THE IMPROVED TECHNOLOGY OF BIOMASS PROCESSING TO OBTAIN PRODUCTS OF VARIOUS APPLICATIONS

S. Yaheliuk[1], **V. Didukh**[1], **G. Boyko**[2]

[1]Lutsk National Technical University, Lutsk, Ukraine
[2]Kherson National Technical University, Kherson, Ukraine

AGRICULTURAL MACHINES
АСМ
СІЛЬСЬКОГОСПОДАРСЬКІ МАШИНИ

Key words:
biomass,
textile flax,
linseed flax,
biomass processing technology,
fuel briquettes and rolls

Article history:
Received 12.08.2020
Accepted 15.10.2020

Corresponding author:
cler2010@gmail.com

ABSTRACT

The article is devoted to processing technologies for biomass, formed during flax harvesting. These technologies take into account the fiber potential of stems to obtain products of various applications. The best area in Ukraine to use the classical technologies of flax harvesting and processing is Western Polissya. However, due to the crisis that lasts for two decades the Ukrainian Flax Industry requires radical changes of the existing approaches. Nowadays the classical technologies are inefficient, energy-consuming and in many cases result in a poor-quality fiber. The proposed ways to overcome the crisis are the gradual introduction of linseed flax into the Western Polissya crop rotation and the revival of Textile Flax production. Based of modern research analyzing the world's and the Ukrainian flax market status, it can be confirmed that the revival of flax production depends on the integrated use of all components of linseed flax and textile flax. The experiments have proved that the varieties of linseed flax growing in the Western Polissya have a length that allows the stems to be processed into a fiber. However, the biomass windrows are remained in the field during a machine harvesting. They have a considerable size and do not turn into a retted straw for a long time. Therefore, it is difficult to obtain fiber in the traditional way. The manufacturers recycle flax stems by burning. A similar situation is observed in the case of the harvesting and processing of the other crops (sunflower, corn, hemp and etc.) Raw biomass is utilized by burning. Burning plant biomass in the field pollutes and destroys the soil. Air pollution with combustion products also occurs. This is a modern ecological problem of agricultural production in the Ukraine and in the world.

https://doi.org/10.36910/acm.vi45.382

УДК 677.11:677.021.15

УДОСКОНАЛЕНА ТЕХНОЛОГІЯ ПЕРЕРОБКИ БІОМАСИ ДЛЯ ОТРИМАННЯ ПРОДУКЦІЇ РІЗНОГО ПРИЗНАЧЕННЯ

С.В. Ягелюк[1], В.Ф. Дідух[1], Г.А. Бойко[2]

[1]Луцький національний технічний університет, Луцьк, Україна
[2]Херсонський національний технічний університет, Херсон, Україна

AGRICULTURAL MACHINES
АСМ
СІЛЬСЬКОГОСПОДАРСЬКІ МАШИНИ

Ключові слова:
біомаса,
льон-довгунець,
льон олійний,
технологія переробки біомаси,
паливні брикети та рулони

Історія публікації:
Отримано 12.08.2020
Затверджено15.10.2020

Автор для листування:
cler2010@gmail.com

АНОТАЦІЯ

Стаття присвячена технологіям переробки біомаси, яка утворюється під час збирання льону. Ці технології ураховують волокнистий потенціал стебла для отримання продукції різного призначення. Найкращий в Україні регіон для застосування класичних технологій збирання та переробки льону – Західне Полісся. Однак, через кризу, яка триває два десятиліття, українське льонарство вимагає кардинальних змін існуючих підходів. На сьогодні класичні технології неефективні, енергоємні і в багатьох випадках призводять до отримання неякісного волокна. Запропонованими шляхами подолання кризи є поступове впровадження льону олійного в сівозміну Західного Полісся та пожвавлення виробництва льону-довгунця. На основі сучасних досліджень, що аналізують стан світового та українського ринку льону, можна стверджувати, що пожвавлення виробництва льону залежить від комплексного використання всіх компонентів льону олійного та льону-довгунця. Експерименти довели, що сорти льону олійного, що вирощуються у Західному Поліссі, мають довжину, яка дозволяє переробляти стебла на волокно. Однак, під час збирання урожаю біомаса залишається на полі; виробники її спалюють. Подібна ситуація спостерігається під час збирання і переробки інших сільськогосподарських культур (соняшника, кукурудзи, конопель тощо). Спалювання біомаси рослин у полі забруднює навколишнє середовище. Це сучасна екологічна проблема сільськогосподарського виробництва в Україні та світі.

https://doi.org/10.36910/acm.vi45.382

Introduction and Problem Statement

Theoretical and experimental research of flax raw materials properties was held by many authors in different years and conditions [1–4]. Properties of flax stems and deformations in them caused by machine are examined in the "Plant material mechanics" research by G. Hajlis [4]. The processing of stems must begin immediately after cleaning the seed part in accordance with the fiber maturity state and the environmental conditions [5]. Some researchers proposed methods and systems of quality control of bast raw material [6].

Commercial applications include fiber, paper manufacturing, horse bedding and pelletizing leftover flax or other plants materials for bioenergy – but none of these options offer maximum value to the farmer. Farmers are burning plant straw [7]. The solution of problems of safe use and utilization of a flax stem part is connected with development of technologies of processing of flax straw for reception of production having industrial functional value.

"Fiber extraction from oleaginous flax for technical textile applications: influence of pre-processing parameters on fiber extraction yield, size distribution and mechanical properties" by Pierre Ouagne shows that the individual fiber length of oleaginous flax (between 3 and 6 cm) is comparable to that of the scutched textile flax fibers. This makes them suitable for the production of carded aligned fiber yarns for technical textiles. These results demonstrate the interest and the potential added value of harvesting the stems for technical fiber applications [8]. The properties of flax fiber and textiles have also been studied [9, 10].

If the quality of the stem part of the flax does not allow us to obtain a qualitative fiber, then one of the ways out is the manufacture of pressed fuel briquettes by means of frozen sapropel. The scientists of Lutsk National Technical University conducted the research on the production of fuel materials in the form of briquettes by using frozen lacustrine sapropel as a binder. As a result of study, the energy potential of the samples and the time of their combustion were obtained [11]. However, the production of the fuel briquettes is a labor-consuming process. It is possible only in stationary conditions.

Another option is the manufacture of fuel materials in the form of packages or rolls [12]. The production of rolls for combustion directly in the field will allow the use flax stems that are not suitable in the textile industry. The development of flax production is possible due to the justification of environmentally safe technologies to process flax plant stand based on its classification properties and the combination of operations of harvesting and processing the flax stems.

The results of the research allowed us to offer technologies that efficiently combine the processes of harvesting and the stem part of the flax crop processing. These technologies satisfy the modern requirements of environmental regulatory documents.

The Goal of the Study is to improve the quality and environmental safety of flax and other plant stems processing thanks to the development of technologies with a maximum using of the raw material potential.

Materials and Methods

The research was carried out in laboratory conditions and in production; standard and specially designed devices were used. The research is used straw of flax varieties: Lirina, Soniechny, Gladiator, Glinum from Western Ukraine. The average height of plants was ranged from 55 cm to 98 cm. The test methods are in accordance to the standards [13, 14], etc.

Results and Discussion

In the study [15] a classification of flax stems (straw) is suggested. It allows us to choose an efficient technology to process the stems or biomass at the stage of flax harvesting. A concept model of technologies for processing flax stem is substantiated based on the developed classification [15, 16]. According to the concept model [15], the choice of a processing technology variant depends upon the length of the stem, the ripeness phase, the bast content and the type of the flax. When the length of textile flax is 0.75–0.95 m and higher in the phase of early yellow ripeness, it is harvested by pulling apparatus. If the length and phase of the flax stem ripeness are sufficient to obtain fiber of a proper quality, it is offered to use the technology of the stem primary processing directly within the field conditions with a subsequent processing at a flax mill (Fig. 1).

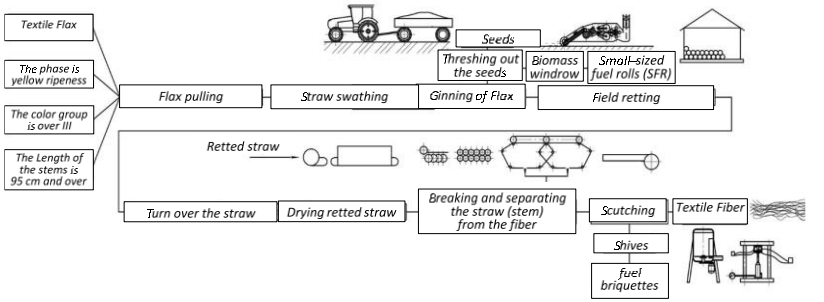

Fig. 1 – Technology of the flax stem primary processing, when length and phase of the flax stem ripeness are sufficient to obtain fiber of a proper quality

If the length of the flax stem (regardless of the type) is less than acceptable for processing into fiber, the proposed technology allows the biomass to be turned into the small-sized fuel rolls (SFR) (Fig. 2).

Fig. 2 – Technology of the flax stem primary processing, when length and bast content of the flax stems are not sufficient to obtain fiber of a proper quality

The research suggests the technological operations sequence for stems with a height of less than 50 cm regardless of the type of flax at the full ripeness phase or with bast content less than 15%, that includes stems cutting with a seed release, destruction of the biomass to reduce the elastic forces and twisting it in the SFRs of a given diameter. Therefore, the improved combine harvester is able to perform all technologic operations, besides SFRs transportation.

When the length of stems is 0.5–0.75 m in the phase of early yellow ripeness, flax is harvested for the production of short undirected fiber or fuel briquettes. We offer the technology to produce a fibrous material from linseed flax that is suitable for use in the textile industry. The technology is based on changing the sequence of operations for the flax harvesting taking into account the phase of its ripeness (Fig. 3).

The proposed biomass processing technology is based on theoretical studies [16]. For successful application of the used biomass processing technology special device should be used. That are must be devices for the biomass destruction or grinding and making of SFRs with a further possibility to install these devices onto a combine harvester are determined. In order to make SFRs out of flax biomass a five-roller compaction chamber of variable volume is offered. The advantage of the press chamber is that at the initial twisting stage there is a minimum of free space between the rollers. It allows us to begin the roll making process right at the rollers first turning.

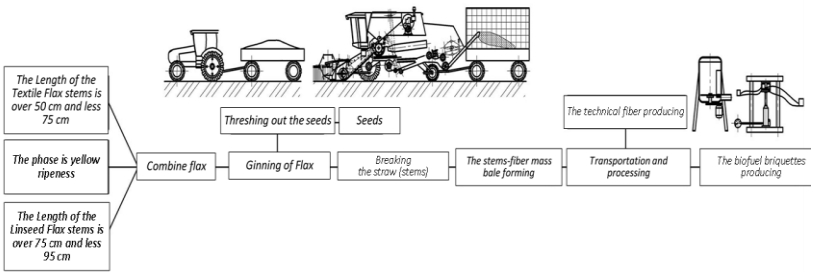

Fig. 3 – The technology processing of stems to obtain seeds, technical fiber and fuel briquettes

This provides an increase in the efficiency of harvesting technology, while taking into account the characteristics of flax or other plant stems.

Experimental studies as to the technologic properties and the quality indicators of stems, biomass, fibers and solid fuel materials made of biomass were carried out. Thus, they permitted to establish efficient operation modes of the proposed means for harvesting and processing the flax stem parts. The possibility to obtain short non-oriented fibers and solid fuel materials from both linseed flax and textile flax has been experimentally confirmed.

Conclusions

Based on a carried out set of studies the prepositions to create innovation technologies and equipment was developed. As a result, these technologies and equipment efficiently combine the processes of the flax crop stems harvesting and processing, as well as enable to offer a produce of diverse functional application.

The propositions should be made to agricultural producers on harvesting technologies that enable at the same time to process the flax stems as well as the flax biomass. These proposals are based on the flax stems classification features.

Also, it was proposed to obtain a similar fiber material from linseed flax by changing the sequence of operations for linseed flax harvesting, taking into account the phase of its ripeness.

References

1. Burning agricultural waste: a source of dioxins. (2014). Commission for Environmental Cooperation. Montreal, Canada, 6.
2. Kumar, P. et al. (2014). Socioeconomic and environmental implications of agricultural residue burning. Springer Briefs in Environmental Science. Springer, London, 157. https://doi.org/10.1007/978-81-322-2014-5_7

3. Gaba, A., Iordache, S.F. (2011). Reduction of air pollution by combustion processes. https://doi.org/10.5772/16959
4. Hajlis, G. (2004). Plant material mechanics. Lutsk State Technical University, Lutsk, 301.
5. Chursina, L., Tikhosova, H., Holovenko, T., Shovkomud, O., Kniaziev, O., Yanyuk, T. (2019). Innovative technologies of oilseed flax straw mechanical processing and quality of obtained fibers. INMATEH – Agricultural Engineering, 57(1), 207–214.
6. Holovenko, T., Yanyuk, T., Boyko, G., Dyagilev, A., Shovkomud, A. (2019). Promising methods and systems of quality control of innovative bast raw material. Science and Innovation: Academic and Research Journal NAS Ukraine, 15(3), 91–104.
7. New retting studies to help farmers spin straw into fibre gold. (2019). https://www.gov.mb.ca/agriculture/innovation-and-research/new-retting-studies-to-help-farmers.html
8. Ouagne, P., Barthod-Malat, B., Evon, P., Labonne, L., Placet, V. (2017). Fibre extraction from oleaginous flax for technical textile applications: influence of pre-processing parameters on fibre extraction yield, size distribution and mechanical properties. Procedia Engineering, 200, 213–220.
9. Yaheliuk, S. (2016). The generation of linen materials properties: monograph [Формування властивостей льняних матеріалів: монографія]. Lutsk NTU, Lutsk, 128 (in Ukrainian).
10. Baidakova, L., Yaheliuk, S., Baidakova, I. (2014). Goods expert examination: textbook [Експертиза товарів: підручник]. Publishing House "Word", Kyiv, 380 (in Ukrainian).
11. Didukh, V., Yaheliuk, S., Kirchuk, R., Busnyuk, R. (2018). Modeling of utilization means of oilseed flax stem part. Teka. Commission of Motorization and Energetic in Agriculture, 18(4), 63–70.
12. Yaheliuk, S., Didukh, V., Tom'yk, V. (2019). Justification of the new technology of processing residues of flax stem mass in Western Polissya. Teka. A Quarterly Journal of Agri Food Industry, 19(1), 5–12.
13. ISO 20706-1:2019. Textiles – Qualitative and quantitative analysis of some bast fibres (flax, hemp, ramie) and their blends – Part 1: Fibre identification using microscopy methods, 2019. https://www.iso.org/obp/ui/#iso:std:iso:20706:-1:ed-1:v2:en
14. Directive 2010/75/EU. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010L0075
15. Yaheliuk, S., Didukh, V. (2020). A concept model of technologies for processing flax stems [Концептуальна модель технології переробки стебел]. Agricultural Machines, 44, 155–164 (in Ukrainian).
16. Yaheliuk, S. (2019). The development of scientific fundamentals of technologies for flax straw stems processing based on flax plant stand classification properties [Doctoral dissertation]. Lutsk National Technical University, Lutsk, 362.