FEATURES OF THE PRIMARY PREPARATION OF HEMP STRAW STALKS SUITABLE FOR OBTAINING CELLULOSE-CONTAINING MATERIALS AND PAPER

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Abstract: *The features of the primary preparation of hemp straw stalks suitable for obtaining cellulose-containing materials and paper are considered in the article. The primary processes of the preparation of hemp raw materials for pulp production, which include harvesting, storage of straw stalks, transportation, and primary processing of raw materials suitable for obtaining cellulose-containing materials, are described. Methods of shortening stems and fibers applied in the pulping process are studied in detail. Technological methods of shortening straw stalks of technical hemp and cleaning raw materials from grains and garbage impurities are mentioned. The necessity of applying the processes of stalks crushing and wet purification of chopped straw stalks of technical hemp is proved.*

Keywords*: technical hemp stalks, shortening of stem length, cleaning, cellulose materials, paper.*

1 INTRODUCTION

The main raw material of the pulp and paper industry for the production of pulp and paper is wood but taking into account the fact that the current state of the forest complex of Ukraine, according to the experts (Doskich V.), belongs, in particular, to the least forested countries, forest supply accounts for only 15.9%, so our country cannot provide the paper industry with its resources. Therefore, hemp can be one of the most practical renewable natural resources, which significantly reduces the cost of production of cellulose-containing products. Cultivation of industrial crops of technical hemp has high profitability of cultivation and processing. Hemp yields from a land unsuitable for agriculture are about 6 tons of pulp per hectare per year, which is several times more than the annual forest yield per hectare. A distinct advantage of hemp cultivation is an opportunity to obtain a large amount of hemp raw materials in a much shorter (4 months) period compared with the period of obtaining wood (50 years).

In European countries, paper manufacturers have already abandoned producing pulp from wood, and they mainly use annual fibrous materials: stems and fibers of cotton and bast plants: flax and hemp. The cellulose content in these plants varies widely from 70 to 96%, while the cellulose content in coniferous wood is only 45-58%.

Stems of technical hemp are used as the main raw material for cellulose production in European countries. A significant advantage of annual fibrous plants as raw materials for manufacturing cellulose semi-finished products, compared to wood, is their annual regeneration, though ten years is required for growing wood suitable for manufacturing cellulose semi-finished products.

However, the use of annual plants in the production of cellulose semi-finished products involves several time-consuming operations: harvesting, storage of straw stalks, transportation, and primary processing of raw materials suitable for the production of cellulose-containing materials. Therefore, this research is devoted mainly to eliminating shortcomings in the preparation of straw stalks of technical hemp for obtaining cellulose-containing materials.

2 MATERIALS AND METHODS

As an object of research work examines the stems of technical hemp straw, suitable for the production of cellulose-containing materials and paper. Technical help can be one of the most realistic renewable natural resources, that significantly reduces the cost of cellulose-containing products production.

The research was conducted using methods based on comparative and systematic analysis, generalization methods. Methods of stems and fibers shortening for the application of the boiling process are described in detail. Technological methods of shortening straw stalks of technical hemp and cleaning of raw materials from grains and garbage are given.

3 RESULTS AND DISCUSSION

The composition of pulp and paper production includes the production of fibrous semi-finished products, pulp and wood pulp, and their processing into various types of paper and cardboard.

Straw stalks of technical hemp are loose raw materials. 1 m^3 of this raw material without pressing weighs 30-40 kg, and 125-150 kg in pressed form. The most valuable in hemp plants are thin cells of bast fibers, the length of which reaches 1.5 mm. Compared to the chemical composition of coniferous wood, these plants have a lower content of lignin, 25 instead of 28, and a higher content of pectin 30 instead of 11. Comparative characteristics of pulps obtained from hemp and wood raw materials are given in the Table. 1.

Table 1 Comparative characteristics of pulp obtained from hemp and wood raw materials

Indicators	Stem of hemp straw	Larch
Alpha cellulose [%]	92.02	Maximum up to 94
Pentosans [%]	4.55	3.2
Ash [%]	0.48	0.2
Resin [%]	0.73	0.2
Lignin [%]	0.00	0.0
Copper number	0.92	1.4-1.8
Degree of brightness [%]	89.0	90-92
Viscosity [mP]	180-200	270-320

The fibers of cotton and bast crops such as flax and hemp are of particular interest to the pulp and paper industry. These fibers are much longer and stronger than wood pulp fibers. The length of cotton fibers reaches about 40 mm, linen 30 mm and hemp 25 mm. This is especially important in the production of high-quality paper of banknote range, in which the ratio of the length of the fibers to their cross-section in flax fibers is 1200 units, but in coniferous wood, this ratio is only 100 units. The strength and elasticity of bast fibers and cotton are distinct in the high content of the pulp. It is equal to 80% in bast flax fibers, 77% in hemp, and 90-96% in cotton. Table 2 shows the characteristics of technical and elementary fibers of the basic bast crops.

Analyzing this table, it can be inferred that most characteristics of the elementary fibers of flax, hemp and cotton are close to each other and can be considered as an additional source of raw materials for different areas. The properties of technical fibers are determined by the properties of elementary fibers, as well as the chemical composition of encrustants and adhesive agents [1-3].

Under production conditions, the processes of obtaining cellulosic materials from bast crops, depending on the reagents used are divided into three groups: acid, alkaline, and combined.

The first group includes the sulfite method, which is the most common. Sulfate and partially sodium methods have an industrial significance in the second group of alkaline methods.

According to the combined method, pulp and semi-chemical pulp are obtained by processing vegetable raw materials with acidic and then alkaline reagents. This process includes the chlorine-alkaline method. It has a consistent effect of alkaline solutions and chlorine in an acidic environment on the stalks of annual plants.

According to the acid method, the plant material is affected by chemical reagents, which include acidic and neutral salts of sulfuric acid (sulfites), and in some cases, sulfuric acid itself. Thus, if sulfuric acid and its acid salts (bisulfites) are present in the cooking liquor, sulfite pulp or semi-chemical pulp is obtained as a result of processing. When a solution of sodium bisulfite salt of sulfuric acid is applied to plant raw materials without free sulfuric acid, bisulfite semi-chemical pulp is obtained. In the neutral-sulfite preparation process of pulp or semi-chemical pulp, cooking liquor containing a mixture of two chemical compounds such as sodium sulfite and sodium carbonate is used.

When processing vegetable raw materials by alkaline methods, the composition of the cooking liquor includes various chemical components such as sodium hydroxide using the sodium method, and a mixture of sodium hydroxide and sodium sulfide using the sulfate method.

Table 2 Characteristics of technical and elementary fibers of annual crops

Name of characteristics	Fibre		
	hemp	flax	cotton
Length of technical fiber [mm]	700-1500	500-750	-
Linear density of technical fiber [tex]	8-40	5-8	-
The average length of elementary fiber [mm]	15-25	15-26	22-45
Maximum length of elementary fiber [mm]	65	130	45
The size of the cross-section of elementary fibers [mm]	14-50	12-20	1-2
Average linear density of elementary fibers [mtex]	220-440	200-350	130-220
Specific density [g/cm^3]	1.48-1.50	1.43-1.50	1.47-1.50
Tonin index [mm^2]	0.13-0.29	0.11-0.22	0.09-0.15
Average coefficient of prosenchyma *	600-1000	1000-1500	-
The average extensibility at breaku [%]	2.2-3.0	2.2-2.8	6.9-7.2

*The coefficient of prosenchyma is a number that characterizes the ratio of the length of elementary fiber to its cross-section

For the production of pulp or semi-chemical pulp by the combined method, cooking liquors containing such reagents as sodium bisulfite, sodium hydroxide, soda ash, and others are used.

Sulfite and sulfate processes are of priority importance for the production of paper, cardboard paper, and products derived from vegetable cellulose. Bisulfite and neutral-sulfite methods are also used.

Regardless of the method of the production of pulp or semi-chemical pulp, all efforts should be directed to the production of these semi-finished products with specified chemical and mechanical properties and with a high yield.

When crushed wood is cooked or treated with a solution of chemical reagents (cooking liquor) at high temperature and pressure, it is delignified. So, most of the lignin dissolves, the wood cells are separated, and fibrous technical cellulose is obtained. To achieve a high yield of cellulose-containing materials from the straw stalks of technical hemp it is necessary to conduct a thorough initial preparation of raw materials to obtain a homogeneous mass before the process of delignification.

The technological cycle of the production of cellulose semi-finished products from annual plants is described in known literature sources [4-10]. Preparation of straw of annual plants consists of two operations: shredding and cleaning. Straw choppers used in industry, similar in design to agricultural, differ mainly in capacity. On a special table, piles of raw materials are untied, and the dressing material (metal or film) is removed. The straw is fed by a conveyor into a straw chopper equipped with rotating knives. The length of the chopped straw depends on the number of cuts, which in turn is determined by the rotating speed and the number of knives. As the number of cuts increases, the chopped straw becomes shorter and more uniform. The theory of obtaining chopped straw is similar to the theory of cutting wood and is expressed by the same mathematical dependencies. Accordingly, the length of the chopped straw should be as long as possible. However, to increase the degree of purification of straw and the uniformity of its cooking, attempts are made to bring the length of the chopped straw to a few centimeters [8].

Fibers from straw stalks of annual plants, as well as wood, have a definite orientation. But since the straw stalks are fed to the straw chopper blades in a disoriented state, the increasing length of the cut increases the unevenness of the chopped straw. Chopped straw is even ideally less uniform than wood chips. Longer chopped straw easily becomes compressed and downy with difficulty, which complicates its cleaning (dedusting, removal of metal impurities, removal of grain and shive).

Wood chips during cooking become uniformly saturated with chemicals. When cooking straw stalks, fast and uniform saturation of chemicals into the chopped straw occurs only if the stalk is cut between two joints (Figure 1). In this case, the wall of the plant cell both outside and inside comes into contact with cooking chemicals. If the stalk is not cut between two joints, then part of the stalk remains closed, and the chemicals come into contact with plant tissue only externally, as a result, the saturation is slower. Cooking chemicals penetrate through the inner walls of the plant faster than the outer ones. There are no joints in the straw stalks of technical hemp, so the cooking liquor penetrates into the hemp chaffs more uniformly than in the stems of wheat and bamboo.

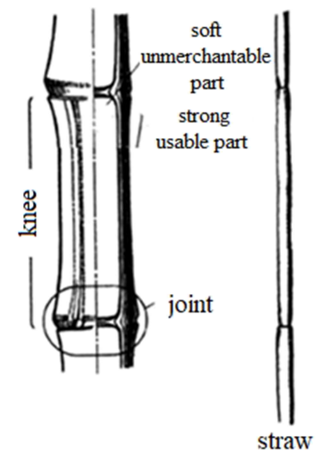

Figure 1 The structure of the straw stalk of annual plants

The uniformity of chopped straw is important for filling the continuous digests. Shorter chopped straw provides more uniform and dense filling and the formation of a pressure-tight that increases the tightness of the pressure fryer. In this regard, apparatuses for additional shredding of the chopped straw were designed.

Figure 2 shows a straw chopper that provides maximum length of the chopped straw of 30-50 mm. The minimum length of the chopped straw is 12-18 mm. For pneumatic feeding of the chopped straw to the first stage of cleaning and sorting, the straw chopper is equipped with an air blower. The pneumatic system sizes should ensure the concentration of the chopped straw in the system is not more than 200-250 g/m^3 of air, because at higher densities the chopped straw easily becomes compressed, which leads to clogging of the system.

At the first stage of cleaning, there is a preliminary dedusting of the chopped straw. For this process, the apparatus for cleaning and sorting the chopped straw is equipped with a cyclone, inside of which two brushes for cleaning the chopped straw from dust rotate.

The chopped straw under the action of gravity enters the drum with beats, which are equipped with needles, where the grains are separated from the straw. At the same time dust is formed on the surface of the chopped straw. Then with the help of an electromagnet metal impurities are removed. For this process, the chopped straw is distributed in a vibrating singeing plate with a magnet. This method enables extracting most of the metal impurities, which are the remnants of the metal wire used for tying bales, from the chopped straw. Usually, a second electromagnet is turned on for more thorough cleaning of the chopped straw. Then the dedusting and removal of crushed straw in a drum sorter, similar in design to a single-hull drum sorter for chips take place.

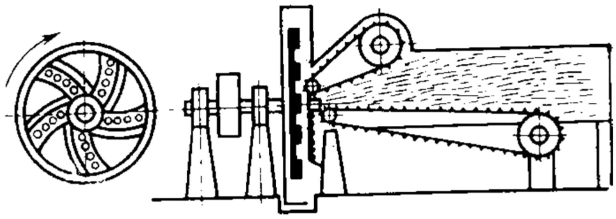

Figure 2 The existing technological scheme of the shortening of straw stalks of technical hemp

Grains and joints are removed with the help of an air separator at the next stage of cleaning. The chopped straw is blown into vacuum channels, where grains and chopped straw that have higher specific gravity than the chaff fall down and fall on vibrating screens. This process can be considered as the third stage of dedusting. Another air separator is installed for a more thorough separation of grains and chopped straw from the chopper. The grains can also be further sorted, which improves the use of sorting waste. The scheme of the sorting system is shown in Figure 3.

From the straw chopper, the chopped straw is fed pneumatically or by a belt conveyor for further processing. The energy consumption for pneumatic transportation of the chopped straw is greater than the transportation of chips. This is because, firstly, the density of the transported material, as indicated above, should be in the first case as low as possible, and secondly, the shop for preparing the chopped straw due to high fire risk should usually be at a sufficient distance from other industrial buildings. Usually, the shop is located directly next to the straw warehouses. In addition, the transportation of straw bales is much more expensive than the transportation of chopped straw.

Some attempts have been made to facilitate the cutting, cleaning, and sorting of straw. In 1959, at the symposium of the European Liaison Committee for Pulp and Paper (EUSERA) on straw processing, Achison [9] proposed the technology of shredding straw in a hydrobeater. Wet cleaning of straw by this method is the same principle as wet cleaning of waste paper.

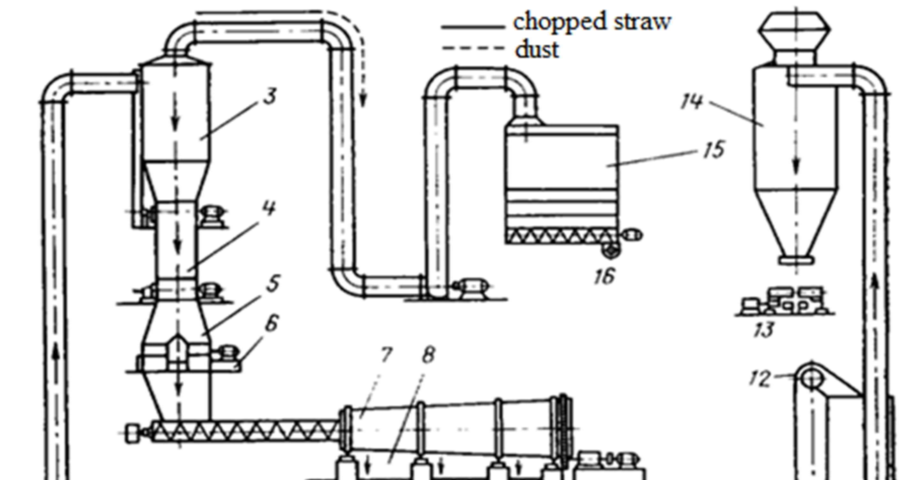

Figure 3 Preparation and cleaning of chopped straw from straw stalks of technical hemp: 1 - untying of piles; 2 - straw chopper; 3 - preliminary dedusting; 4 - duster; 5 - shake apparatus; 6 - magnetic drum separator; 7 - vibration sorting; 8 - straw waste; 9 - conveyor; 10 - elevator; 11 - removal of grains; 12 - separation of grains; 13 - conveyor for chopped straw; 14 - cyclone; 15 - dust collection; 16 - dust removal

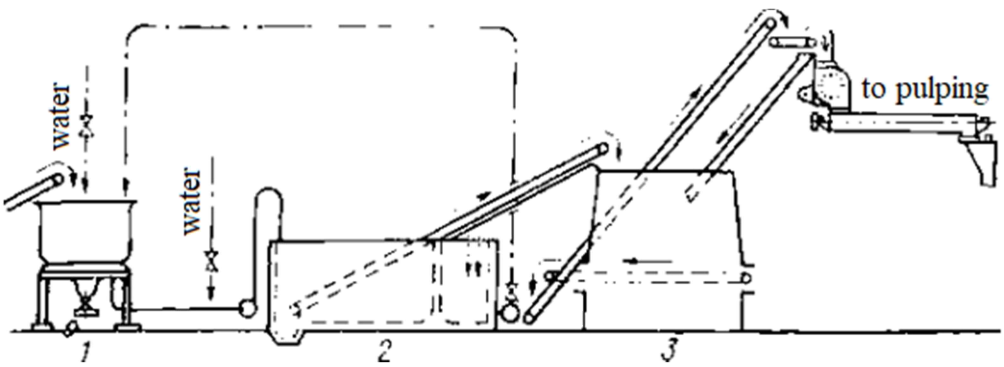

Figure 4 Wet method of cleaning the chopped straw: 1 - hydrobeater; 2 - tank; 3 - hopper

The proposed technology has particular advantages in the processing not only straw but, for example, corn stalks, as it enables removing parenchymal fibers. In the 1930s, attempts were made to separate parenchymal cells of a hydrophobic nature from the chopped straw by mixing them with water; in this case, when a proper concentration is reached, the hydrophobic particles are gathered on the water surface, from where they are easily removed. Since the design of the hydrobeater and the vortex motion of its content, starting during operation, provided a good effect of separation of hydrophobic substances only, this method was not further developed. The scheme of the described system is shown in Figure 4. Wet cleaning makes it easier to remove dust. That is why in the dry method of cleaning after filtering the air and separating the dust generated in the system, it should be precipitated with water (or circulating water). For this purpose, special fans are used, through the axis of which water is sprayed [11].

Removal of straw dust from preparatory shops is necessary for sanitary and hygienic purposes as it can cause, among other diseases, silicosis. Cleanliness for the enterprise can be maintained only at the high efficiency of dedusting. The importance of this problem is easy to determine, given that the dust content in the straw of cereals is 1-1.2%, in rice straw - 5%, morover 30-40% of it is comprised of inorganic substances, of which 80% is SiO_2.

4 CONCLUSION

Based on theoretical studies of the primary preparation of plant stalks for obtaining cellulose-containing materials, it can be concluded that the straw stalks of technical hemp at the first stage of preparation for pulping require shortening to a certain length, thorough cleaning from dust, metal and seeds. The most suitable way to clean the crushed stalks of technical hemp, in our opinion, is a wet method of cleaning chopped straw.

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