

## EXPERIMENTAL RESEARCH REGARDING THE REALIZATION OF AN EQUIPMENT INTENDED FOR THE CHOPPING OF WOODY WASTE

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## CERCETĂRI EXPERIMENTALE PRIVIND REALIZAREA UNUI ECHIPAMENT DESTINAT TOCĂRII RESTURILOR VEGETALE LEMNOASE

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### ABSTRACT

*This article presents the results obtained through experimental research carried out with a machine for shredding woody plant residues (twigs, vine ropes), residues obtained from dry or green cuttings, in fruit or wine plantations. The obtained shredding is intended for utilization in the form of compost or biofuel (pellet type). The machine was designed and made by a group of researchers from INMA Bucharest, with the aim of developing the machine system made available to farmers, for mechanized work in small and medium-sized fruit plantations. The sizes of the fractions of the wood fragments resulting from the chopping process, their humidity and volumetric weight were determined. Using as raw material greener or drier branches, with dimensions between 10-45 mm, with an adjustment of the chopping drum at an average speed of 1400rpm and an average speed of the conveyor chain of 0.425 m/s, wood chips with different sizes between 4-16 mm were obtained, the proportions varying from 13% to 16%. The average working capacity of the equipment was approx. 14.2 mc/h. Research will continue to determine the energy indices of the machine designed and made at INMA Bucharest, and the results will be presented in another article.*

### REZUMAT

*Acest articol prezintă rezultatele obținute în cadrul unor cercetări experimentale efectuate cu o mașina de tocat resturi vegetale lemnoase (crengi, coarde de viță de vie), resturi obținute din tăierile în uscat sau în verde, în plantațiile pomicele sau viticole. Tocătura obținută este destinată valorificării sub formă de compost sau biocombustibil (de tip peleți). Mașina a fost proiectată și realizată de către un grup de cercetători din INMA București, cu scopul dezvoltării sistemului de mașini pusă la dispoziția fermierilor, pentru efectuarea de lucrări mecanizate în plantațiile pomicele de dimensiuni mici și mijlocii. Au fost determinate dimensiunile fracțiilor lemnoase rezultate în urma procesului de tocare, umiditatea acestora și masa volumică. Utilizând ca materie primă crengi mai verzi sau mai uscate, cu dimensiuni cuprinse între 10-45 mm, cu un reglaj al tamburului de tocare la o turație medie a de 1400 rot/min și la o viteză medie de avans a benzii transportoare de cca.0.425 m/s, s-a obținut o tocătură lemnoasă cu diferite dimensiuni cuprinse între 4 și 16 mm, proporțiile variind de la 13% la 16%. Capacitatea medie de lucru a echipamentului a fost de cca.14.2 mc/h. Cercetările vor continua pentru a determina indicii energetici ai mașinii proiectată și realizată la INMA București, iar rezultatele vor fi prezentate într-un alt articol.*

### INTRODUCTION

On a global level, as mentioned in the Green Deal pact, there are preoccupations for the recovery of waste in order to reduce pollution, to maintain a green planet, to reduce the carbon footprint and to reach in 2050 the target of 0 (zero) polluting emissions. Reducing energy consumption is another objective for which in-depth research is being done, in order to use renewable energy sources instead of conventional ones, which have been used indiscriminately and which can be exhausted, so the planet and all of humanity would suffer. For these reasons, research is being carried out in all areas that could bring a favourable contribution to the fulfillment of these objectives (Jasinskas et al, 2017; Kopac et al, 2003; Caba, 2019)

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Biomasses from agriculture could be used as a dry fuel, when harvested at maturity with about 85% dry matter by baling or chopping, or as a humid fuel with up to 60% dry matter, when harvested before maturity with a chopper, conserved by ensiling and mechanical dehydration before thermal use. To characterize both fuels from different crops chopped with a theoretical cutting length of 4 mm, particle-size-distribution, bulk density and an apparent density as well as nutrient contents and ash fusibility are determined. Wood chips (10 and 20 mm cutting length) has been investigated by *Stulpnagel, (1998)*.

Every year, in orchard plantations or in vineyards, pruning branches in autumn or spring, can offer biomass which can be chopped using special machines. To be profitable, these machines must have high-performances, in order to obtain wood chips at a low cost.

Chopped woody residues can be used to obtain compost or pellets. Pellets are a source of alternative energy and can be obtained from agricultural and forestry materials such as: sawdust, branches, scraps of boards or other wooden scraps, leaves, straw, sunflower or corn stalks, soybeans, etc. The pellet production line also includes biomass chopping or shredding equipment (*Mady, 2015*). The importance of using pellets has determined the performance of numerous researches both on how to obtain them and on the benefits of using them. In the last period, wood pellets are increasingly used, because they are a less polluting source of energy, having less greenhouse gas emissions, and also a renewable fuel, replacing fossil fuels (*Jasinskas et al., 2017; Nedelcu A., 2020; Supin, 2015; Gageanu, 2019*).

*Hamzah et al., (2017)*, analysed the wood pellets and torrefied wood pellets (named black pellets) as compared coal and the conclusion was that torrefaction improve the fuel properties of wood pellet similar to coal. Torrefied biomass is more brittle than raw biomass and has a higher carbon content.

Compost is considered one of the best natural and organic fertilizers, obtained by decomposing plant biomass, and chopped branches can also be part of its composition (*Ciuperca et al., 2022; Lixandru et al., 2021; Stefan et al, 2020; Stefan et al, 2021*)

Some researchers have carried out experimental research of a chopper equipment for shredding residual wood branches, in order to improve its technical and technological performance. For this purpose, they implemented sensors and transducers on the equipment to record the evolution of the mechanical and hydraulic parameters. (*Cristescu et al., 2021*).

Researchers from Poland have developed and tested an innovative system for controlling the variable feeding of an equipment for chopping woody plant residues with low power engine. Fuel consumption in the case of the pilot system equipped with an adaptive feeding system was optimized, compared to the constant feeding system. The favourable effects of the tested systems have been demonstrated (*Wargula Łukasz et al, 2022*). *Wargula et al., (2018)*, designed and realized a research stand that allowed both the analysis of the constructive and functional characteristics of the chopper, as well as the evaluation of the wood chopping process. The research carried out by this research team was valuable because it brought important information regarding the factors and their influence on the wood chips shape produced after chopping, as well as the influence on the energy consumption used in the chopping process. Important conclusions could be drawn that lead to the improvement of the work process of this equipment, taking into account that it is influenced by the orthotropic properties of the chopped material, which has an inhomogeneous structure.

*Lyashenko et al., (2022)*, tested a wood branch chopper under specific conditions and obtained certain results that made it possible to provide instructions for its operation as well as its adaptation to the conditions of small plantations in individual fruit orchard.

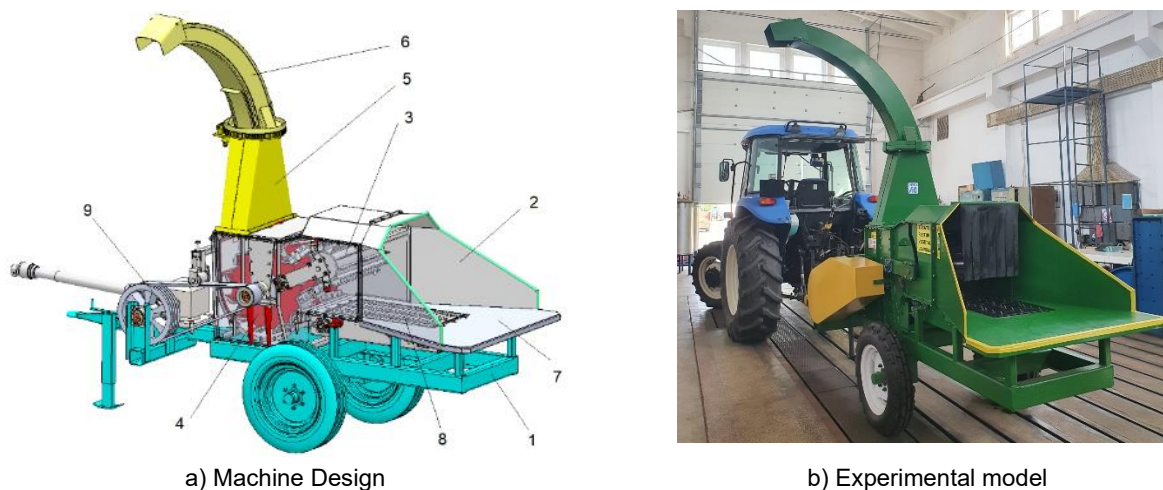
Taking into account the importance of research in order to diversify and improve machinery for chopping wood waste, especially branches, researchers from INMA Bucharest have proposed a technology and an equipment, the use of which will lead to obtaining wood chips, a technology that will contribute to reducing pollution environment and use wood chips as an organic fertilizer or mulch.

The main objectives of this research are: to justify the technology of non-waste utilization of tree branches; to choose the optimal design parameters for the developed chopper, which is used in the technological process of chopping the tree branches; and to analyze the effect of the cutting angle of tree branches and the on the size of wood chips.

## MATERIALS AND METHODS

The research carried out had as preliminary stages the analysis of the state of the art worldwide, followed by the design and realization of the experimental model for an equipment designed to chop wood tree branches, acronym TRL (*Popa et al, 2022a; Popa et al, 2022b*).

The existing research infrastructure within the research-development-innovation laboratories, the execution section and the testing department was used for the realization of the project and the execution, as well as the experiments (<https://www.erris.gov.ro/System-of-designing-execution-and-optimising-the-technical-equipment-and-technologies>; <https://www.erris.gov.ro/research-infrastructure-for-agriculture-forestry-and-food-industry>). The design was carried out using SolidWorks, 3D design software, which made it possible to obtain the 2D execution documentation and manufacture the experimental model within the execution department of the research institute. Using this software the time for development was reduced, and the quality of the final product was higher. Tests under real work conditions, by simulation of the working process have been done. 3D Solidworks ensure product quality while reducing prototyping and physical testing costs. In the figure 1 are presented the main assemblies of the machine.



**Fig. 1 - Technical equipment for wood waste chopping**

1 – infrastructure; 2 – assembled housing; 3 – wood drive drum; 4 – chopping drum; 5 – intermediate section; 6 – material discharge basket; 7 – loading platform; 8 – conveyor chain; 9 – mechanical transmission; 10 – hydraulic transmission  
(Source: Popa et al., 2022b)

The equipment consists of welded assemblies and elements in series production (gear motor, transmission chains, bearings, wheels, hydraulic cylinders, hydraulic components, removable fasteners: screws, nuts, washers, flat washers Grower and so on). The “core” of the equipment is the chopping drum, which it is different from the constructive solutions currently in production. The knives are disposed staggered, to improve the cutting process. The knives are made by a special steel, HARDOX 500, characterized by very good resistance to shocks and deformations.



**Fig. 2 - Chopping drum with staggered knives**

**Fig. 3 - Chopping process**

The chopper is also equipped with a counter-knife, realized by the same special steel. Together they work like a scissors, under the acting force and inertia force. The cutting of the branches is done transversely, the size of the chips depending on the speed of the scraper conveyor, of the type with scrapers arranged on chains with special sprockets.

Before the experiments, the machine was put into operation empty, so that the preliminary adjustments could be made. Experimental research carried out in November 2022, on the research platform in the INMA enclosure. The purpose of the research was the analysis of the degree of shredding of chopped branches, at certain functional parameters of the machine. The resistant moment was also registered, when the machine works without load and under load.

For registered the resistant effort at the chopping drum, a data acquisition system type MGCplus – HBM (Hottinger-Baldwin-Messtechnik)(Fig.4a) was used. It was used a moment transducer type T 4WA -S3 (Fig.4b), a connecting system interface (Fig.4c), an acquired data setup interface (fig.4d) and a softwere CatmanEasy for data acquisition.



Fig. 4 – Data acquisition system

Rotational speed of the feed drum and of the chopper drum have been measured using a digital tachometer (Fig.5), which allows the operator to make revolutions per minute (RPM's) and speed (m/min) measurements. It offers a high accuracy (0.005%) up to 1 m distance (without contact).

A vibratory sieve shaker AS 200 Basic was used to separate the material into fractions (Fig.6). (<https://www.retsch.com/products/sieving/sieve-shakers/as-200-tap/>). Each vibratory sieve shaker of the series AS 200 is equipped with an electromagnetic drive that is patented by RETSCH (EP 0642844). This drive produces a 3D throwing motion that moves the product to be sieved equally over the whole sieving surface.

The advantage: high stress capacity, extremely smooth operation and short sieving times with high separation efficiency. The moisture and volumetric weight were also analysed, using a Moisture Analyzer, MB120 AM (<https://us.ohaus.com/en-US/Products/Balances-Scales/Moisture-Analyzers/MB45/Moisture-Analyzer-MB45-AM>) (Fig.7)



Fig. 5 – Digital tachometer

Fig. 6 – Vibratory sieve shaker AS 200 Basic

Fig. 7 – Moisture analyzer

Volumetric weight ( $\rho_v$ ) is a property of vegetable materials, in the form of chopped or ground, which defines the weight of fragments ( $m_f$ ) of chopped plants related to the whole volume they occupy (relation 1). The total volume ( $V_t$ ) occupied consists of the volume of the fragments and the volume of the voids between the fragments.

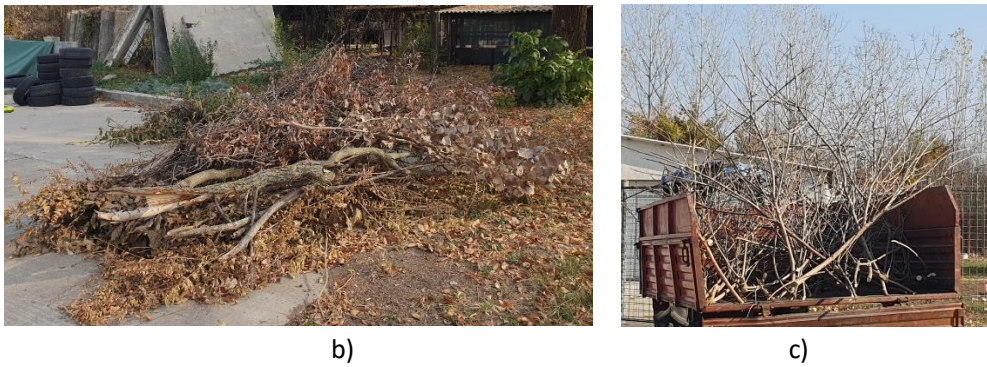
$$\rho_v = \frac{m_f}{V_t} \quad [\text{kg/m}^3] \quad (1)$$

**RESULTS AND DISCUSSIONS**

The experiments were performed using branches obtained from trees, green and dry branches, having dimensions between 10-45 mm (Fig.8a,b,c).



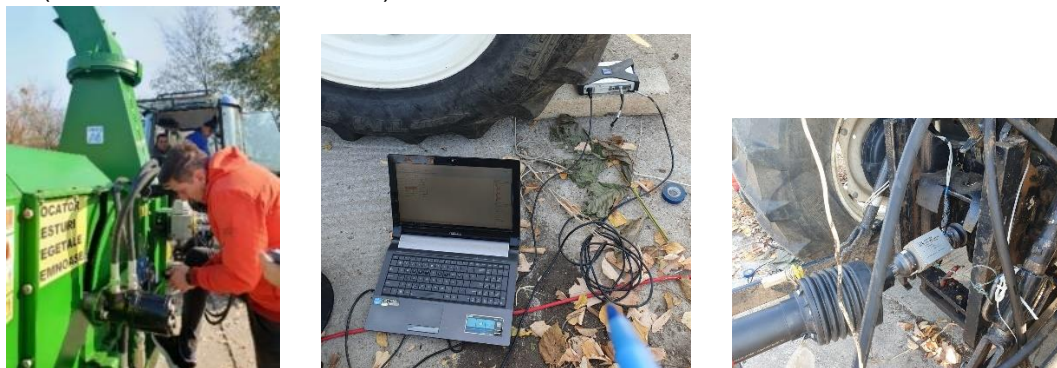
a)



**Fig. 8 – The woody plant material used for experiments**

Feeding drum rotational speed was measured and noted, as we can see in Fig.9. For the drum chopper also. Feeding drum has been set using the hydraulic distributor and also a hydraulic drossel, and the quantity of chopped wood material was collected on a tarp and weighted.

The tests have been repeated for 3 speeds of the conveyor chain that supplies the shredder with wood branches, (0,425; 0,375; and 0,325 m/s), to check the behavior of the shredder and the machine productivity.



**Fig. 9 – Aspects during the work parameters recording**

After the chopping process was finished, we collected the chopped wood material and proceeded to determine the sizes of the chopped fractions, the volumetric weight of the material collected by dimensional fractions and then we calculated the percentage of each dimensional fraction. The moisture content was determined. Three samples of 1500g each, collected randomly, were analysed, precisely to ensure accuracy in the processing and interpretation of the results obtained from the experimental tests, and the data thus obtained were tabulated and graphically represented.



**Fig. 10 – Aspects regarding the collected chopped material and their analyse**

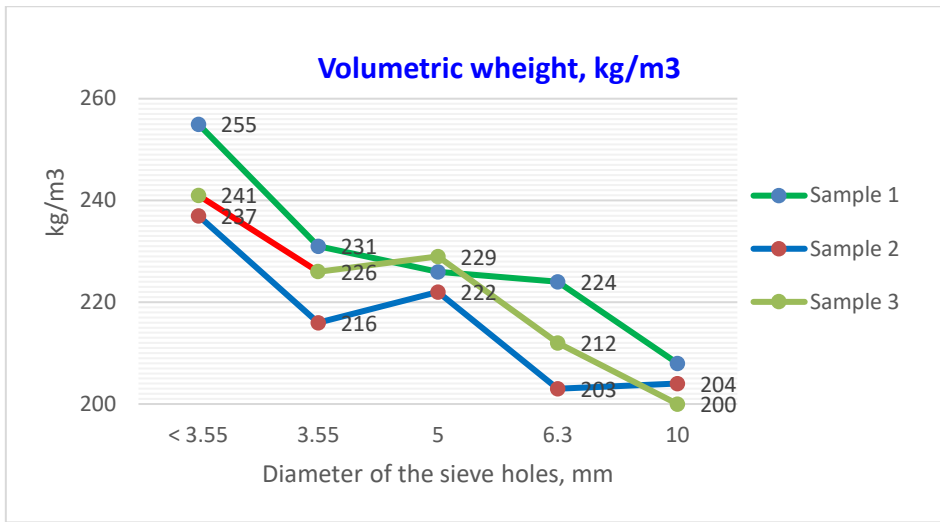
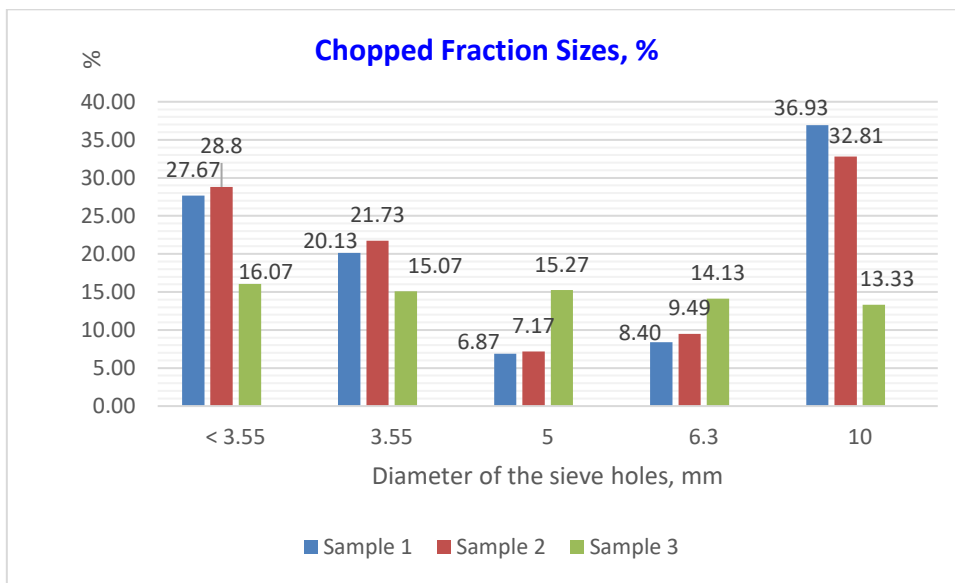
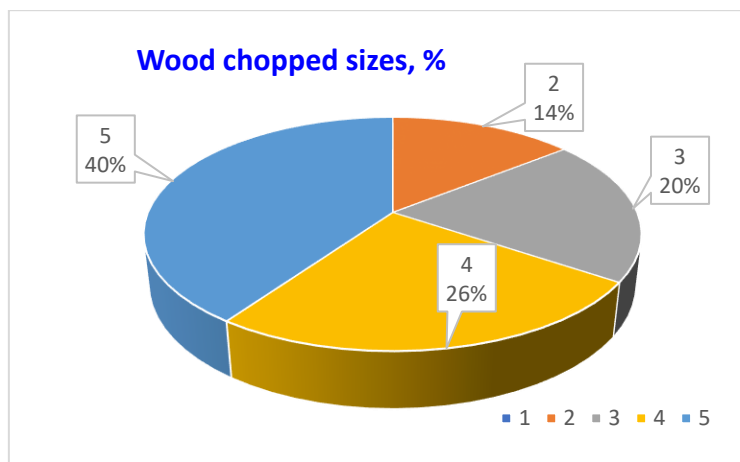


Fig. 12 – Volumetric weight for three samples



a) For each sample



b) Average of the three samples

Fig. 13 – Wood chopped fraction sizes, %

1 – Rejection < 3.55 mm; 2 – Ø3.55 sieve holes; 3– Ø5 sieve holes; 4 – Ø6.3 sieve holes; 5 - Ø10 sieve holes

The moisture content for each wood chopped fraction was determined and the results are presented in the next graphs.

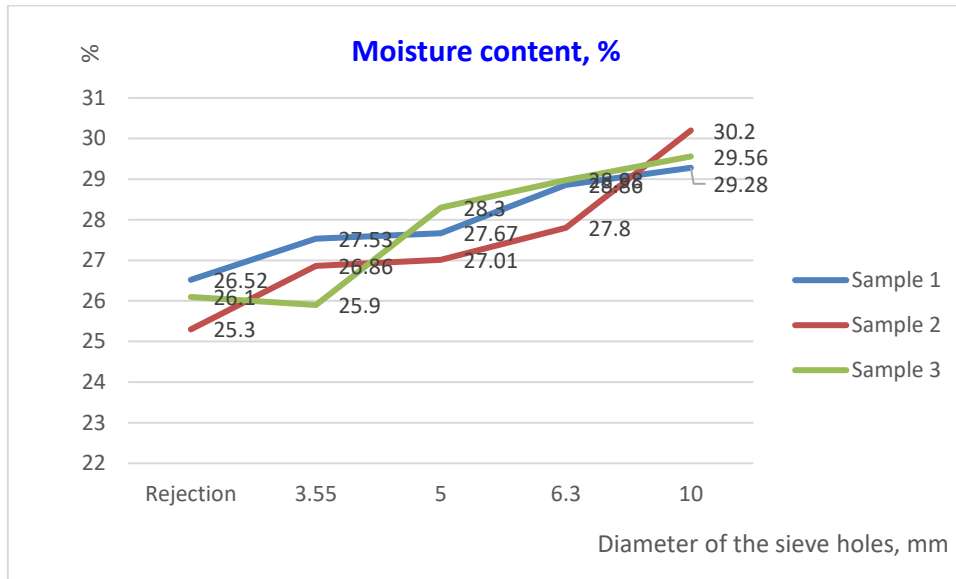
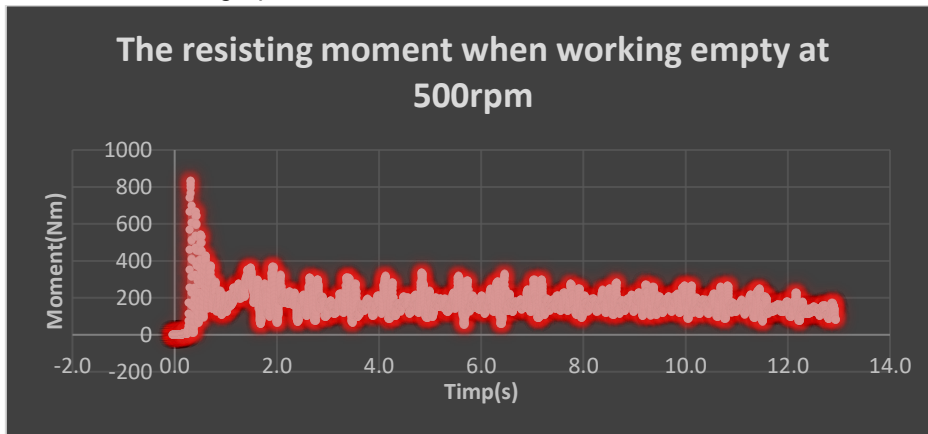


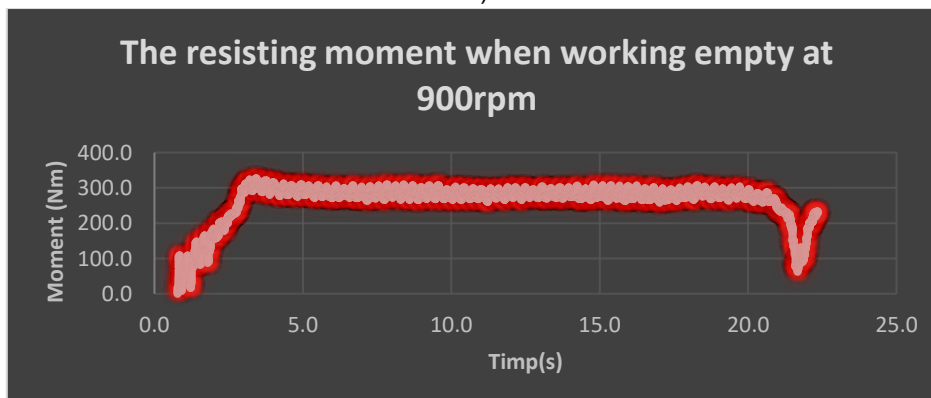
Fig. 14 – Moisture content for wood chopped fraction, %

Chopping drum is acted by a mechanical transmission, where the movement is taken from the tractor's power take-off shaft, through a cardan, then transmitted through a conical group to a belt transmission, whose multiplication ratio is  $i=3.2$ , and finally multiplying the rotational speed of the chopper.

The rotational speed of the chopping drum can be variable, depending on the nominal speed of the tractor engine. During these experiments, with the help of the equipment described in the previous chapter, the moment resistant to the chopping rotor was recorded for 4 nominal revolutions of the tractor engine 500rpm; 900rpm; 125rpm and 1500rpm). The determinations were made when the equipment works unloaded, and the research will be continued with the recording of the resistant moment when the equipment is loaded. The results are presented in the next graphs.



a)



b)



c)



d)

Fig. 15 – Resisting moment when working empty

Taking into consideration the experiments performed, a working average capacity was obtained, the values being as in Table 1.

Table 1

Working capacity of the equipment TRL-0

	Measure unit	Sample 1	Sample 2	Sample 3	Average
Working capacity	m <sup>3</sup> /h	14.2	14.1	14.3	14.2

**CONCLUSIONS**

Not all chopping equipment provide good results if they are used in different conditions and using different wood residues and not all chopping machines are suitable for use on different plantations. It depends on the wood characteristics (moisture content, stress resistance, branch dimensions etc.).

Productivity depends a lot on the shape of the branches, the processed material not being homogeneous. The experiments performed did not aim at determining the performance characteristics of the car, but its functionality.

Research has shown that the machine produces wood chips with dimensions between 4 and 16 mm, those collected on sieves with a hole diameter of 3.55 mm as well as those collected on a sieve with a hole diameter of 10 mm being in a larger proportion than the other two.

The measurement of the moment resistant to the chopping rotor when working empty cannot measure the required power, for the optimization of the energy source in the aggregate, respectively the tractor engine power, but these data were collected to see the magnitude of the moment of inertia at start-up and the required surplus power for putting the machine into operation, in case of overload.



Other energetic and performance parameters of the machine will be carried out in a later stage of the research, when in-depth research will be undertaken, using several species of wood, and several variables will be set to different values (advance speed of the conveyor belt, rotation of the rotor chopping)

To obtain good performances it is necessary to concluded that appropriate adjustments of the working organs of the machine can lead to obtaining the desired performances.

The productivity depends on the wood physical characteristics which also determines the resistance to cutting and can vary greatly. The moisture content influences the cutting resistance. The drier it is, the higher the cutting resistance. In this experiments we used poplar, which is relatively light in weight, has good strength in both tension and compression; and provides rigidity, toughness and insulating properties.

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