masche M. et al. (2019,) reach the same conclusion. An interesting fact is that the energy required for shredding pine wood (10 kWh/t) is greater than that for beech wood (7 kWh/t).

About 40,000 oil-bearing roses are grown in Bulgaria. The total residual green mass is about 20,000 tons. There is currently no unilateral decision on how this biomass can be used.

The aim of this study is to establish:

1. What type of wood (soft or hard) is the residual contour of oil-bearing roses;
2. The hardness and energy required to destroy these residues.

MATERIALS AND METHODS

The experiments were carried out at the Department of Mechanization of the Agricultural University of Plovdiv in the period June-September 2017.

For Brinell 10/100 method, the experimental setup shown in Figure 1 was developed Zahariev I. (2017). The required force of 100 N is created by gravity.

Place the test piece on the base of the unit. The weight, together with the steel sphere, slowly, without any impact, descends until it rests on the surface of the test body and loosens the rope. Wait for 120 s and slowly lift the weight. Remove the test body. Record the size of the footprint in two perpendicular planes (Figure 2) using a binocular magnifier (12.5x magnification) with a built-in Poldi hardness tester.

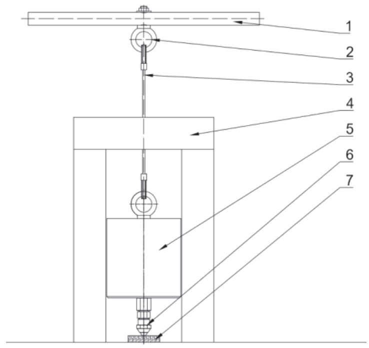

Figure 1. Test facility: 1 - handle; 2 - bolt special; 3 - rope; 4 - an attachment frame; 5 - weight; 6 - spout with steel sphere Ø10mm; 7 - test body

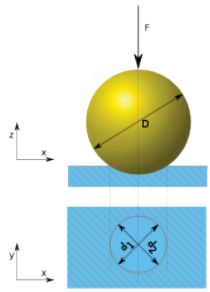

Figure 2. Hardness measurement chart of material using Brinell method. Source: https://bg.wikipedia.org/ Brinell Method (20 February 2017)

Brinell Hardness Number [BHN] https://bg.wikipedia.org/The Brinell Method (February 20, 2017) is defined by the formula:

$$BHN = \frac{2P}{\pi D(D - \sqrt{(D^2 - d^2)})}, \qquad (1)$$

where:

P - applied force, N;

D - diameter of the nozzle (steel sphere), mm

d - footprint diameter, mm.

To measure the energy required for destruction, a stand developed and described by Zahariev I. (2018) is used (Figure 3).

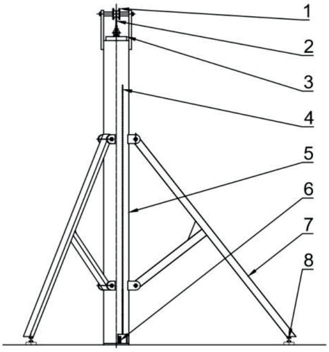

Figure 3. Bench: 1-roller support; 2-rope lifting; 3-stroke body; 4-hole holes; 5-housing; 6-piece body; 7-foot support; 8-foot adjustable

The force required to act on the test body is created by a shock body weighing 144 N and a maximum impact angle of 1.5 m.
The test bodies are correct prisms made according to Rostovsky Y. (2017).
At the bottom of the casing a test body is placed through a window. The impactor rises to a height of 1.2 m and runs on the test body. Remove the test body and visually determine its condition. If it is not crushed, a new test body is placed in the stand and the procedure is repeated, with the impact body rising and running at a higher height. This operation is repeated until the test piece is crushed.
The energy required to break down the test bodies is expressed by the dependence:

$$E = \frac{m.v^2}{2}, \text{ J} \qquad (2)$$

In Equation (2), the body speed is unknown at the moment of impact. For its determination, the impact body is represented as a material point falling freely down into the air. According to Partinov P. et al. (1985) the law of movement of the striking body has the type:

$$y = \frac{g}{k^2}\left(e^{-k.t} + k.t - 1\right) \qquad (3)$$

where:
y - the launching height of the impactor, m;
t - time to impact with the test body, s;
k = 0.055807086 - constant.

To find the speed of the hammer at the moment of impact, the time (t) from release to contact with the test pieces should be determined. This is hampered by the condition that equality (3) can only have an approximate solution.
In the present work, according to Kehayov D. (2007), in equation (3) the time is replaced with real values - 0 to 1 s at an interval of 0.05 s. The path from the impact body for the appropriate time is obtained. A regression equation was constructed with the obtained data Draper N., Smith G. (1986), Draper H., Smith G. (1987); Mitkov A., Minkov D. (1989).

$$Y = A_1.t + A_{11}.t^2, \quad \text{m} \qquad (4)$$

Equation (4) is a quadratic equation with one unknown, namely the motion time of the impact body. The road is equal to the height from which the striking body is released. The speed is obtained privately from the road and the time it takes to travel.

$$v = \frac{Y}{t}, \quad \text{m/s} \qquad (5)$$

RESULTS AND ANALYSIS

The results of the tests and subsequent analyses are given in tabular form and illustrated with figures and graphs.
Hardness of residual biomass from rose production
- Straightness of fiber direction by Brinell method 10/100.

Table 1. Comparison of the average values for stiffness in the direction of the fibers

T-test for Independent Samples Note: Variables were treated as independent samples					
Compare wood	Oil-bearing rose [BHN]	Comparable wood [BHN]	Student's Criterion	Degrees of freedom	Level of significance – p
Oil-bearing rose - Walnut	1.4646	1.7056	-1.9761	13	0.069762
Oil-bearing rose - Elder	1.4646	1.3294	1.0968	13	0.292628
Oil-bearing rose - Elm	1.4646	2.1130	-4.9474	13	0.000267
Oil-bearing rose - Seventh	1.4646	3.2152	-10.8729	13	0.000000
Oil-bearing rose - Dogwood	1.4646	1.8086	-2.8769	13	0.012970
Oil-bearing rose - Beech	1.4646	2.1406	-5.4726	13	0.000107
Oil-bearing rose - Oak	1.4646	2.5350	-6.8969	14	0.000007
Oil-bearing rose - Pine	1.4646	1.1330	2.4318	13	0.030229

The fiber stiffness data shown in Table 1 indicate that the level of significance (p) is greater than 0.05 when comparing oil-bearing rose-walnut (p = 0.069762) and oil-bearing rose-elder (p = 0.292628). In Figure 4 shows that the values for the oil-bearing rose overlap with the walnut and eldered values and partly with the pine values.

- Hardness perpendicular to the fibers by Brinell 10/100 method.

The hardness data perpendicular to the fibers presented in Table 2 show that the level of significance (p) is greater than 0.05 in the variants of oil-bearing rose - walnut (p = 0.760673) and oleaginous oil-bearing rose - elm (p = 0.196778). It can be seen in Figure 5 that the values of the oil-bearing rose overlap with those for walnut and elm and exceed the pine values.

The observations made point to the conclusion that the wood of oil-bearing rose, walnut, elder and elm are of the same group in terms of the monitored parameter. This gives reason to recommend that the waste biomass of oil-bearing rose be processed with the same machines and modes of operation as the other "soft" woods.

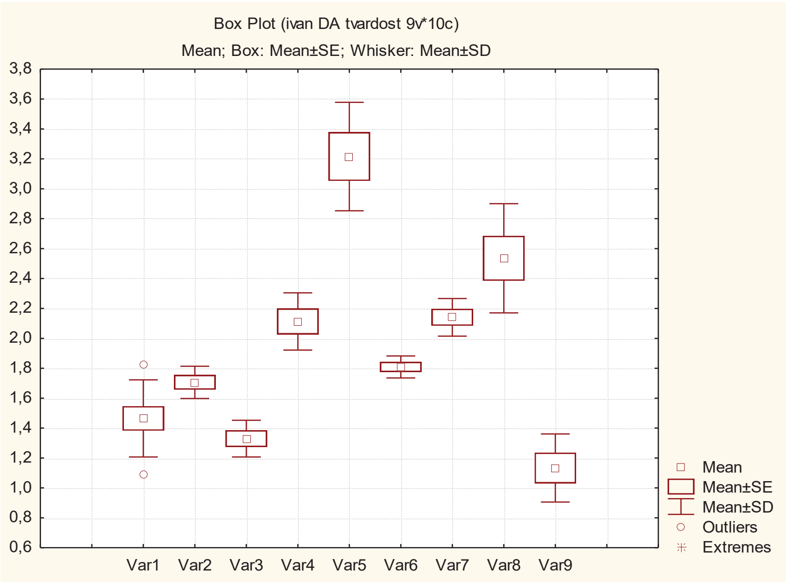

Figure 4. Comparison of the average values of stiffness in the direction of the fibers: Var 1 - oil-bearing rose; Var 2 - walnut; Var 3 - elder; Var 4 - elm; Var 5 - seventh; Var 6 - dogwood; Var 7 - beech; Var 8 - oak; Var 9 - pine

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Table 2. Compare the average values for stiffness perpendicular to the fibers

T-test for Independent Samples, Note: Variables were treated as independent samples					
Compare wood	Oil-bearing rose, [BHN]	Comparable wood, [BHN]	Student's Criterion	Degrees of freedom	Level of significance – p
Oil-bearing rose - Walnut	2.8390	2.7662	0.31305	10	0.760673
Oil-bearing rose - Elder	2.8390	1.8648	4.38459	10	0.001368
Oil-bearing rose - Elm	2.8390	3.1712	-1.38295	10	0.196778
Oil-bearing rose - Seventh	2.8390	4.0914	-5.04483	10	0.000503
Oil-bearing rose - Dogwood	2.8390	4,0080	-4.40211	10	0.001331
Oil-bearing rose - Beech	2.8390	3.6388	-3.00885	10	0.013143
Oil-bearing rose - Oak	2.8390	3.7108	-3.97160	11	0.002190
Oil-bearing rose - Pine	2.8390	1.3792	6.35907	10	0.000083

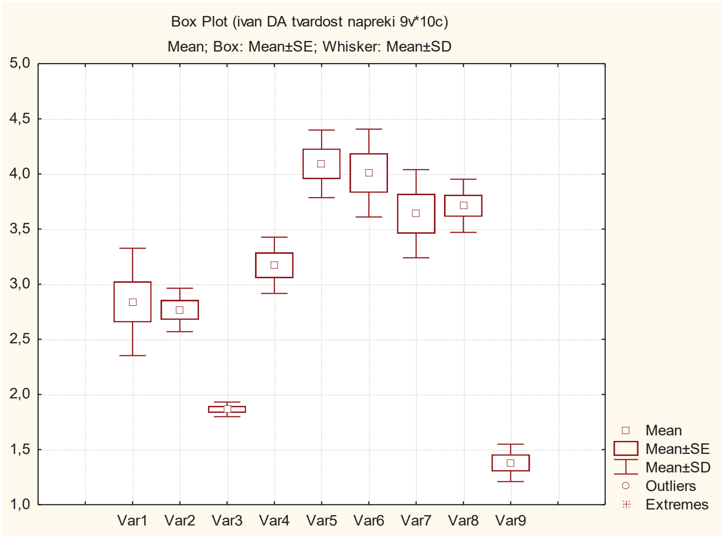

Figure 5. Comparison of average hardness values perpendicular to the fibers: Var 1 - oil-bearing rose; Var 2 - walnut; Var 3 - elder; Var 4 - elm; Var 5 - seventh; Var 6 - dogwood; Var 7 - beech; Var 8 - oak; Var 9 - pine

Energy required to break the sheet

Using the dependence (5) and substituting the constants g and k, the path passed by the free fall body into the air environment for a different time period is determined. The obtained data were processed by the single factor regression analysis method. Results are shown in Table 3.

Table 3 Single-factor regression analysis results

Regression Summary for Dependent Variable: Route-Time R = 0.99990212, R^2 = 0.99980424, Adjusted R^2 = 0.99979026, F(1.14) = 71503, p = 0.000001						
	Beta	Std.Err.	A	Std.Err.	t (14)	p-level
X^2	0.999902	0.003739	4.844342	0.018116	267.4005	0.000001

The regression equation has the form:

$$Y = 4.8443.t^2 \quad (6)$$

In this equation the left side is known - the height from which the hammer is released. The roots of the square equation (6), at different paths Y, determine the time for this path. Knowing the path that the impactor travels to the collision with the test and the time to impact, it is possible to determine the speed at the moment of impact and the applied energy (Table 4).

Table 4. Route, time, speed, and applied energy

Route [m]	1.200	1.240	1.300	1.400	1.500
Time [s]	0.498	0.506	0.518	0.537	0.556
Speed [m/s]	2.410	2.450	2.510	2.600	2.700
Applied energy [J]	41.82	43.22	45.36	48.67	52.49

To determine the energy required for destruction of oil-bearing rose oil samples, a series of experiments were carried out. The results are shown in Table 5.

Table 5. Results of the Experiment of Demolition of Test Bodies

Test body №	Impact height of the impactor [m]	Distance between impactor and test body [m]	Calculated time on fall to stroke [s]	Visual test state of a test body
1	1.480	1.458	0.547984	destroyed
2	1.400	1.379	0.532758	destroyed
3	1.380	1.357	0.528568	destroyed
4	1.360	1.339	0.525073	destroyed
5	1.340	1.316	0.520483	destroyed
6	1.320	1.297	0.516694	destroyed
7	1.300	1.278	0.512877	destroyed
8	1.280	1.257	0.508625	cracked
9	1.260	1.238	0.504749	destroyed
10	1.240	1.218	0.500635	cracked
11	1.220	1.198	0.496489	cracked
12	1.200	1.177	0.492098	cracked

It can be seen from Table 5 that the destruction of the test bodies occurs when the impactor is released from a height of more than 1.28 m.
The applied energy at which 100% destruction of the test bodies is observed, regardless of their geometric tolerances, is at a launching height of the impactor of 1.3 m.

$E_{1.30} = (2.51^2 * 14.4)/2 = 45.361$ J (7)

From the measurements made during the experiments it was found that the average mass of the test bodies was 2.74 g. Here it follows that the energy needed to destroy 1 g of biomass from oil-bearing rose is:

45.361 J / 2.74 g = 16.555 J/g (8)

From the equation 1, J = $2.777 * 10^{-7}$ kWh the required energy in kWh is obtained:

16.555 J/g * $2.777 * 10^{-7}$ kWh =
= 4.6 kWh/t (9)

CONCLUSIONS

1. The results of the experience suggest that a sheet of oil-bearing rose can be processed with machines designed for crushing and pelleting / briquetting of softwood.

2. The energy required to destroy 1g of oil-bearing rose mass with a moisture content of about 14% is 16.56 J, which is equivalent to 4.6 kWh/t.

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