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APPLICATION OF BIOLOGICALLY ACTIVE SUBSTANCES TO STORAGE OF OIL FLAX STRAW

Introduction. *In Ukraine, considerable volumes of raw flax material do not undergo preprocessing, which results in worsening of its quality, with the lapse of time. It is related to non-observance of agro-engineering requirements for collection, adverse weather conditions and other factors.*

Problem Statement. *The capacity of flax processing enterprises does not enable recycling the entire amount of raw material for a short period of time, therefore long-time storage is required. Environmentally safe, inexpensive preservation agents having inhibitory, bactericidal, and fungicidal properties can secure a high quality of oil flax straw.*

Purpose. *The purpose of research is to study the influence of biologically active substances on the quality of oil flax straw and to determinate proper storage conditions.*

Materials and Methods. *For research, the oil flax varieties Vira, Pivdenna Nich, and Debut are selected. The tasks of research have been solved by means of theoretical and experimental methods used for preprocessing of raw material and in textile material science. The mathematical modelling of processes has been made in MathCad.*

Results. *Influence of biologically active substances on storage of oil flax straw has been studied. The action mechanism of the studied preservation agents and dynamic changes in qualitative parameters of raw materials during long-time storage of straw have been determined. The statistical models of influence of oil flax straw storage conditions on the qualitative parameters of fiber have been obtained, optimal concentrations of preservation agents, conditions and terms of their effect have been established.*

Conclusions. *Application of new environmentally safe bioactive substances for storing oil flax straw with a wide range of humidity has been substantiated.*

Keywords: oil flax straw, storage methods, preservation agent, and statistical model.

The advanced technology of harvesting oil flax involves its pressing and packaging in various forms, depending on the further transportation, storage, and processing of the material. According to the Institute of Bast Crops of the National Academy of Agrarian Sciences of Ukraine and other domestic and foreign agro-industrial research institutions, the best form of packaging the fibrous raw materials is the roll. This is due to the fact that it is convenient to transport the raw material as rolled by the combine from field to processing plant, and to ensure a due quality of the material [1—3].

The pressing of flax straw into rolls positively affects the fiber output and quality, insofar as the stems of raw material not as much intertwine during transportation and downloading/uploading operations, and, accordingly, less of raw material is wasted during processing. The application of roll technology provides continuous flow of technological process, significantly reduces the harvesting period, reduces the use of manual labor, and minimizes the loss of fiber products [1, 2].

The existing methods for storing the raw material in rolls were developed as far back as in the 1960—1980s, for long-stalked (fiber) flax, but they are not suitable for storing oil flax straw because of different anatomical structure of its stems and further applications [5]. Today, the problem of using oil flax straw is actively studied in many countries [6—8].

Today, in Ukraine, about 20—50% of the raw flax harvest does not undergo any primary processing. This is caused by non-observance of agronomic terms of harvesting, unfavorable weather conditions, and the lack of advanced technical means of harvesting. As a result, oil flax stems stay in the field under high humidity conditions for a long period. Wet flax straw and retted straw are a favorable environment for the growth of many cellulose-destroying microorganisms. Consequently, the flax quality degrades, which results in losses [9].

Rolled raw flax arrive in linen factories in autumn. Because of the inability to process the entire amount of raw material in a short period of time and interruptions in the operation of many enterprises, for various reasons, there is a need to store the material in the raw yard for a period from a few months to a year. During this time, the raw material should keep its merchantable quality, and, consequently, the problem of prolonged storage of oil flax straw is relevant.

The studies of foreign and domestic researchers have shown that the main factors that affect the preservation of rolled straw are the initial moisture content in raw material and the storage conditions (temperature and humidity of the environment) [2, 10—14]. According to the regulative and technical documentation, the standard moisture content of the flax straw to be pressed is 19%, while the maximum permissible humidity should not exceed 23%. The temperature inside the rolls made of raw materials with a moisture content of 16—19% is close to the ambient temperature throughout the whole storage period, while in the rolls of wet raw flax (a moisture content of 26—30%) it rises to 20—25 °C within the first three days, and in the rolls with a moisture content of 30—40% the temperature reaches 40—60 °C. After three days of storage, the temperature inside the rolls noticeably decreases, and in 2 weeks it becomes equal to the ambient temperature. At a temperature of 5 °C, the biological processes completely stop and the straw is kept in the state of natural preservation.

The analysis of recent studies has shown that prolonged storage of raw material without damage to it is possible if the moisture content of the material does not exceed the standard one (19—23%); the initial moisture content in flax straw reach 65%, in the early yellow maturity phase, and 55%, in the yellow phase. The harvested straw is usually dried naturally, on the field. If the drying requirements are not met and the process is not controlled, the quality of material worsens [5].

Since the oil flax straw is not the main product of processing of this crop, the straw rolls are stored in the open air, or covered with a protective coating, with the material exposed to external weather conditions.

Chemical or biological preservation can provide much less dependence of storage technology on changing weather conditions. The preservatives inhibit the development of microflora that decomposes cellulose.

It is a known fact that various organisms, including bacteria, molds, and yeasts, depending on the conditions, are engaged in the destruction of wet raw flax material. Very often, cellulose-destroying fungi *Septoria linicola, Dothiorela gregaria, Gonatobotrys flava, Fusarium gibbosum,* and *Fusarium graminearum* develop during the storage of wet flax straw. Most known preservatives are not universal, since they affect only certain types of microorganisms. As temperature inside the straw rolls increases during storage the effectiveness of preservatives decreases [1]. Many chemical preservatives that have been used previously are toxic, therefore they have an adverse effect on the flax products and on the environment.

The desiccation involves chemical drying of plants on the root. Today, in the market, there is a large range of preparations for desiccation: *Glyfovit*, *Basta*, *Alfa-Dikvat*, *Reglon Super*, etc. *Reglon Super* is the most often recommended for desiccation of oil flax [15, 16]. Researchers have studied the effects of various preparations and their dosage on reducing the moisture content of plants, yield, and fiber quality. Low air temperature and rains have been established to significantly reduce the effectiveness of desiccation [2, 15]. Hot and dry weather that is typical for the period of storage on the south of Ukraine are unfavorable for desiccation as well. If the flax processed with desiccants is harvested untimely, this increases the loss of seeds and adversely affects the fiber quality. It should be noted also that chemical drying is more effective for the seed portion of the oil flax crop, since it increases the yield of seeds. In this case, straw remains for a certain period of time on the field for spreading, and the moisture content may rise again due to precipitations, therefore, from the standpoint of straw storage, the use of preservatives is more effective.

The paper [17] presents the results of a theoretical and experimental study to find the best preservative for maintaining the quality of fiber flax straw and retted straw, which have been used up to this time in various countries. The existing and promising preservatives such as carbamide, ammonium nitrate, aethonium chloride, sodium carbonate, sodium chloride, and formaldehyde have been analyzed as well. The studies have shown that carbamide is the best preservative for storage of wet flax. Despite the practical significance of these results, it should be pointed out that these and other researches on the storage of flax concern the straw of fiber flax that significantly differs from that of oil flax.

Today, the search for effective preservatives continues inasmuch as they do not all possess a set of necessary properties: efficiency, environment safety, and cheapness. Consequently, in order to ensure the quality of oil flax straw in present-day conditions, new effective preservatives are required. They must have inhibitory bactericidal, fungicidal properties, interact with the raw material, and be environment friendly and cheap.

Proceeding from the above one can suggest that the problem of oil flax straw is a relevant task that must be addressed. The purpose of this research is to study an effect of biologically active substances on the quality of oil flax straw that undergoes long-term storage and to identify rational parameters of storage process for obtaining high-quality flax fiber that further can be used in various industries.

To achieve this purpose, the following problems must be solved:

- To analyze the existing methods for storing raw flax and the main factors that affect changes in quality characteristics of the raw material during its storage;
- To find the most suitable method of preservation of oil flax straw for its long-term storage;
- To choose environment friendly and cheap preparations that have a high biologic, in particular, fungicide and bactericide, activity;
- To define rational parameters for oil flax straw storage based on statistical models obtained from regressive analysis.

The three types of oil flax: *Vira, Pivdenna Nich*, and *Debut* were selected for the study. These varieties are grown in the climatic conditions of southern Ukraine, on the fields of *Askaniiske* Experiment Farm of the Askaniisk State Agricultural Experimental Station of the Institute for Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, in the village of Taurichanka, Kakhovka District, Kherson Oblast, which is the largest producer of oil flax in the area.

Flax for research was grown with strict observance of all requirements of recommended technology. The trial sections had the soil conditions typical for the flax plantation area in the region. All agrotechnical techniques for soil preparation, sowing, care of crops, and harvesting of flax straw for each variety were done in the same day, with the same tools and purity of experiments [18].

The research was carried out on the basis of laboratories of *Askaniiske*, as well as on trial sections and in laboratories of the Department for Commodity Studies, Standardization, and Certification of the Kherson National Technical University, during the six years (2010—2016).

The initial study was carried out using industrially packed (rolled) flax straw stored on the lands of Askaniiske. Because of the lack of special conditions for storage (warehouses, stacks), oil flax rolls were kept in field conditions for 1—2 years.

The further study was carried out using small straws sub-samples of 50 g, which enabled to observe the changes occurring in the flax stems, to find out the main pattern and the causes of these changes, as well as the effectiveness of various technological techniques. The study was carried out on a trial asphalted site where there was an artificial open storage with a canopy for storing the pressed flax for a specified time.

The straw sample weights were chosen proceeding from general accepted standards, given the future analyses of raw material quality. Flax stems of the same quality reaped by combined harvester were used for the experiments.

During the experiments, the principle of one difference was observed. On separate research facilities, the samples were treated with preservative solutions, rolled, and further studied on the same day, with the use of same tools and implements.

The following preparations were chosen as preservatives: carbamide, *AF9-10* composite preparation based on carbamate phosphate and oxyethylated nonylphenol, and biologically active preparations *Trichodermin* and *Phytosoporin-M*. The preservatives were applied as aqueous solutions of different concentrations by uniformly spraying the straw stalks. Having been processed in this way, the straw was pressed and rolled with an average density of 120 kg/m^3, which in the best way ensures the storage of rolled raw flax material and meets the specification requirements. For comparison, a reference sample with unprocessed straw stems was used. All samples were stored in natural conditions for 6, 12, 18, and 24 months. At the end of storage period, the flax straw samples were analyzed in terms of organoleptic and physico-mechanical parameters, according to the applicable specifications [19, 20].

Experiments on the storage of wet straw with high humidity were carried out to study the effect of storage duration, the moisture content in stems, the action of preservatives, and the complex effect of these factors on the quality of raw flax in the course of storage [12].

The storage of wet flax straw was studied in laboratory conditions. As the moisture content in straw samples reached 25, 30 and 35%, they were irrigated at a dose rate of 150 ml solution per 1000 g straw (7.5 ml solution of the studied preparation per 50 g straw). The samples were placed in polyethylene bags that were not sealed to create aerobic conditions. The bags were marked with tags and placed in closed containers, with the moisture content in straw continuously monitored.

The samples were stored at a temperature of 12—19 °C and a relative humidity of 24—30% during 30, 60, and 90 days. At the end of specified period, they were dried in natural conditions, and the raw material quality was determined. Then, the quality indices of the initial raw material, the reference samples with different moisture content, and the samples treated with preparations were compared.

To determine the moisture content in flax straw to be stored, the straw was cleaned from impurities, its stems were thoroughly mixed and 50 g sub-samples were made of them. The sub-samples were put into cassettes. One of the cassettes was suspended on the hook of *US-4* drier for drying, and the other was placed in the same device for pre-drying. Drying was carried out at a temperature of 100–105 °C, and stopped in 5 minutes after stopping the quadrant arrow. The suspended cassette was removed, with the pre-dried one hung instead of it. The moisture content in each sub-sample (%) was calculated according to the formula:

$$W_в = \frac{G_в - G_c}{G_c} \cdot 100\,\%, \quad (1)$$

where $W_в$ is moisture content in flax straw, %; $G_в$ is sub-sample weight before drying, g; G_c is weight of absolutely dried sub-sample, g.

Having determined the moisture content in the straw taken for experiments, the weight of absolutely dried straw in the samples G_c:

$$G_c = \frac{G_в \cdot 100 \cdot M_1}{W_ф}, \quad (2)$$

where $G_в$ is weight of the wet straw samples, g; $W_ф$ is actual weight of straw in the samples, %.

The qualitative parameters of oil flax straw to be stored were determined in accordance with applicable standards and generally accepted methods [19—21].

The quality of flax straw was evaluated by instrumental methods according to GOST 28285-89 *Flax Straw. Requirements for Storage* [19]. The bast output was determined by the gravimetric method. The quality of flax retted straw obtained was evaluated based on the separability characteristics and fiber color, which were determined according to DSTU 4149:2003 *Flax Retted Straw. Specifications* [20].

The fiber content was determined with an accuracy of 0.1% and further rounding, by weighing the samples after processing them using laboratory breaking machine *ML-5*. For this, the stems passed through the rollers 5—6 times, and then were shaken manually until the boon stops to separate. This operation was repeated until the boon content in fiber exceeded 10%. The rest of the boon was separated manually.

The fiber content C in straw or retted straw (%) was calculated by the formula:

$$C = \frac{100 \cdot M_1}{M_2}, \quad (3)$$

where M_1 is fiber weight, g; M_2 is weight of straw or retted straw, g.

The separability of fiber from wooden part was determined using a special device (according to DSTU 4149:2003).

The following limits of separability indices are established: the retted straw with a separability index of 2.1 and below is considered straw; the retted straw with an index of 2.1–4.0 is referred to immature one, and that with an index of 4.1 and higher is normally mature retted straw.

The fiber rupture stress was measured using a *DKV-60* dynamometer. The fiber strips were twisted using a *KV-3* device. The twisted piece was fixed in the clamps of breaking machine. The distance between the clamps was 70 mm. The accuracy of measurements was 0.1 daN (1 decanewton [daN] = 1.01971 kg-force [kgf]) with further rounding to an integer. The final result was arithmetic mean of thirty tests. The rupture stress was calculated by the formula:

$$Rs = \frac{1}{30} \sum_{i=1}^{30} Rs_i, \quad (4)$$

where Rs_i is rupture stress of fiber sub-sample, daN; 30 is number of tests.

The linear density of raw materials was measured based on the splitting of complex fibers [21]. Segments having a length L_s = 20 mm and a total mass M_s, mg were made of fiber strands of a certain length. Then the total number of fibers n_0 was counted. The whole fibers and those split for less than half their length were considered one fiber, while those split for more than half their length were counted as so many fibers as they split into.

The linear density of the split fibers T_p, tex (weight of length unit, mg/m or g/km) [21] was calculated by the formula:

$$T_p = 1000\, M_s / (L_s n). \quad (5)$$

where n is conventional number of fibers split for more than 0.5 length; L_s = 20 mm.

There are several methods for storing wet raw flax. It can be stored by bringing the moisture content in it to normal amount by drying or treating with chemical and biological preparations (Fig. 1). Natural drying in rolls, except for the outer part, are complicated because of high compaction. Artificial drying is the most reliable technology for product preservation, however, in Ukraine, it has not been widely put into practice because of a considerable power consumption and a high cost, although abroad this method is used for ensuring due quality of raw flax [22, 23].

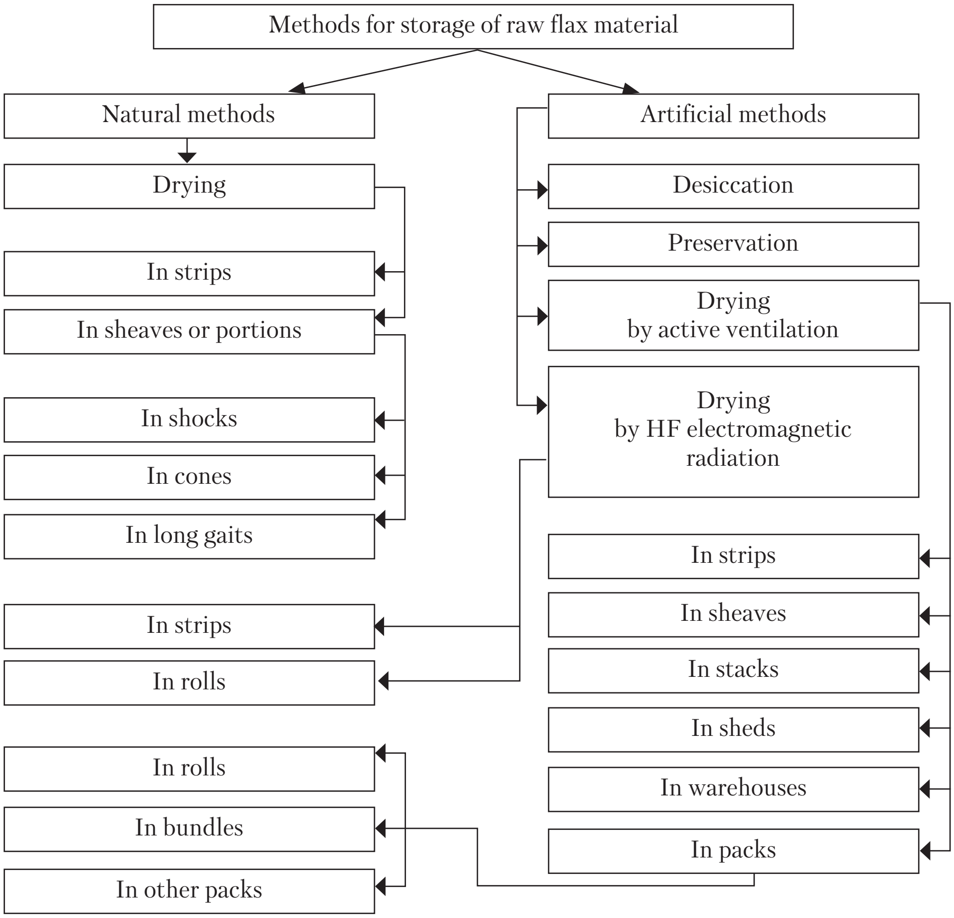


Fig. 1. Methods for storage of wet flax straw

Chemical or biological preservation can result in weakening dependence on changing weather conditions. The preservatives inhibit the development of microflora that decomposes fiber.

The scheme of studies on the storage of oil flax straw involved the use of following preservatives in the form of aqueous solutions: carbamide, a composite preparation based on carbamide phosphate and oxylated nonylphenol *AF 9-10*, and biologically active preparations *Trichodermin* and *Phytossporin-M*. All selected preparations have the ability to suppress the development of microflora and almost completely inhibit rotting, molds, and bacteria, which are rapidly growing on flax stems at a high humidity and adversely affect the preservation of flax straw. Consequently, all preparations have a high biological (in particular, fungicidal and bactericidal) activity, first of all, against cellulosolytic fungi and bacteria, are environmentally safe and cheap.

In order to determine the main directions for improving the storage and planning of the main experiment, the dependence of changes in the qualitative indices of raw flax of the three flax varieties (*Vira, PivdennaNich*, and *Debut*) on the period of storage in industrial conditions, according to the roll technology has been studied at the preliminary stage of the research.

During the study of flax straw storage, recent scientific information has been analyzed. The most important factors that influence the quality of raw flax have been established to be moisture content in flax straw, compaction of material, temperature of the inner layers of raw material, storage duration, concentration of preservatives, and uniformity of their application [24]. The analysis of the abovementioned factors has enabled to choose the most significant ones for further research, in particular, moisture content, duration of storage, and concentration of preservatives.

The research results have shown that the flax material obtained from flax stems during storage with the use of preservatives has better physico-mechanical parameters as compared with untreated flax. All qualitative characteristics have been established to vary in the course of storage, depending on the type of preservative. Figs. 2, 3 show changes in the main qualitative indices of *Vira* variety raw material (separability and rupture stress) stored for 12 and 24 months. According to the diagrams, the indices of the raw material treated with biologically active preparations changed least of all. Thus, according to the results of organoleptic and instrumental evaluation of the bast fibrous material obtained after 24 months of storage, it has been established that the biologically active preparations *Phytosporin-M* and *Trichodermin* have the highest preservation properties, the second effective is the composite preparation AF 9—10 based on carbamide phosphate and nonylphenol, and the least effective is carbamide.

The research has shown that during prolonged storage of flax stems with the use of preservative solutions, under the influence of abiotic and microbiological factors the biological processes in the flax straw, and, accordingly, the changes in its qualitative parameters significantly slow down as compared with the reference samples [25].

To establish the mechanism of action of selected preservatives, the changes in the species and quantity compositions of microorganisms developing on the flax stems with a high moisture content during storage has been analyzed. It has been established that the treatment of straw by the studied preservatives contributes to a significant reduction in the amount of cellulose-destroying microflora. As a result, after the treatment, the microbiological processes slow down, which causes a partial conservation of straw.

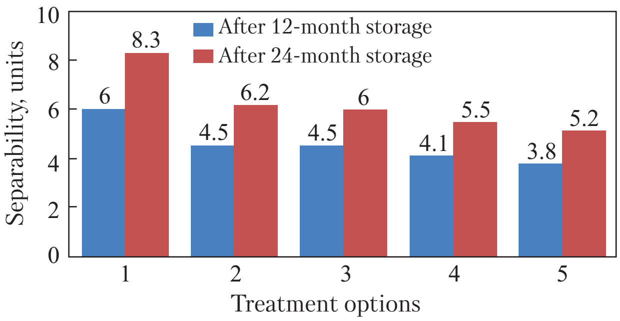


Fig. 2. Dynamics of fiber separability in flax straw after 12- and 24-month storage for various treatments: *1* — without preservative; *2* — carbamide; *3* — composite preparation; *4* — *Trichodermin*; *5* — *Phytosporin-M*

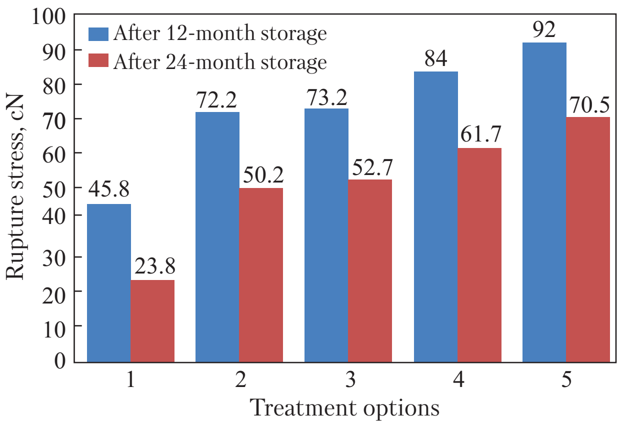
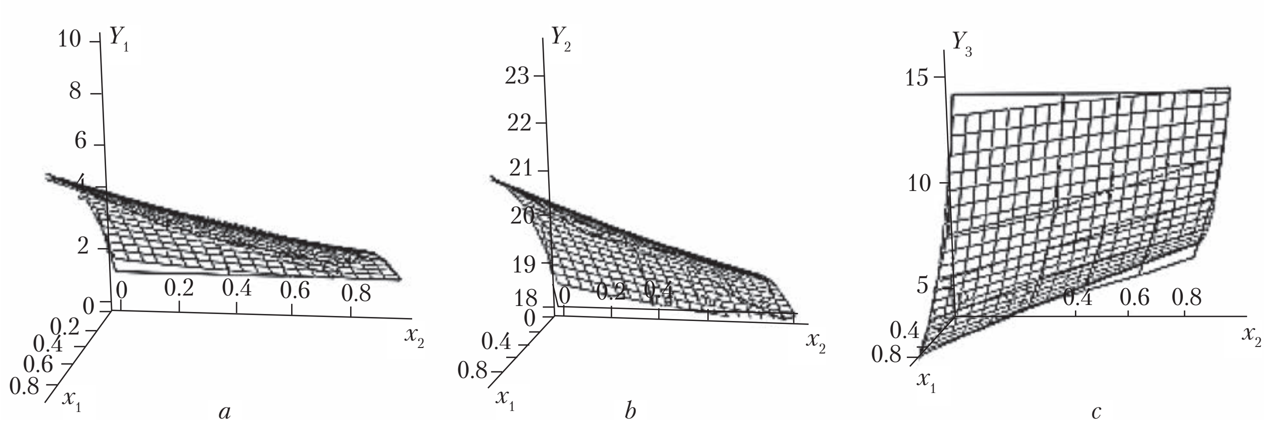


Fig. 3. Dynamics of rupture stress of fiber obtained from flax straw after 12- and 24-month storage for various treatments: *1* — without preservative; *2* — carbamide; *3* — composite preparation; *4* — *Trichodermin*; *5* — *Phytosporin-M*

The best preservative properties have been shown by biologically active preparation *Phytosporin-M* that has a pronounced antiseptic effect. The data obtained give reason to state that the used preparations inhibit the development of epiphytic microflora, partially preserve the straw during storage, and prevent almost any damage of flax stems by cellulose-destroying fungi and bacteria.

Based on the obtained data, a statistical model for storing oil flax straw with the use of *Phytosporin-M* preparation was created in the form of the corresponding regression equations:



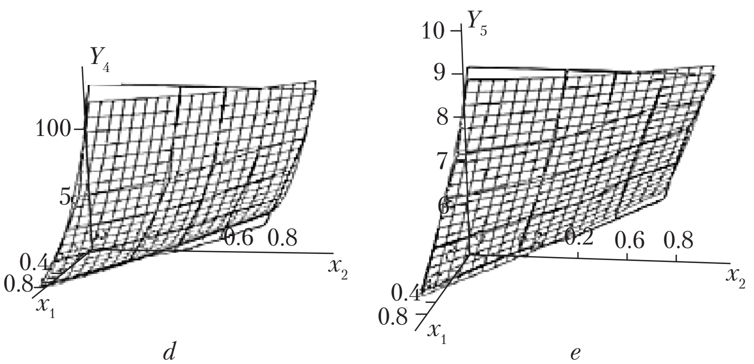


Fig. 4. Results of simulation of dependence of oil flax quality parameters on duration of storage (x_1, months) and Phytosporin-M concentration (x_2, %) at encoded values of factors: *a* — separability, Y_1; *b* — fiber content, Y_2; *c* — linear density, Y_3, tex; *d* — fiber rupture stress, Y_4, cN; *e* — relative rupture stress, Y_5, cN/tex

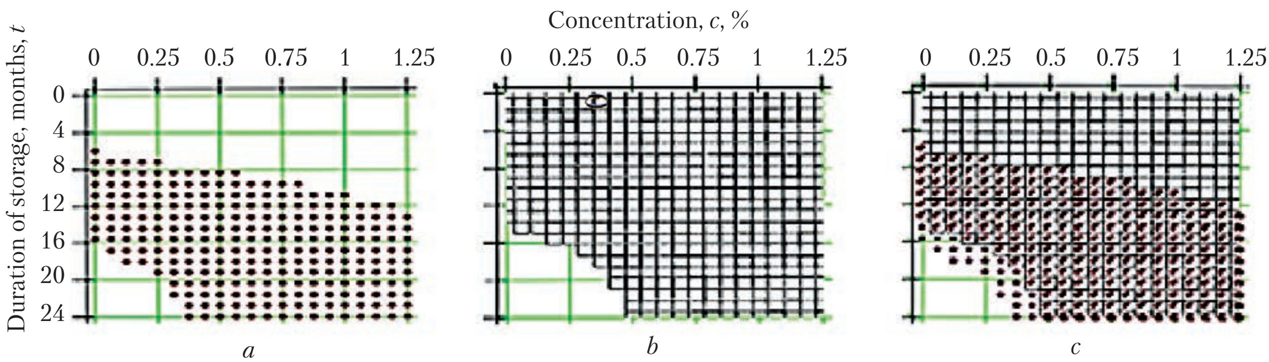


Fig. 5. Areas of standard values of parameters for the straw with a moisture content of 19—23%: *a* — separability, Y_1, units; *b* — rupture stress, Y_4, cN; c — intersection of Y_1 and Y_4 areas

– separability Y_1, units:

$$Y_1 = 1.775 + 10.361x_1 - 0.944\,x_2 - 4.046x_1^2 - 2.835x_1x_2 + 0.462x_2^2; \quad (6)$$

– fiber content Y_2, %:

$$Y_2 = 18.613 + 5.903x_1 - 1.04\,x_2 - 2.286x_1^2 - 1.259x_1x_2 + 0.24x_2^2; \quad (7)$$

– linear density Y_3, tex:

$$Y_3 = 13.259 + 17.258x_1 - 1.582\,x_2 - 8.19x_1^2 - 3.908x_1x_2 + 0.257x_2^2; \quad (8)$$

– rupture stress Y_4, cN (centinewton, 1 newton [N] = 100 centinewtons [cN]):

$$Y_4 = 119.236 + 186.979x_1 - 10.617\,x_2 - 89.595x_1^2 - 37.41x_1x_2 + 7.664x_2^2; \quad (9)$$

– relative rupture stress Y_5, cN/tex:

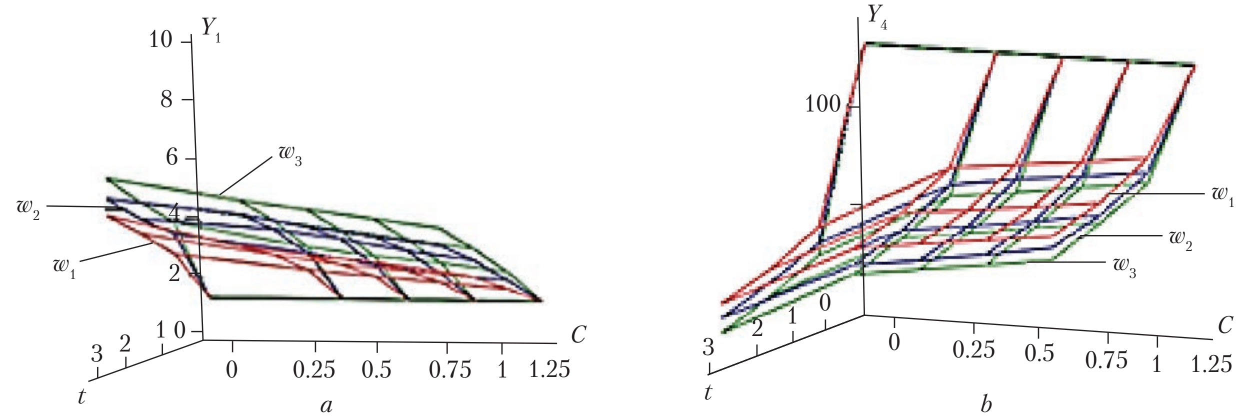


Fig. 6. Dependence of oil flax straw parameters on duration of storage and concentration of preparation, at a high moisture content: w_1 — 25%; w_2 — 30%; w_3 — 35%; at natural values of factors: *a* — separability, Y_1, units; *b* — fiber rupture stress, Y_4, cN

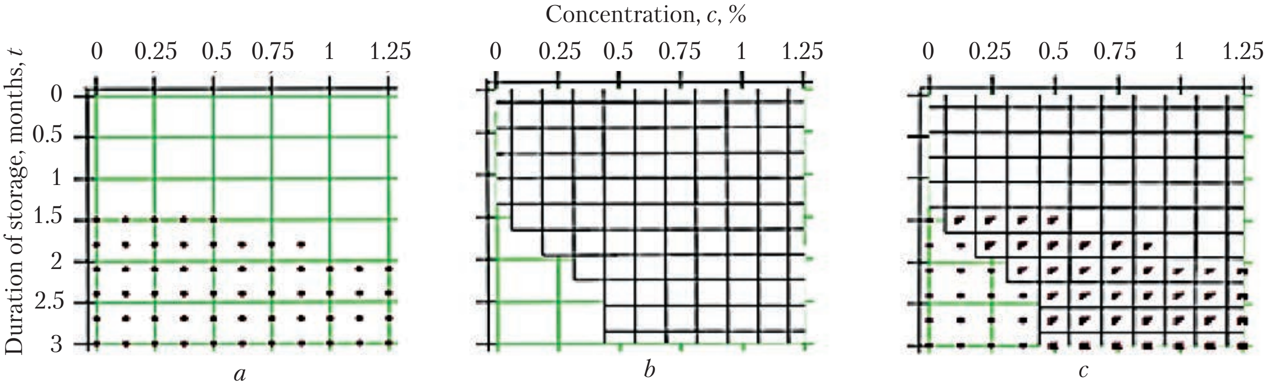


Fig. 7. Areas of standard values of parameters for the straw with a moisture content of 35%: *a* — separability, Y_1, units; *b* — rupture stress of single fiber, Y_4, cN; *c* — intersection of Y_1 and Y_4 areas

$$Y_5 = 8.909 + 4.12x_1 - 0.204\,x_2 - 0.823x_1^2 - \\ - 2.059x_1x_2 + 0.305x_2^2, \qquad (10)$$

where x_1 isstorage duration, months; x_2 is concentration of preparation, %.

The modelling was done in *MathCad;* the step ΔX_1 for straw storage duration was 6 months or 0.25 in code values; the step ΔX_2 for concentration of *Phytosporin-M*preparation was 0.25% or 0.2 in code values.

Response surfaces Y_i depending on x_1 and x_2 are given in Figs. 4. The results show that as concentration of *Phytosporin-M* increases from 0.5 to 1.25%, the quality of final product obtained from oil flax straw stored in conditions close to the real production during 24 months improves essentially.

The separability was 5.2 units at a *Phytosporin-M* concentration of 1.25%, in 24 months, and 6.5 units at a concentration of 0.5%. The amount of bast-like fiber and linear density were 20.4% and 8.81 tex, respectively, at a concentration of 1.25%, and 21.1% and 6.48 tex, respectively, at a concentration 0.5%. Absolute and relative rupture stress amounted to 70.5 cN and 8.0 cN/tex, respectively, at a *Phytosporin-M* concentration of 1.25% and 43.4 cN and 6.7 cN/tex, at a concentration of 0.5.

The specifications [26] define separability and rupture stress as key parameters of the quality of retted straw and fiber, therefore, based on the obtained models, areas of dependence of abovementioned parameters on *Phytosporin-M* concentration and duration of storage have been built (Fig. 5). Maturity of flax retted straw is acceptable provided its separability ranges from 4.1 to 7 units and rupture stress of single fiber is, at least, 40 cN. Therefore, the obtainment of these values while storing raw flax is considered achievement of the purpose.

The analysis of modelling results (Figs. 4, 5) has shown that at a *Phytosporin-M* concentration of 0.5—1.25%, oil flax retted straw keeps required maturity for up to 24 months of storage. Thus, the use of *Phytosporin-M* enables storing oil flax straw with a standard moisture content of 19—23% during a long term without worsening its technological quality.

Similar studies with above mentioned preservatives have been carried out using the samples with an initial moisture content of 25, 30, and 35%. The corresponding regression equations have been obtained:

– separability, units:

$$Y_1 = 1.434 + 0.591x_1 + 5.383\,x_2 - 0.488x_3 - 0.396x_1^2 + 1.43x_1, x_2 - 1.647x_2^2 - 0.1x_1, x_3 + 0.167x_3^2 + 1.474x_2, x_3; \quad (11)$$

– rupture stress of single fiber, cN:

$$Y_4 = 120.752 - 8.344x_1 - 200.579\,x_2 + 47.532x_3 + 3.296x_1^2 - 10.814x_1, x_2 + 110.712x_2^2 - 2.081x_1, x_3 - 35.912x_3^2 - 39.293x_2, x_3, \quad (12)$$

where x is variation factors: x_1 is moisture content, %; x_2 is duration of storage, months; x_3 is concentration of preparation, %.

Dependences of separability and rupture stress on duration of storage and *Phytosporin-M* concentration are given in Fig. 6.

Graphical presentation of optimal area of parameters of stored raw flax with a moisture content of 35% is shown in Fig. 7.

The analysis of results (Fig. 6) has shown that the separability of fibers treated with *Phytosporin-M* slightly decreases to 5.0—5.9 units as compared with the reference sample (6.6 units). However, the rupture stress at a concentration of 1.25% accounted for 63.0 cN, while in the reference study it was 16.2 cN.

The analysis of obtained mathematical models (11), (12) and their graphic presentations (Figs. 6, 7) has shown that the qualitative parameters of raw flax with a moisture content up to 35% at the studied concentrations of *Phytosospin-M* in 3 months of storage reach their optimal values for further mechanical treatment. The raw flax treated with a 1.25% concentration solution keeps its quality in the best way.

CONCLUSIONS

1. The application of new environment friendly biologically active substances for the storage of flax straw with a wide range of moisture content has been substantiated. It has been found that the studied preparations inhibit the development of cellulolytic fungi and bacteria, which contributes to the preservation of cellulose fiber in flax stems. The selected preservatives *Trihodermin* and *Phytosporin-M* do not inhibit the development of pectin-destroying microflora, so over time, the straw can turn into the retted straw without spreading out.

2. Using the mathematical modeling of oil flax straw storage statistical models for dependence of separability, content of fibers, linear density, fiber rupture stress, and relative rupture stress on moisture content in flax straw, duration of storage and concentration of preservative have been obtained. Due to the obtained models one can choose an appropriate concentration of preparation and duration of storage of oil flax straw to produce materials with different properties depending on further applications. The proposed mathematical models are statistically reliable.

3. In order to ensure long-term storage of oil flax straw under production conditions, it is recommended to take the following measures:

- To apply as preservatives environment safe biological preparations with fungicidal and bactericidal activity against cellulosolytic fungi and bacteria, in particular, *Trichodermin* (at a concentration of 0.50%) and *Phytosporin-M* (at a concentration of 1.25%). Uniform application of preparations to raw materials is ensured by the use of industrial agricultural sprayers of various types. The indicated concentrations enable to obtain retted straw of normal maturity in 18 and 24 months of storage;

- To create favorable conditions for storage in the southern Ukraine, the rolled straw of oil flax should be placed on asphalted sites covered with tents.

The implementation of developed technology for oil flax straw storage provides an additional raw material base for the production of technical textiles for various functional purposes.

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ЗАСТОСУВАННЯ БІОЛОГІЧНО АКТИВНИХ ПРЕПАРАТІВ ДЛЯ ЗБЕРІГАННЯ СОЛОМИ ЛЬОНУ ОЛІЙНОГО

Вступ. В Україні значні обсяги лляної сировини не надходять відразу на первинну переробку, а з часом спостерігається погіршення її якості. Це пов'язано з недотриманням агротехнічних норм збирання, несприятливими погодними умовами та іншими факторами в процесі зберігання сировини.

Проблематика. Потужності льонопереробних підприємств не дозволяють переробити весь обсяг сировини за короткий період часу, тому виникає потреба у її тривалому зберіганні. Забезпечити високі якісні показники соломи льону олійного можуть екологічно безпечні, відносно дешеві сучасні консерванти, які мають інгібіторні, бактерицидні, фунгіцидні властивості.

Мета. Дослідження впливу біологічно активних речовин на показники якості соломи льону олійного та визначення раціональних параметрів процесу зберігання.

Матеріали й методи. Для проведення досліджень відібрано сорти льону олійного: Віра, Південна ніч та Дебют. Окреслені завдання вирішували за допомогою теоретичних та експериментальних методів дослідження, що є чинними в галузі первинної переробки сировини й текстильного матеріалознавства. Математичне моделювання процесів виконано в середовищі MathCad.

Результати. Досліджено вплив біологічно активних препаратів на ступінь збереження соломи льону олійного. Визначено механізм дії досліджуваних консервантів та динаміку зміни якісних параметрів сировини у процесі її тривалого зберігання. Отримано статистичні моделі впливу умов зберігання льоносоломи на якісні параметри волокна, а також визначено оптимальний консервант, його концентрацію, умови та строки його дії.

Висновки. Обґрунтовано застосування нових екологічно безпечних біологічно активних речовин для зберігання соломи льону олійного з широким діапазоном вологості.

Ключові слова: солома льону олійного, способи зберігання, консервант, статистична модель.

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ПРИМЕНЕНИЕ БИОЛОГИЧЕСКИ АКТИВНЫХ ПРЕПАРАТОВ ДЛЯ ХРАНЕНИЯ СОЛОМЫ ЛЬНА МАСЛИЧНОГО

Введение. В Украине значительные объемы льняного сырья не поступают сразу на первичную переработку, а со временем наблюдается ухудшение его качества. Это связано с несоблюдением агротехнических норм сбора, неблагоприятными погодными условиями и другими факторами в процессе хранения сырья.

Проблематика. Мощности льноперерабатывающих предприятий не позволяют переработать весь объем сырья за короткий период времени, поэтому возникает потребность в его длительном хранении. Обеспечить высокие качественные показатели соломы льна масличного могут экологически безопасные, недорогие современные консерванты, которые имеют ингибиторные, бактерицидные, фунгицидные свойства.

Цель. Исследование влияния биологически активных веществ на показатели качества соломы льна масличного и определение рациональных параметров процесса хранения.

Материалы и методы. Для проведения исследований отобраны сорта льна масличного: Вера, Южная ночь и Дебют. Поставленные задачи решались с помощью теоретических и экспериментальных методов исследования, которые действуют в области первичной переработки сырья и текстильного материаловедения. Математическое моделирование процессов выполнено в среде MathCad.

Результаты. Исследовано влияние биологически активных препаратов на сохранность соломы льна масличного. Определен механизм действия исследуемых консервантов и динамика изменения качественных параметров сырья в процессе ее длительного хранения. Получены статистические модели влияния условий хранения соломы льна масличного на качественные параметры волокна, а также определено оптимальный консервант, его концентрация, условия и сроки его действия.

Выводы. Обосновано применение новых экологически безопасных биологически активных веществ для хранения соломы льна масличного с широким диапазоном влажности.

Ключевые слова: солома льна масличного, способы хранения, консервант, статистическая модель.