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THE INFLUENCE OF MORPHOLOGICAL PARTICULARITIES OF HEMP PLANTS ON TECHNICAL EQUIPMENT DURING THE HARVESTING PROCESS

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Abstract: Hemp is not a crop prohibited or restricted by law, only that such a plantation must be authorized and monitored by the Ministry of Health, the Ministry of Internal Affairs and the Ministry of Agriculture and Rural Development. Beyond the impediment to authorization and monitoring, hemp cultivation brings more than profitable gains to those who invest in it. It is grown for its relatively high natural fiber content and for its seeds rich in drying oil. Hemp fibers are longer than flax, very durable and quite resistant. They are used to make a wide range of rot–resistant textiles, even in water. Short fibers (tows) are used in the manufacture of mattresses as well as as an insulating material. Lately, the market demand for green hemp inflorescence has increased. The paper will present the partial results obtained in a research project in which a piece of equipment for harvesting green hemp stems was grounded and made in order to process these stems to obtain fibers. However, there are factors in the agro–industrial chain that limit the large–scale marketing of these crops and their products. From an agronomic point of view, some of the problems are associated with technological gaps in harvesting technologies, which prevent the full exploitation of some crops. For example, the production of high–quality textile fibers depends primarily on the quality of the raw material, which in turn is linked, inter alia, to the efficiency of the harvesting system adopted. In most cases, these systems have been developed locally, based on available solutions related to specific local agricultural practice. The purpose of this paper is to present a review of existing mechanical harvesting systems for hemp fiber crops with special reference to hemp. In addition, the paper will provide a description of the innovations that have been adopted in recent years to improve harvesting processes to increase the value of these crops and their products, made by INMA Bucharest.
Keywords: green hemp stalks, industrial plant, technology, processing

1. INTRODUCTION

The traditional (pre–industrial) methods of producing and processing hemp (Cannabis) once used in Europe are compared to those in Asia. The common climate characteristics of Eurasian hemp growing regions, in line with the essential characteristics of all Liberian fibers and the use of hemp in particular, impose functional constraints on the cultivation and processing of hemp. (*Clarke, Robert C, 2010*) .

The dynamic changes in the European and world economies have had inclusive effects on agricultural production systems as well. High prices, currently for traditional commodities (such as cereals, oil and biogas crops), lead to new approaches to traditional crops, namely the introduction of non–energy and non–food plants into crop rotation. Increasingly in industrial applications, technical crops and especially hemp cutting and other Liberian fibers, some technical developments have been made to increase efficiency and reduce operating costs for plant harvesting and biomass handling (*Hans–Jörg Dr. Gusovius, 2009).*

The interest in hemp cultivation today is due to the special qualities of this plant. Hemp oil is rich in protein, vitamins and minerals and the protein is complete, being rich in nutritionally important essential amino acids.

For this reason, there is a real chance that hemp seed powder will be part of the food ration of animals in the future, being able to successfully replace soy (*Carus M. et al. 2013*). Compared to soy, hemp protein is much easier to digest.

The huge potential of hemp for cultivation in order to extract fiber and cannabidiol for medicine, makes this plant return today to the attention of agronomists and medical researchers. On the other hand, it is currently desired to eliminate plastics (dependent on fossil fuels), and hemp could successfully replace these products and even construction materials. In addition, hemp would be a more economically attractive alternative to ethanol production. Of particular interest worldwide is the cultivation of hemp for cannabidiol (CBD) extraction for the pharmaceutical industry. In this regard, breeders have produced hemp varieties to produce compounds that may have pharmaceutical value. One such product is cannabidiol.

Regarding cannabidiol, studies show that it has antiemetic, neuroprotective, antiepileptic, antipsychotic, anti–inflammatory properties, etc. (*Grotenheim and Müller – Vahl, 2016*).

Over the last 15 years, research and practice in natural fiber technology have shown that, in addition to their use as textiles, natural fibers can also be used successfully as reinforcing fibers in composite materials, in building materials, as insulating material and in many other applications (*Mohanty et al. 2005*).

Hemp is part of the Cannabaceae family, along with hops. Within the family, hemp is found in the genus Cannabis which has two species, figure 1:

- Cannabis sativa L;
- Cannabis indica (Law.)

Hemp strains from local populations and wild hemp contain 10–12% fiber, and improved varieties, 26–32% (*Nedelcu A. et al, 2020*).

Several ecological groups (borealis, medioruthenica, australis) are known in fiber hemp; in our country and in general in Europe, the ecological group australis, also called southern hemp, is cultivated. Among the temperate climate textile plants, hemp ensures the highest fiber production (averages between 2210 and 2790 kg / ha for varieties and hybrids cultivated in our country).

Comparatively higher prices and variable quality of natural fiber products for the consumer compared to synthetic materials mainly lie in the costs for cultivation and processing of hemp fibers. Also for farmers, in turn, the income from natural fiber stems hardly covers the costs. This results in the following situations in Romania and beyond:

≡ there are fewer and fewer farmers who are willing to grow natural fibers;
≡ high consumer prices for construction materials and insulation lead to insufficient market demand, even taking into account the environmental aspects;
≡ although the general demand for natural materials is growing, the automotive industry mainly prefers to buy cheaper fibers from abroad;

a)

b) c)

Figure 1. Hemp species
a-part aerial (*cannapyhealth.com*); b-all components of the Sativa plant; c-section through a green Sativa hemp stem (Găgeanu P. et al, 2020)

In order to meet the requirements of the beneficiaries, who grow or process hemp, INMA has developed within the Core Program two technologies for harvesting and processing green hemp stems and two technical equipments, experimental models for harvesting and processing green hemp stems. This equipment aims to simplify and lower costs in the process of obtaining natural hemp fibers.

2. MATERIALS AND METHODS

In order to establish the technologies for harvesting and processing hemp stalks, it is necessary to take into account the general morphological characteristics of this crop. , the compound responsible for the main psychoactive effects of most cannabis for medicinal preparations), An important role in Romania having also the research station from Secuieni, with the varieties: Dacia Secuieni, approved in 2011, with the length of the plant in the culture for strains: 1,8–2,8 m and in seed culture: 3 – 4,5 m and Secuieni Jubilee approved in 2012, with plant length in stem culture: 1,3–1,5 m and in seed culture: 1,3 – 2,2 m.

Tabel 1. The fibers total length (cm) of the monoecious hemp varieties from ARDS Secuieni tested in SIVTR network during 2015-2016 *(Popa L. D et al, 2019).*

Test centre	Cultivar	Total length				Average (2015-2016)	
		2015		2016			
		cm	%	cm	%	cm	%
Şimleu Silvaniei	Zenit (control)	173	100	169	100	171	100
	Succesiv	170	98	163	96	167	98
Average of all monoecious cultivars		172		166		169	
Sibiu	Zenit (control)	182	100	210	100	196	100
	Succesiv	185	102	205	98	195	99
Average of all monoecious cultivars		184		208		196	
Satu Mare	Zenit (control)	267	100	276	100	272	100
	Succesiv	280	105	285	103	283	104
Average of all monoecious cultivars		274		281		278	
Negreşti	Zenit (control)	182	100	204	100	193	100
	Succesiv	185	102	189	93	187	97
Average of all monoecious cultivars		184		197		190	
Luduş	Zenit (control)	190	100	216	100	203	100
	Succesiv	180	95	209	97	195	96
Average of all monoecious cultivars		185		213		199	
Average	Zenit (control)	199	100	215	100	207	100
	Succesiv	200	101	210	98	205	99
Average of all monoecious cultivars		200		213		206	

The hemp stalk from which the fibers are extracted is straight and has branches at the bottom. Its length is between 1 and 3 m, and the thickness varies from 4 to 8 mm. The anatomical tissues of the bark are more complex compared to linseed, thickness and humidity. The mechanical rupture of the stems is known as dehulling and results in the separation of free fibers from the less valuable wood core (ie waste). The fiber content in the stems is influenced by variety, technological and pedoclimatic conditions. Fibers have a number of particularly valuable properties in strength (tensile, torsional, friction, rot), extensibility (elastic and plastic), spinning capacity, longer than sisal, jute, manila or cotton fibers, which make them usable in a number of areas. The value of the total fiber length was influenced by the climatic and soil conditions specific to each test center in the SIVTR network. This is the case of Satu Mare test center, where the Successive variety, presented a total length of the stem superior to that of the control variety, both in 2015 and in 2016, of 5% and 3%, respectively, table 1 *(Popa L. D et al, 2019)*.

Physical properties of hemp fiber: the length of the hemp cells is between 3 and 55 mm (average 22 mm) and the thickness is between 5 and 50 micrometers (average 22 micrometers). The cells are less transparent and more irregular in diameter than the flax cells, and their tip is rounded or branched. The fineness of the elementary fibers is between 3,000 Nm and 5,000 Nm. The length of the technical fibers varies within very large limits. Thus, the length of the technical fibers in the string is more than 50–65 cm. The color of the fibers varies: in general, it is gray–green and tends to white. The specific weight of hemp is 1.43 – 1.48 g / cm^3.

Unlike flax, hemp does not withstand heat because the fibers crack due to pressure and temperature. This is one of the reasons why hemp is not recommended for bedding, which should be washed and ironed often.

Mechanical properties of hemp fiber: the specific strength of hemp fiber is 41–52 N / cm^2. This depends, among other things, on the degree of maturity. Summer hemp (male) is less resistant than autumn hemp. The strength of the fibers is even greater, as they come from an area of the stem closer to the root. The fibers in a bunch of hemp are more strongly bound together than flax, due to the higher content of lignin and pectic substances. The elongation at break is 3–5%. A complete process of primary processing of hemp according to the variant of obtaining the melted or unmelted fibers involves the following technological phases *(Cuzic–Zvonaru C. et al, 2002)*:

≡ 1 – preparing the stems for melting;
≡ 2 – melting the stems;
≡ 3 – drying the molten stems;
≡ 4 – mechanical processing of molten stems by crushing and melting;
≡ 5 – processing and sorting of melita tow by drying, shaking and ennobling;
≡ 6 – sorting the hemp string;
≡ 7 – pressing and packing the rope or tow.

If melting is excluded, the resulting fiber being unitary, from the seven phases are excluded those concerning melting and, respectively, the grouping of technical fibers into strings and tow. Because in the country the smelters used for hemp stalks are almost non–existent, in order to solve the problem we try to apply harvesting technologies and process the stalks in green. Figures 2 and 3 show green harvesting and processing technologies.

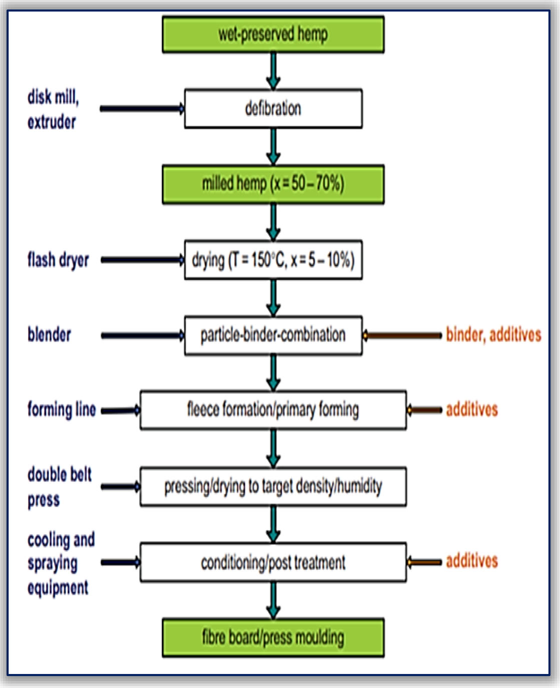

Figure 2. Technologies for the preservation and wet processing of fiber plants (*Idler Ch.,. et al, 2011*)

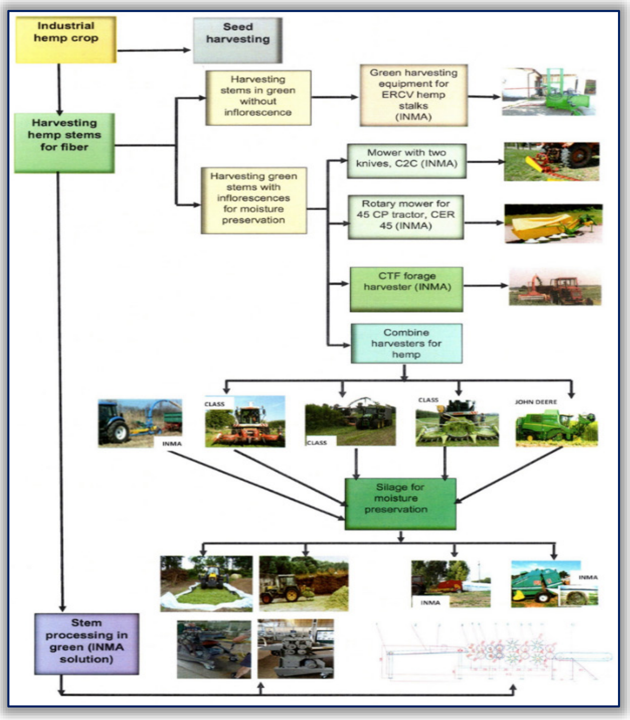

Figure 3. Green hemp stem harvesting and processing technologies

Normally, the production of fibers from agricultural crops is based on field drying. As the weather conditions during the harvest are often problematic for the harvesting and processing of hemp stalks, researchers in the field have developed supply technologies independent of the weather. Meteorological risk can be avoided if, for example, hemp after being harvested with a forage harvester is processed directly into the final products or stored by wet preservation. Investigations have shown that conventional silage technologies are able to ensure the preservation of hemp for more than a year (*Idler Ch.,. Et al, 2011*).
Figure 3 shows a processing technology for hemp stems applicable in Romania as well.

3. RESULTS

In order to meet the requirements of the beneficiaries, who grow or process hemp in Romania, INMA has developed Green Hemp Stem Harvesting Equipment ERCV is intended for sequential harvesting of hemp stalks, in order to process them to obtain the string (figure 4).

Figure 4. Green harvesting equipment for ERCV hemp stalks

When using this equipment, the cut plants remain mixed in the furrow, the inflorescence with the stems. When making the technical harvesting equipment, the technological requirements, the general morphological characteristics of the hemp crop were taken into account, in the case of hemp harvesting for fiber: the average cutting height from the ground should not exceed 7 cm; stem losses to be less than 5%; broken stems of up to 6%. It should be noted that this equipment is intended for small and medium–sized hemp farms. The green harvesting equipment of ERCV hemp stems is based on a patent application (*Păun A. et al, 2019)*.
The experimental model provides the following general characteristics:

≡ type of machine: trailed
≡ energy source: tractor> 65 CP
≡ type of the cutting machine: double–edged
≡ number of cutting knives: 2
≡ cutting height:
  ✓ rear cutting device: 100 mm
  ✓ front cutting device: 1500–2500 mm

Also within the project PN 19 10 01 03–Substantion of the technology for harvesting and primary processing green hemp stalks, two variants of stem processing equipment were made: variant I, figure 5 and variant II, figure 6. Of the two variants, only the experimental model for variant II was performed. The technical equipment for hemp hulling, EDC 450 (450 represents the active length of the rollers) consists of the following main subassemblies (see Figure 5). Positions 1, 2 and 3 are welded sheet metal constructions that ensure the supply of hemp stalks and the guidance to the guide rollers, pos 4, (*Olan M., et al, 2020*).
The guide rollers are special constructions and consist of an upper roller that provides guidance and drive of the stems and a lower roller that provides only guidance.
The flattening rollers, position 5, are 2 drums with shallow rifles that ensure the flattening of the hemp stalks passed through the guide rollers.
The splitting rollers, position 6 (see Figure 5), have the role of splitting the flattened stems into strips, in which it will be easier to break the wooden part. Both rollers have a serrated surface, the pitch of the teeth is 8 mm and their depth is 7 mm. The upper roller is equipped with 4 blades, 6 mm deep equidistant, which ensures in addition to splitting and advancing the material. The lower roller is provided with only teeth for splitting. The teeth on the drums are staggered so that they intertwine, the pitch remaining constant.
Crushing rollers I, are special constructions that make the first crushing of the split strips, and consist of an upper and a lower roller. Displacement rollers I, are special constructions that make the first detachment of wood material that was crushed by the previous pair of rollers) and consist of an upper roller 1 and a lower roller. Crushing rollers II and III consist of an upper and a lower roller. The difference between crushing rollers II and III lies in the depth of the rifles. In the case of crushing rollers II the depth of the rifles is 6 mm and in the case of

crushing rollers III it is 9 mm. The lattice dislocator, pos.12, (see Figure 5), is the last subassembly that has the role of detaching the wood part from the fiber.

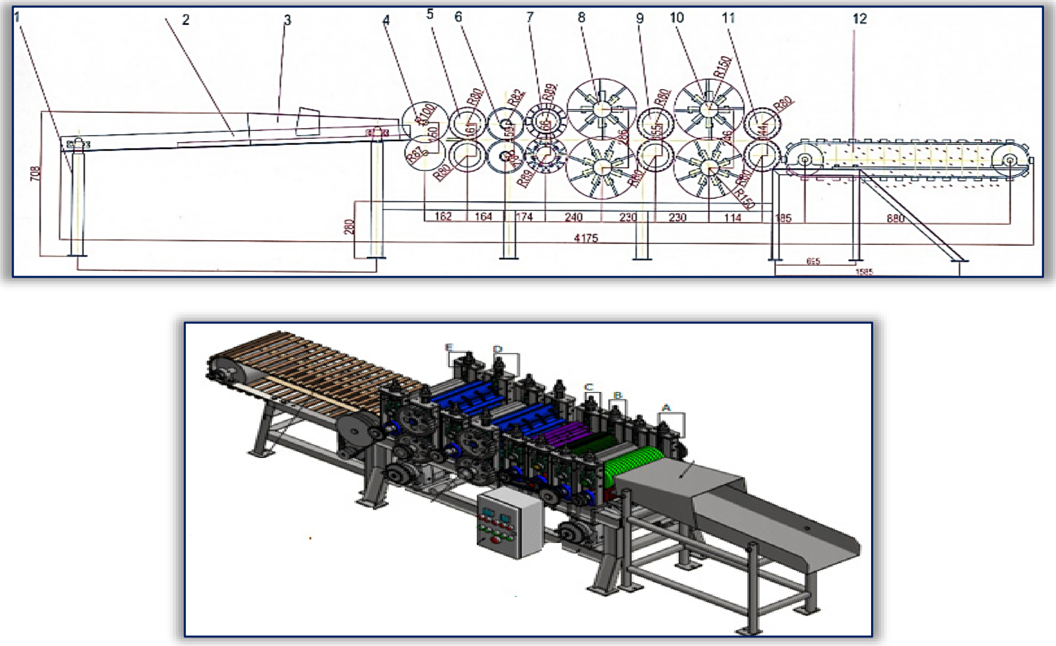

Figure 5. EPC 450 Green Hemp Stem Processing Equipment – Longitudinal Section:
1. Supply table; 2. Guides; 3. Hood; 4. Guide rollers; 5. Flattening rollers;6. Splitting rollers; 7. Crushing rollers I; 8. Displacement rollers I; 9. Crushing rollers II; 10. Displacement rollers II; 11. Crushing rollers III; 12. Lattice dislocator;

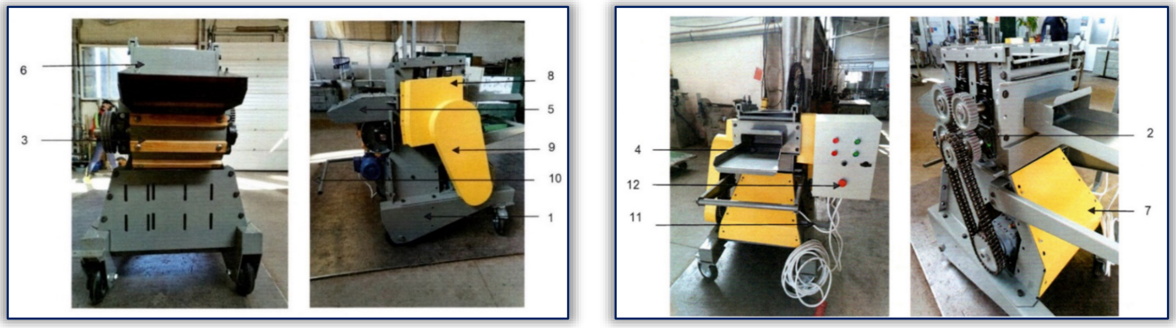

Figure 6. Hemp processing equipment EPC 450

The experimental model of EPC 450 hemp processing equipment (simplified version II) consists of the following subassemblies: 1– Mobile support EPC 450–1.0; 2– Processing module EPC 450–2.0; 3– Fiber cleaning module EPC 450–3.0; 4– Feeding table EPC 450–4.0; 5– Discharge table EPC 450–5.0 ; 6–Top cover EPC 450–6.0; 7–Side guard 1 EPC 450–7.0; 8–Side guard 2 EPC 450–8.0; 9–Side guard 3 EPC 450–9.0; 10– Collector support EPC 450–10.0; 11–Electrical panel support EPC 450–11.0; 12–Electrical panel EPC 450–12.0.

Start the technical equipment on the electrical and control panel. The hemp stalks sit on the feeding table. The stems are taken and processed by the two pairs of rollers. At the exit of the last pair of rollers, the fibers are taken up by the cleaning module and then discharged to the unloading table and from there to the collector bracket.

General technical characteristics:

- Stem processing capacity: 0.3–0.5 m^3 / h
- Drive the processing mode:
  - ✓ coaxial gear moto: MR202–112M2
  - ✓ power: 4 kW
  - ✓ input speed: 3000 rpm
  - ✓ output speed: 833 rpm
- Fiber cleaning mode operation:
  - ✓ electric motor: with sole
  - ✓ power: 1,5 kW
  - ✓ speed: 1500 rpm

4. CONCLUSIONS

Because hemp is a multifunctional crop, the development of specialized finished plant products requires a more realistic approach to metabolic control, both in terms of genetic and molecular mechanisms, in order to promote a reshaping of metabolic pathways. In order to establish the technologies and technical solutions of the equipment for harvesting and processing hemp stalks, it is necessary to take into account the general morphological characteristics of this crop. The constructive solutions adopted for the harvesting equipment were aimed at ensuring the following technological requirements in the case of fiber hemp harvesting:

≡ the average cutting height from the ground must not exceed 100 mm;
≡ strain losses should be less than 5%;
≡ the percentage of broken stems must not be higher than 6%;
≡ realization at a lower cost price than externally.

The hemp processing equipment was subjected only to in–house testing, and both the harvesting and processing equipment were to draw the final conclusions after the in–service experiments.

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