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Shredding Roller Effect on the *Cannabis sativa* L. Residues and Environment

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Abstract: Fiber cannabis has been grown in Lithuania for a long time, but its cultivation technologies have not been widely studied. However, the growing population and consumption forces us to look to alternatives and to make efforts and find solutions to facilitate the cultivation of fiber cannabis because the use of fiber cannabis can be for many different types of products. The aim of the study was to evaluate the impact of the interaction of fibrous cannabis (*Cannabis sativa* L.) residue and soil on the mechanical properties of the residue and the environment in cultivation technology using a shredding roller. The study determined the effect of the shredding roller on the moisture content of cannabis residues, lignin content, visual changes, and mechanical characteristics of breaking and cutting. Examining cannabis residues according to the dominant different diameters of 5-, 8-, and 10-mm organic cannabis residues, it was found that the highest efficiency of the shredding roller is when rolling 5 mm diameter cannabis residue stems. The efficiency of the shredding roller for reducing the mechanical characteristics of cannabis residues and the need for shredding force was up to 20.78%. The results obtained are significant if the cannabis crop used with the shredding roller is organic, as the smallest diameter plant residues would be the most abundant. Studies have concluded that the moisture content of cannabis residues, the visual changes, and the need for crushing force prove the efficiency of the shredding roller, and the cannabis cultivation technology influences the decomposition of cannabis residues.

Keywords: fibrous cannabis; roller; soil; plant residues; sustainable agriculture

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1. Introduction

The recognized negative environmental and soil impacts of intensive farming have led to the practice of sustainable ecosystems. With reduced tillage, crop residue management is largely encouraged to enhance multiple ecosystem functions [1]. In order to contribute to the mitigation of climate change and to increase soil organic carbon, the management of plant residues by reducing tillage is proposed [2,3]. This practice promotes the abundance and activity of soil biota and contributes to the maintenance of organic carbon and nutrient balance, ultimately contributing to higher yields [4–6]. In agroecosystems, plant residue decomposition is related to litter quality parameters such as C:N ratio or lignin content, and in some research studies, it has been evaluated as an effect of different agricultural practices [7–9]. Photodegradation of complex polymers in plant residues, such as lignin, leads to chemical changes in the residue quality that can promote decomposition (photofacilitation) [10,11].

Under natural conditions, plant remains are exposed to weather conditions (moisture, temperature, sun, etc.), so they decompose and significantly weaken the mechanical properties of plant remains, but this requires a long period of time. In modern agricultural technologies, it is not always possible to wait until the plant remains in natural conditions to weaken its mechanical properties, which affects the technological processes of the working parts of tillage and seeding machines. Very often, a few weeks after harvesting the plants, new plants are already sown. When applying non-tillage technologies, all plant remains of the previous crop remain on the soil surface and directly influence the working process of the working parts. As a result, plant remains that have been lying on the surface of the soil for a short time may have preserved strong mechanical properties, and disc knives will not be able to cut or break the plant remains. In this case, plant remains will be pressed into the soil. In order to prevent this from happening, it is necessary to seek to speed up the processes of mineralization and weakening of the mechanical properties of plant residues. Various biological preparations with live nitrogen bacteria are used to activate such processes [12]. Using a biological preparation with nitrogen-fixing bacteria significantly reduces the amount of cellulose, hemicellulose, and lignin in wheat straw [13]. Using a biological preparation not only has benefits, but also comes with additional costs. In addition, it is not known how quickly biological preparations will activate the decomposition process of the large-stemmed plant, ornamental cannabis.

It has been estimated that when cotton stalks are processed and chopped into small pieces of 50–60 mm using a cotton chopper, with the addition of a compost culture, the plant residues decompose in less than 120 days. In cotton crops under dry farming conditions, ex situ composting of stalks with a chopper was found to produce the highest yield compared to other management practices [14]. For large quantities of plant residues, it is important to apply appropriate in situ management of crop residues in a variety of ways, using the right machinery package, composting, and thermal decomposition methods [15].

The science of the past is not very advanced with technology in the mechanical solutions of cannabis. However, the growing population and consumption force us to turn to alternatives and use fiber cannabis for many different types of products, including paper, plastic, furniture, fuel, textiles, and even household items. In addition, cannabis cultivation shows substantial environmental benefits, e.g., it can restore polluted soils [16]. Cannabis may be an ideal crop for organic agriculture due to its low nutrient requirement, and it shows high resistance to pathogens [17] and weed suppression [18]. In 2020 the US was the world's largest producer of industrial cannabis, with a licensed area of 465,787 acres [19]. The declared area of cultivated fiber cannabis is 5334.29 ha in Lithuania in 2022, 12% more than in 2021 [20]. This shows that farms are actively interested in growing cannabis, and companies that process various cannabis raw materials are already operating and being established. In addition, by growing and processing fibrous cannabis, Lithuania can greatly contribute to the implementation of the European Union's bioeconomy strategy. Cannabis growing shows essential environmental benefits, e.g., it has the potential to remediate contaminated soils, also ideal for conversion of high amounts of atmospheric CO_2 to biomass through bio-sequestration [16,21,22]. Therefore, it is important to make efforts and find solutions to facilitate the cultivation technologies of fiber cannabis without causing more damage to the world due to environmental pollution, soil erosion, and leakage, plant residue damage to working parts of machines using no-till technologies, by the way, ensuring water retention in soil, saving costs using combined equipment.

As most production products (equipment, cars, appliances, etc.) become increasingly individualized, this process has not escaped the agricultural sector either. Farmers want innovative solutions that meet their needs. Tractors are becoming more powerful, and tillage equipment is becoming more efficient and versatile. In the past, a separate unit (cultivator, harrow, roller, plow, etc.) was used to perform each function, while today, farms aim to reduce costs by using units that perform several functions simultaneously. As in the case of our research, the newly constructed roller used performs the following several functions: it mixes and partially crushes plant remains, it shallowly loosens the soil, thereby creating a better work of microorganisms, and it crushes soil clods. The aim of this work is to evaluate the effect of the interaction of fibrous cannabis (*Cannabis sativa* L.) residue and soil on the mechanical properties of the residue and environment in cultivation technology using a shredding roller.

2. Materials and Methods

A stationary field experiment was performed in Panevėžys district, Lithuania. Soil area was sandy loam in the northern highlands. Soil properties in this area are greatly influenced by the maritime climate, which promotes leaching and silting processes, making them more acidic and less alkaline. Due to the relatively flat terrain, the soils are soaked and muddy throughout the profile, drained, and systematically limed. The soil cover is of low contrast (relatively uniform). The productivity of soil in this area is estimated at 38–43 points [23].

The rotation of the plants in the experiment was fibrous cannabis grown for 5 years in a row. Fiber cannabis: variety—'FUTURA 75', seed rate—25 kg ha^{-1}. Sowing depth—2 cm. Sowing time—April. Cannabis is harvested with a special combination (reconstructed CLAAS Jaguar), which performs several functions at the same time. The remains of the plants are chopped into 60 cm long sticks, which are left in the swathes, and at the same time, the cannabis flowers are combed into a special container. After combing, plant raw materials are poured directly into the selected container. After harvesting, the remains of cannabis residues (60 cm long) lying in the swathes cause problems. The microscopic fungi and microorganisms present to break down the cannabis residues left after the harvester are not sufficient to deal with such a large amount of cannabis residues. Therefore, in order to achieve a higher intensity of cannabis residue decomposition, a specially designed and newly adapted cannabis residue shredding roller (Figure 1). During the research, the most optimal mass of the roller was selected by testing—1760.5 kg. The working width of the shredding roller is 4 m. Type—hanging. The diameter of the shredding roller is 800 mm, the rotation speed is 132.8 rpm min^{-1}, the peripheral speed is 5.56 m s^{-1}, and the thickness of the roller band is 10 mm. The 15 cutting knives are attached along the cylindrical roller. The optimal working speed starts from 20 km h^{-1}. The shredding roller is a hollow cylinder with parallel strips of cutting knives, which allows the mass of the implement to be increased when there is more cannabis residue or when the soil is hard. In order to improve the process of shredding cannabis residues, the roller blades are sharpened at an angle of 90 degrees to the front. The shredding roller performs the following functions: mixing, crushing, pulling, cutting, tearing, dividing, crushing, crushing, fiber damage, rotting, and splitting cannabis residues.

Figure 1. Cannabis residue shredding roller.

In order to evaluate the effectiveness of the shredding roller for cannabis residues, the field of experimental research was divided into two parts. In one part of the field, cannabis residues after harvesting were processed with a shredding roller. In another control part of the field, cannabis residues were left as usual on the soil surface. During the period of experimental research, deep shredding was performed with a shredding roller to a depth of 15 cm four times. First time was on 4 April 2020 before seeding fiber cannabis, second time after harvest on 19 September 2020, third time before sowing on 4 May 2021, and after harvest on 29 September 2021.

Next, after the cleaning roller, the effectiveness of the roller for the decomposition of cannabis residues was tested. Research of cannabis residues moisture and lignin, residues cutting and pulling were specifically selected. Samples of cannabis residues for testing were randomly taken from the field and hung on a three-point rear hanger.

Cannabis lignin studies have been carried out because lignin plays a particularly important role. The following nutrients contained in the cells of plant remains are protected by a thick two-layer wall consisting of extremely strong polymer compounds: lignin (about 25%), cellulose (about 50%), and hemicellulose (about 25%). It is because of them that the remains become woody. The stronger the cannabis residues, the more lignin has been accumulated. It is during the breakdown of lignin and cellulose that new organic carbon compounds—humus—are formed in the soil. Due to the different properties of plants to accumulate lignin, the level of woody plants varies. Cannabis residues are extremely strong and difficult to break down and humify. In hummus, nutrients such as biological compounds are less likely to evaporate or leach out. Mineralization—the release of nutrients—occurs in the spring, but before then the lignin and cellulose must be broken down. The fiber contains 73–77% cellulose, 7–9% hemicellulose, and 2–6% lignin, the pulp contains 48%, 21–25%, and 17–19%, respectively. Because of its higher carbohydrate-to-lignin ratio, cannabis biomass is more suitable for biofuel production than other energy crops because it emits fewer greenhouse gases. Research on cannabis residue moisture was carried out because the shredding roller mixes the cannabis residues together with the soil, which affects the moisture of cannabis residues. Higher moisture content of cannabis residues correlates with faster decay and weakening of cannabis residues.

It can be predicted that in the future, applying the shredding roller in cannabis cultivation technology will require less force to cultivate the soil with cannabis residues and will facilitate the work of agricultural machines, reducing energy, fuel consumption, and environmental pollution. Therefore, laboratory simulation research of the cutting and breaking of cannabis residues was carried out, which demonstrates the effectiveness of the shredding roller in the mechanical properties of fibrous cannabis residues. This research shows whether using a shredding roller requires less force and time to cut and break the cannabis residues.

CO_2 is one of the main exhaust gases in the composition of diesel fuel, why, after increasing the decomposition of cannabis residues, lower fuel consumption is required for plant residues and tillage, which in parallel also affects lower CO_2 emissions from tillage machines.

Research has been carried out on the residues of organic fibrous cannabis, comparing cannabis cultivation technology where a shredding roller was used and where it was not used.

2.1. The Assessment of the Mechanical Properties of Fibrous Cannabis Residues

Studies have been carried out on the remains of organic fibrous cannabis, comparing the mechanical properties with the cannabis cultivation technology where a shredding roller was used and where it was not used. Cannabis stem cutting and breaking studies was performed with the experimental research device Instron 5960 (825 University Ave Norwood, MA, 02062-2643, USA) (Figure 2) with software Bluehill. Experimental cutting studies were performed in interaction with the soil in order to achieve the most natural conditions possible for cutting stems on the soil surface. Soil from an experimental industrial research field was used for the research.

The research of cutting and breaking was performed by selecting the following dominant cannabis stem diameters: 5, 8, and 10 mm. After each cannabis stem-cutting study, the soil was re-compacted. Research was carried out 5 repetitions.

(**a**) (**b**) (**c**)

Figure 2. Studies on the mechanical properties of the cannabis residue: (**a**) cutting in the soil, (**b**) breaking, (**c**) control panel.

2.2. The Assessment of Lignin Content

The determination of insoluble lignin (ADL) in the acid detergent solution was performed. Reagents: sulfuric acid H_2SO_4 (72% by weight), acetone. It were used equipment and tools: filtration bags (F57 from ANKOM Technology), bag sealing device (1915 Heat Sealer from ANKOM Technology), desiccator with absorbent material, 2 L and 3 L glasses. Weigh the bags and record their mass. Weigh 0.5 g (±0.05 g) of air-dried ground material directly into bags F57. With a special device, the bags are sealed at a distance of approximately 0.4 cm from the open edge. Distribute the sample evenly in the filter bags. The determination of the ADF with the fiber analyzer Ankom (Hanon Advanced Technology Group Co., Ltd., Financial Business Center of Hanyu, High-Tech Development District, Jinan, China). After setting the ADF, place the dried bags in a 3 L beaker and fill with sufficient (approximately 250 mL) 72% H_2SO_4 to cover the bags. Place a 2 L beaker (or inverted funnel of appropriate size) in a 3 L beaker to immerse all the bags in acid. Stir in a glass at the beginning of the procedure and every 30 min thereafter performed by pressing and lifting a 2 L glass (funnel) about 30 times. After 3 p.m., drain the H_2SO_4 and rinse with tap water until all the acid is washed off. Repeat rinses until the pH is neutral. Rinse with approximately 250 mL of acetone for 3 min to remove water in the course. Dry the samples at 105 °C to constant weight. Place in a desiccator, cool to room temperature, and weigh. For bagging, place the bags in crucibles (30 or 50 mL) and heat at 525 °C for 3 h, or until no charred residue remains, cool and calculate the lost mass. The percentage of ADL in the dry matter is calculated according to the following formula:

$$\text{ADL} = \frac{(\text{W3} - \text{W1}\cdot\text{C2})\cdot 100}{\text{W2}\cdot\text{SM}} \quad (1)$$

here:

- W1—mass of the empty bag, g;
- W2—mass of the sample, g;
- W3—mass of organic matter (OM) (loss of mass on burning of bags and residual fiber), g;
- C2—correction of the blank (control) bag for ash (loss of mass on burning of the bag/initial mass of the bag), g;
- SM—expressed as a fraction of the mass, g.

2.3. The Assessment of the Impact of the Shredding Roller on Energy Consumption and CO_2 Emissions

The area of 10 ha of experimental research was divided into two parts of 5 ha according to the prepared plan. One part of experimental field was loosened with a shredding roller. Used ZETOR tractor (ZETOR TRACTORS a.s., Brno-Líšeň, Czech Republic) which worked with a shredder. A shredding roller with a working width of 3 m was used during operation. The average rolling depth is 15 cm ± 2 cm. The average value of the tractor speed from

20 km h^{-1} to 25 km h^{-1}. The energy parameters were recorded during rolling for an average of 500 m distance of 500 m in length 166 times. During the experimental study, 664 runs with a shredding roller were recorded. Fixed hourly fuel consumption, according to agricultural practice, was converted to fuel consumption per hectare [24–26].

We have tried to reduce carbon emissions by reducing the fuel consumption of less powerful and smaller tractors, which would benefit small and medium-sized farms. In the case of conventional tillage and arable crops emits 136.18 kg of CO_2 ha^{-1} CO_2 [27]. Irrespective of the type of crop, it was found that 47.5 L ha^{-1} of diesel was used after harvest, corresponding to 125.4 kg of CO_2 ha^{-1} [28]. Various researchers have set a limit for burning 1.0 L of diesel fuel from 2.64 kg to 3.76 kg of CO_2 gas (average value 3.2 kg) [29,30]. Minimum, maximum, and average CO_2 emissions are calculated according to other authors' provided values.

2.4. The Assessment of the Impact of the Shredding Roller on Cannabis Residues Moisture

The effect of the shredding roller on the moisture content of cannabis residues was determined in experimental studies. Structural analysis of samples and determination of dry matter during structural analysis, samples were divided into fractions according to plant parts. Samples were dried at 105 °C, 24 h to constant weight in a ventilated oven (Binder).

2.5. Statistical Evaluation

Data for the calculation of baseline results using the ANOVA tool of Microsoft Excel software. Arithmetic means, standard deviation, and their confidence intervals were determined with the probability level ($p < 0.05$), respectively. Mathematical statistics Tukey analysis of the dispersion test by estimating at the 95% confidence level ($p < 0.05$) to ensure that the differences between the data means were significant [31]. Tukey's HSD ("honestly significant difference") test is a statistical tool used to determine whether a relationship between two groups of data is statistically significant—that is, whether there is a high probability that observed numerical changes in one value are causally related to observed values in another a change. Tukey's test is used to compare the means of differences between values. Tukey's test value is obtained by taking the absolute difference between pairs of means and dividing it by the standard error (SE) of the mean determined by a one-way ANOVA test. SE is the square root (variance divided by sample size). The Tukey test is a post hoc test in which variables are compared after the data have already been collected. Columns marked with the same letter mean the results have significant differences.

3. Results and Discussion

3.1. Visual and Moisture Assessment of Rolled and Unrolled Cannabis Residues

Obvious visual differences between rolled and unrolled cannabis residues were found (Figure 3). Rolled cannabis was covered with soil and chopped; by the way, it was obviously more moisture compared with unrolled (Figure 4).

Moisture studies of rolled and unrolled cannabis residues by drying to constant weight showed a significant difference in values. The moisture content of rolled and unpolished cannabis residues showed a mean moisture content of 48.42% for rolled cannabis residues and 13.09% for non-rolled cannabis residues. The effect of the shredding roller on the moisture content of cannabis residues was 72.97%. The moisture content of the rolled cannabis residue is higher because the residue mixed with the soil absorbs water from the soil better due to the strong capillary forces created by the small pores of the plant residue [32,33]. Other researchers have found that overwintered plant residues not mixed with soil but on the soil surface are 77% drier than autumn plant residues [34]. Results indicate that plant residue fragments incorporated into soil likely create moisture microenvironments for microbial decomposers. Moreover, they state water retention capacity of the plant residue incorporated into the soil is greater than the water retention of the soil [33].

Figure 3. Visual differences between rolled and unrolled cannabis residues. Rolled cannabis remains are marked in red.

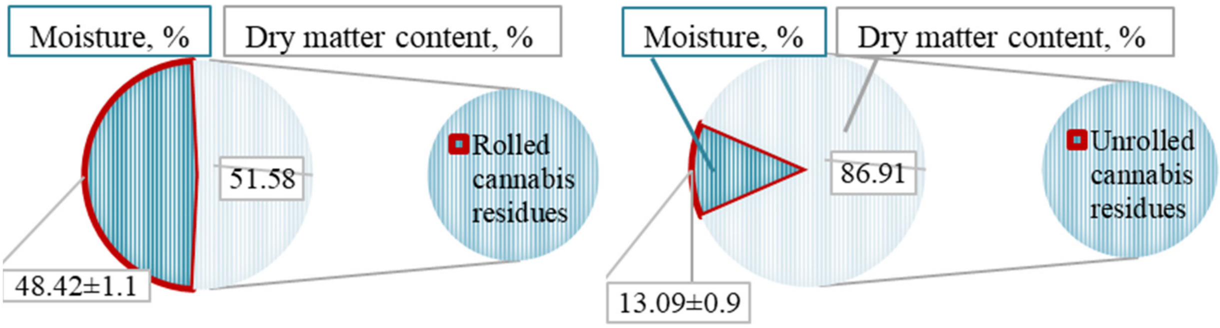

Figure 4. Moisture of rolled and unrolled cannabis residues.

3.2. The Assessment of the Need for Breaking and Cutting Force on Cannabis Residues

Tensile strength studies of rolled and unrolled cannabis residues of different diameters revealed uneven variation in values. Tensile strength studies of rolled and unpolished cannabis residues of different diameters showed that the mean breaking force of rolled cannabis residues ranged from 92.17 to 148.42 N for cannabis residues ranging in diameter 5, 8, and 10 mm. The breaking force of the unrolled cannabis residue ranged from 116.34 to 128.28 N (Figure 5). The efficiency of the shredding roller in reducing the need for the breaking of cannabis residues was up to 20.78% for cannabis residues with a diameter of 5 mm and up to 7.78% when the diameter of the cannabis residues is 8 mm. The force required to crush the material varies according to the volume or mass of the pieces [35]. The efficiency between treatment was not noticed when the cannabis diameter was 10 mm. These results are likely due to the ability of the larger pores in the 10 mm diameter residue to absorb less water from the soil compared to the smaller diameter residue, which are smaller because stronger capillary forces are created by the smaller pores. Compared to different diameter rolled cannabis of breaking force was significant differences between treatments. Unrolled cannabis breaking forces do not have significant differences. State that the breaking of treated plant residues needs significantly less force than untreated. Other researchers have found that breaking characteristics are greatly influenced by the overwintering of plant residues on the soil surface and the type of plant [36]. They found that the breaking force of overwintered winter wheat straw was reduced by about 3.2 times compared to autumn straw, while the breaking force of overwintered spring barley straw was only about 34% reduced [34]. In addition, when plant residues are inserted in the soil, they create a moisture microenvironment, and the soil moisture can be higher and the soil hardness lower than in the case when the plant residues are left on the soil surface. In this case, the penetration resistance of soil decrease, and the force required for crushing plant residues may decrease.

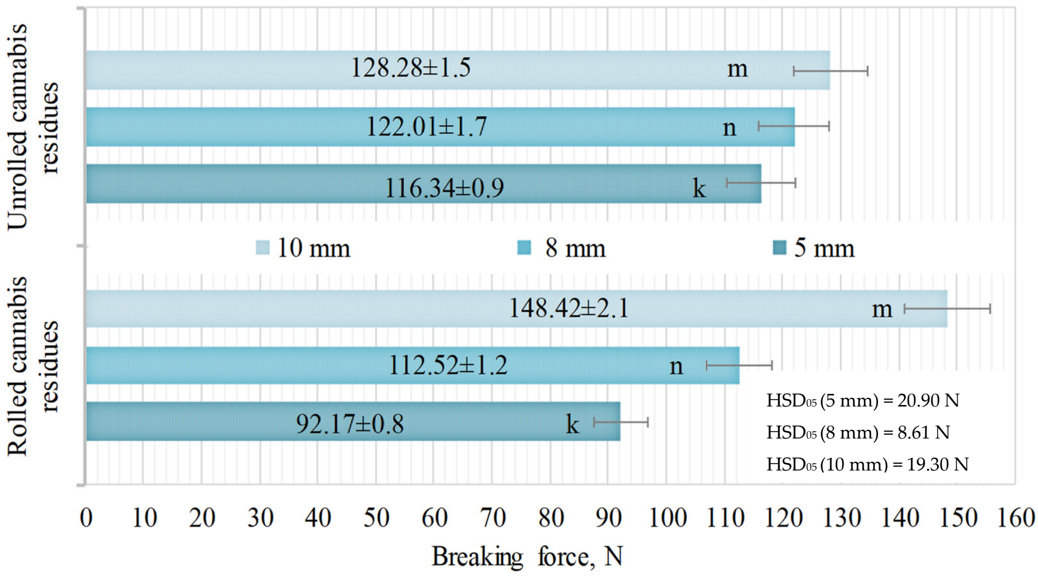

Figure 5. Breaking force demand for rolled and unrolled cannabis residues of different diameters. Columns marked with the same letter mean the results have significant differences (probability level $p < 0.05$).

Research of the cutting force of rolled and unrolled cannabis residues showed uneven variation in values as the diameter of the cannabis increased. The average cutting force of rolled cannabis residue ranged from 58.49 to 134.37 N. The cutting force of unrolled cannabis residue ranged from 26.78 to 79.18 N (Figure 6). The efficiency of the shredding roller in reducing the cutting force requirement of cannabis residue was not effective. This was due to the high humidity of the rolled cannabis residue. Other authors also state that the moisture content of plant residues affects the cutting quality. The researchers found that as stem moisture decreases, the force required for cutting decreases accordingly. By the way, the researchers found that a 32% decrease in stem moisture resulted in a decrease of 16.3% and 16.7% in specific shear energy and shear strength values, respectively [37]. In addition, rolled cannabis residues have higher lignin content (approximately 19%) than unrolled (Figure 6); it can also have an influence on the increasing cutting force of rolled residues. The penetration resistance of the soil surface and the moisture content of plant residues are of the utmost importance for cutting quality [38]. Increasing plant residue moisture increases shear strength and specific shearing energy [39]. The plant residue moisture must be below 17%. In our study, the moisture of the cannabis residue was significantly higher than 17% for the rolled cannabis and slightly lower for the unrolled.

The results obtained are significant if the cannabis crops used with the shredding roller were organic, as the smallest diameter plant residues would be the most abundant. Studies have concluded that the moisture content of cannabis residues, visual changes, and the need for crushing force prove the effectiveness of the crushing roller in some cases. The use of a shredding roller in organic cannabis cultivation technology helps to address the problem of post-harvest treatment of cannabis residues during tillage. The effects of the shredding roller on cannabis residues include cutting, breaking, crushing the cellulose, mixing, and the like. This significantly affects the moisture content of cannabis residues, which promotes the mineralization and degradation of cannabis residues on the soil surface. Thus, the use of a shredding roller in cannabis cultivation technology in the future is expected to require less effort to cultivate the soil with cannabis residues, and facilitate the operation of agricultural machinery, reduce energy, fuel consumption, and environmental pollution.

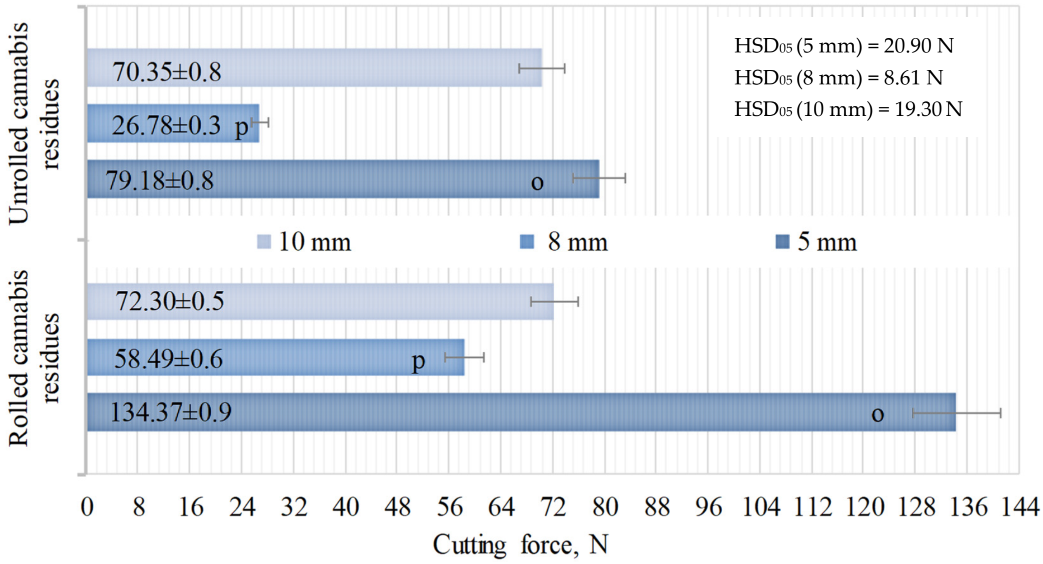

Figure 6. Cutting force demand for rolled and unrolled cannabis residues of different diameters. Columns marked with the same letter mean the results have significant differences (probability level $p < 0.05$).

3.3. Effect of Shredding Roller on Breaking and Cutting Force Change of Cannabis Residues

Summarizing the studies performed, the mean change in breaking force was calculated to estimate the effect of the shredding roller on the mechanical characteristics of cannabis residues (Figure 7). The effect of the shredding roller on the breaking characteristics of cannabis residues was determined by estimating the mean change in breaking force. At a diameter of 10 mm for cannabis residues, a lower breaking force requirement for rolled cannabis residues was calculated, it was 6.48% less force. When the diameter of the cannabis residue was 5 mm, the lower breaking force requirement for the rolled cannabis residue was calculated to be 38.11 N, which accounted for the highest percentage efficiency of the shredding roller at a 32.76% force decrease.

The difference between the force of rolled and unrolled cannabis residues was calculated in the study (Figure 7). The smallest (1.94 N or 2.76%) change in cutting force was obtained when the diameter of cannabis residues was 10 mm, and the largest (55.19 N or 118.43%) when the diameter was 5 mm.

After calculating the average change in cutting force in Newtons and as a percentage during the study, the minimum cutting force requirement for cannabis residues was found to be ~2% when the diameter of cannabis residues was 10 mm. It is known that increasing plant residue moisture increases specific shearing energy [39]. Therefore, it is likely that there was less moisture in the rolled cannabis residues with a diameter of 10 mm than in the rolled residues with a smaller diameter; therefore, cutting force change was less for larger-diameter cannabis residues.

3.4. Effect of Shredding Roller on Cannabis Residue Lignin

To assess the degradation of plant residues, the average determination of lignin content in cannabis residues was performed by comparing rolled (17.2% S.M.) and unrolled residues (14.0% S.M.) (Figure 8).

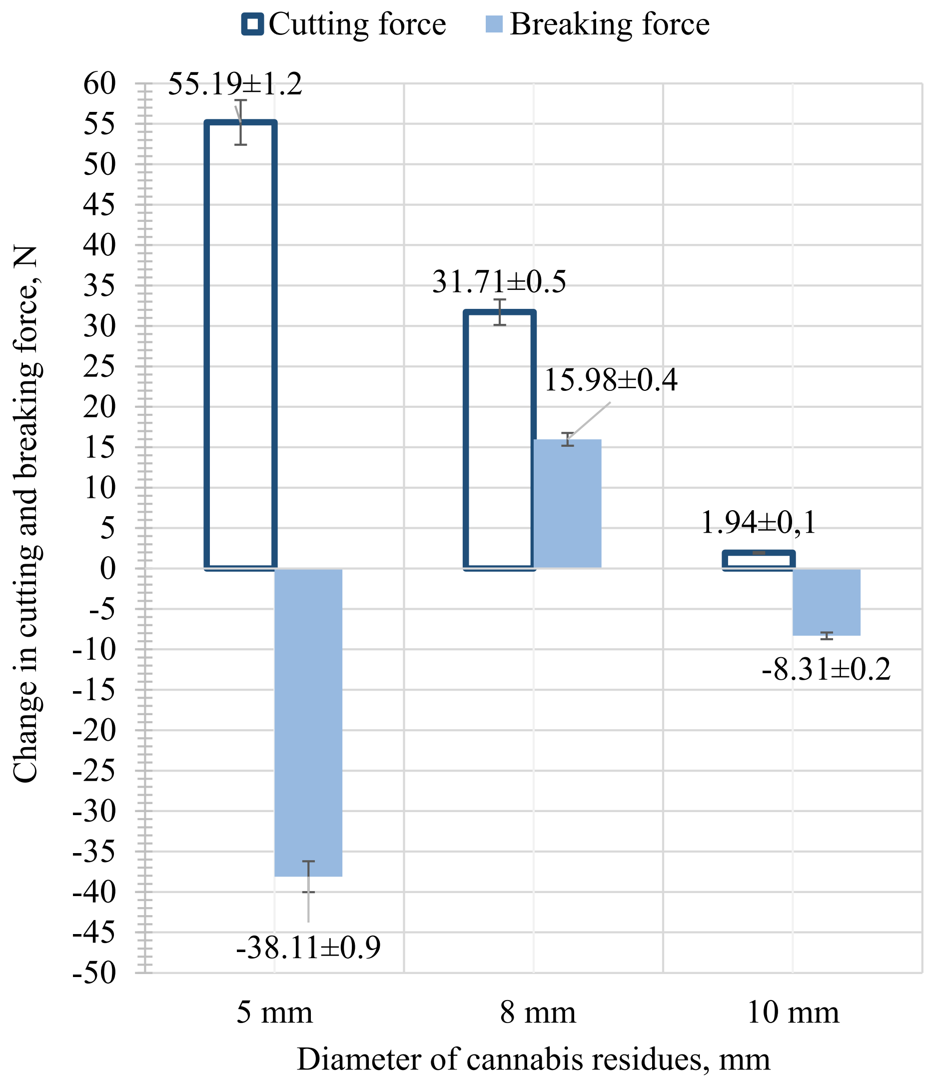

Figure 7. The effect of the shredding roller on the breaking force changes of cannabis residues (probability level $p < 0.05$).

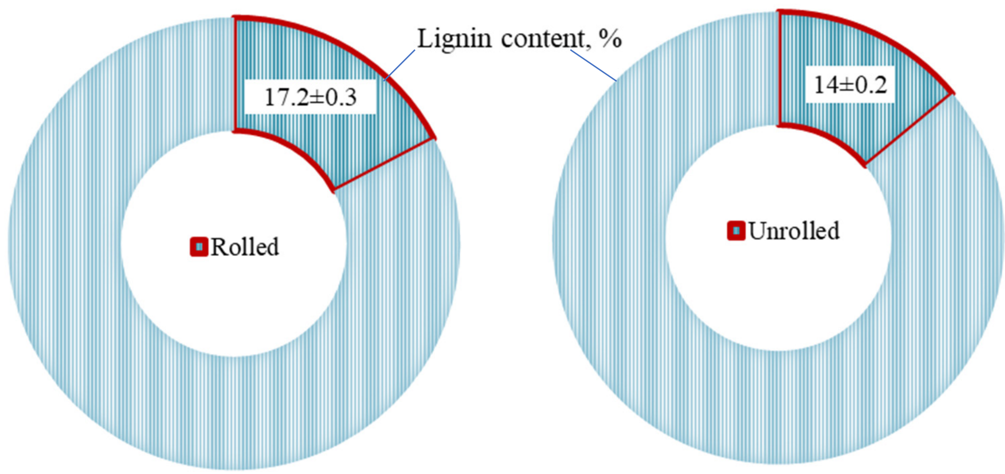

Figure 8. Lignin content in cannabis residues depend on treatment method.

The study found that rolled cannabis had 18.6% higher lignin content. Cannabis stalks are the most valued for their long primary fiber, which is made up of 50 to 70% cellulose and has only about 7 % lignin. The short fiber is found inside the woody part of the cannabis stems. It is about 0.5 mm long and usually has about 20–30% lignin. The dynamics of the content of lignin (ADL) insoluble in acid detergent solution in the studied herbs, the concentration of lignin in plants differs not only depending on the stage of development but also depends on the fraction of the plant measured. Plants accumulate mainly in the stems of lignin, in which lignin intertwines with cellulose and hemicellulose, making the stems strong. As the plant matures, the number of stems increases, resulting in an increase in lignin. Therefore, this may have been one of the most important factors in the increase in lignin content in plants from the end of flowering to flowering. Lignin is not digested by stomach enzymes, so the digestibility of plant stems is the worst due to its higher concentration. Lignin, a complex polymer of phenolic compounds, is an indigestible fiber component of anaerobic microbes and in the production of biogas from plant biomass. The structural polysaccharides cellulose and hemicellulose, intertwined with complex lignin molecules, are more difficult to reach and degrade by hydrolysis enzymes [40]. In our research, it was found that a higher part of lignin in the rolled plant residues had a more significant negative influence on cutting research than on breaking.

3.5. Impact of Shredding Roller on CO_2 Emissions

Fibrous cannabis can grow from 7.5 to 20 tons of dry matter per hectare, and 1 ton can absorb 1.65 t of CO_2. An average of 10 t of dry matter per hectare was obtained in the experimental field. The obtained during research CO_2 emissions ranged from 13 to 21 kg CO_2 ha^{-1}, respectively (Figure 9).

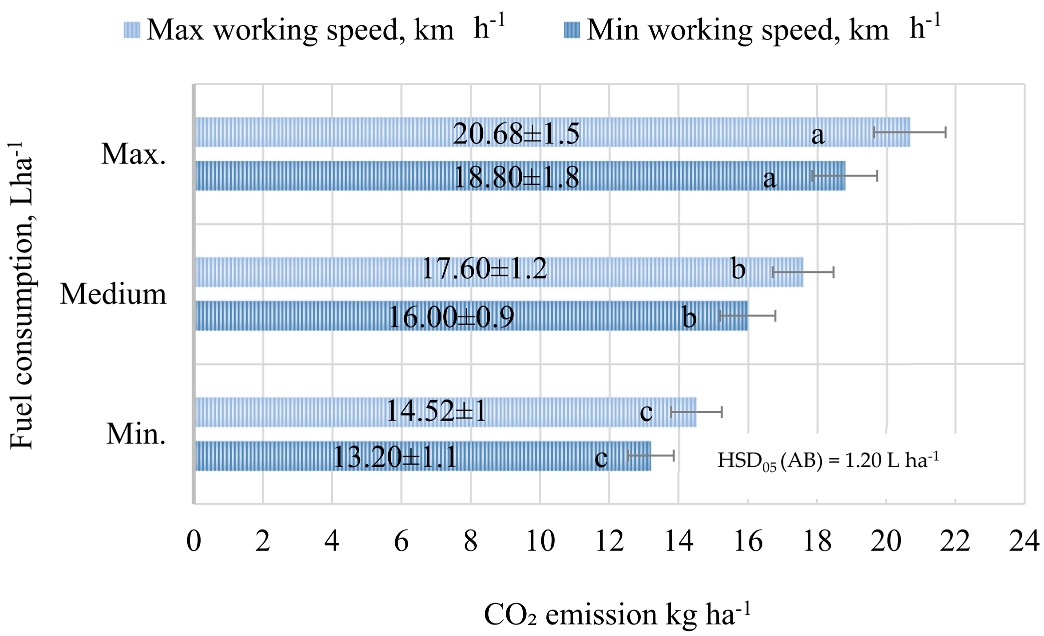

Figure 9. Impact of shredding roller on CO_2 emissions. Columns marked with the same letter mean the results have significant differences (probability level $p < 0.05$).

CO_2 is one of the main exhaust gases in the composition of diesel fuel, consisting of hydrocarbons and impurities, including carbon monoxide (CO—0.5% by volume), hydrogen (H_2), hydrogen sulfur (H_2S), nitrogen (N_2—76% by volume) and oxygen (O_2—76% by volume) [41–43]. Linear regressions of energy and emissions mass and engine power show that more powerful and larger tractors require less energy and emissions per unit of mass or power [44]. We could reduce carbon emissions by reducing the fuel consumption of less powerful and smaller tractors, which would benefit small and medium-sized farms. During the research, it was cannabis harvest—10 t compensated for the CO_2 emissions during rolling. The efficiency of the shredding roller for CO_2 absorption is calculated as the average efficiency of 99.8%. What demonstrates the effectiveness of cannabis technology in effectively absorbing CO_2 and reducing the environmental pollution. Studies by other researchers have found that cannabis residues can also be used to make green composites made from cannabis and bark residues. Thermal and mechanical properties are useful in the use of these wastes as raw materials and in the production of low-density insulation boards. Their potential application can help reduce cooling and heating costs and, at the same time, reduce CO_2 emissions [45].

4. Conclusions

Research has shown that the moisture content of cannabis residues is 72.97% when using a shredding roller in cannabis cultivation technology, higher than in conventional technology where the shredding roller is not used. In addition, significant visual differences were observed when comparing rolled and unrolled remains. Rolled cannabis residues were covered with soil and chopped.

Assessing the mechanical characteristics of the breaking force of cannabis residues of different diameters, it can be stated that rolled and unrolled thinner (5–8 mm diameter) stems of cannabis residues require less breaking force. The reverse trend was found in the cutting force study. The efficiency of the shredding roller in reducing the mechanical characteristics of cannabis residues, the need for shredding force was up to 20.78% for cannabis residues with a diameter of 5 mm and up to 7.78% when the diameter of the cannabis residue is 8 mm. It can be stated that the shredder roller will have a better efficiency in organic farms because such farms are dominated by smaller-diameter fibrous cannabis residues.

The average determination of lignin content in cannabis residues rolled was 17.2% S.M. and unrolled 14.0% S.M. The study found that rolled cannabis had 18.6% higher lignin content.

The CO_2 emissions from the rolling of cannabis residues at speeds between 20 and 25 km h^{-1} were calculated to be between 13 and 21 kg ha^{-1}, respectively. The average efficiency of the shredding roller for CO_2 absorption is calculated—99.8%. What compensated for the CO_2 emissions during rolling effectively absorbed CO_2 from the environment, thus significantly reducing the environmental pollution.

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