ISSN 2409-9066. Sci. innov., 2019, 15(3), 91—104 https://doi.org/10.15407/scine15.03.091

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PROMISING METHODS AND SYSTEMS OF QUALITY CONTROL OF INNOVATIVE BAST RAW MATERIAL

Introduction. *In advanced economies, oilseed flax is used not only for obtaining seeds, but also as a source of additional high-quality textile raw materials. In Ukraine, oilseed flax is the only domestic raw material resource that can become an alternative to imported cotton and fiber flax used for the textile and pulp-and-paper industries and for the production of reinforced composite materials.*

The analysis of the status of standardization of products from oilseed flax stalks indicates the absence of regulatory documents to determine their quality. Therefore, the development of such regulations and standards is a pressing problem of our time, inasmuch as the organization of processing and the implementation of these products in the conditions of the present-day market and customer requirements are impossible without appropriate standardization and certification.

Problem Statement. *The need to develop standards for products from oilseed flax stalks to determine their quality and commercial characteristics is urgent, since the approval of such technical specifications at the government level stimulates the creation of markets for the sale of oilseed flax straw as raw materials for the production of fibers that have a wide industrial application.*

Purpose. *To develop domestic regulatory documents in order to control the quality of "new generation" bast raw material — oilseed flax straw — taking into account the modern consumer requirements.*

Materials and Methods. *Based on the qualimetry methods, a complex methodology for determining the general quality of oilseed flax straw as an industrial raw material has been developed.*

Results. *Technical specifications TU U 01.1-2303511525 — 001: 2016 Oilseed Flax Straw. Technical Specifications have been developed and approved at the state-owned enterprise Khersonstandartmetrologia.*

Conclusions. *The certified domestic raw materials made of oilseed flax straw can be used in textile, pulp-and-paper and other industries of Ukraine for the manufacture of innovative competitive products of various functional purposes.*

Keywords: straw, oilseed flax, quality, and technical specifications.

Recently, the Ukrainian textile industry has faced many problems resulting from the financial crisis, outdated equipment and technical documentation and, the most important, the lack of local raw materials, which have led to its decline. In Ukraine, the operation of textile industry enterprises for 80% depends on the imported resources — fiber flax and cotton. At the same time, Ukraine has got new opportunities that can be used to reach a new stage in the development and establishment of the industry in Ukraine. The analysis of statistical data on the bast crop area for the period 2000—2016 shows that oil flax has been a leader for the last 11 years (Fig. 1) [1].

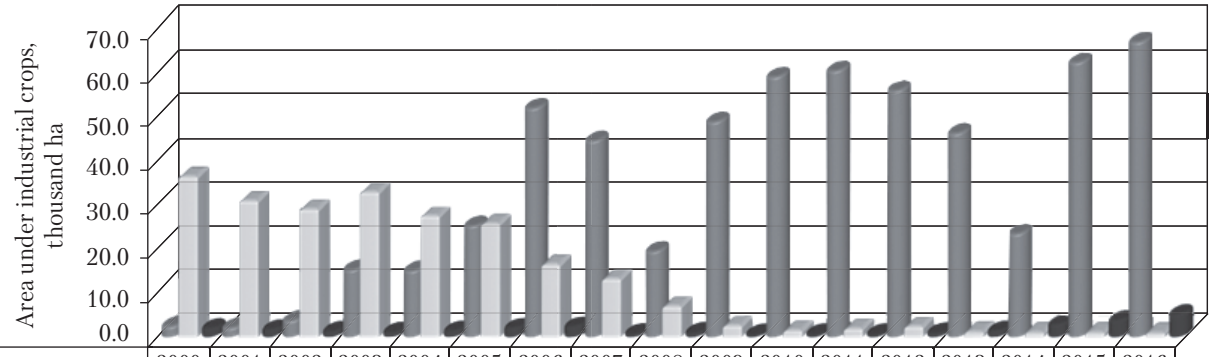
Due to a high sale price of oil flax its cultivation in Ukraine is cost-effective. At the same time, the stalk portion of the above-mentioned crops is practically not processed [2]. However, as the world practice shows [2—5], oil flax is an annually renewable biological source of a new generation, which has many industrial applications (Fig. 2).

Researchers of the Kherson National Technical University have developed technologies for processing oil flax in order to put them into practice of domestic enterprises [6]. In the laboratory and industrial conditions, innovative products for various purposes (cellulose-based semi-finished products, filter paper, composite products, mixed yarn, and nonwoven materials of various types: flax batt, furniture and nonwoven fabrics) have been manufactured [7—9]. Thus, it has been proved that oil flaxen straw is a valuable cellulosic raw material, the main advantage of which is availability and local production.

Today, the organization of an integrated industrial straw processing of oil flax, manufacture of innovative products and their sale on the domestic and world markets is impossible without standardization, certification, and methodology for determining the quality indicators of both raw materials and innovative products made of them. The absence of such quality control systems breaks the entire chain of industrial processing of oil flax stalks, from straw to finished goods for various industrial purposes (Fig. 3).

Taking into account the aforementioned, the world and domestic achievements of the theoretical and practical nature [3—12] have been analyzed in detail in order to identify the available methodology and quality indicators of oil flax straw as a commercial raw material (Table 1).

The analysis of the given data has testified to the complete lack of standards and methodology for assessing the quality of the research object. As the world practice has shown, standardizing the oil flax straw is a pressing problem not only



Years	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Oil-seed flax	2.3	2.0	3.6	15.1	14.9	25.1	51.8	44.4	19.3	48.7	58.9	60.3	55.8	46.1	23.2	62.2	66.8
Flax	36.2	30.7	28.8	32.7	27.3	25.5	16.3	13.0	6.8	2.4	1.3	1.7	2.2	1.0	0.9	0.9	0.8
Hemp	1.8	2.0	1.1	0.9	1.2	1.8	2.2	0.5	0.8	0.3	0.4	0.4	0.7	1.2	2.7	3.6	5.0

Fig. 1. Dynamics of cultivated areas under bast crops in Ukraine, in 2000—2016

Seeds	Human food: ingredient of healthy food, personal care products
	Wild animals: fodder Cattle: fodder
Олія	Human food: ingredient of healthy food, personal care products, bottled oil
	Wild animals: fodder Cattle: fodder ingredient
	Industry: oilcloth, wax cloth, paints, dyes, varnishes, wood stains, tars, and inks
Oil cake	Human food: ingredient of healthy food, further processing
	Wild animals: fodder Cattle: fodder
Fiber	Pulp and paper industry: special and filter paper Textile industry: fabrics Technical and engineering application: geotextile, insulating and absorbing materials, plastic composites of medium and high quality Chemical industry: cellulose sweeteners, esters
Boon	Agriculture: bedding/litter Construction materials: press boards, composite admixtures (pressure casting, artificial timber) Power engineering: heat energy source, biofuel (briquettes, pellets) Chemical industry: activated coal (filtration), extracted aromatic compounds (tars, antioxidants, antimicrobic substances)
Waste	Ground boon and fiber impurities: biofuel, construction materials

Fig. 2. World trends in application of oil flax straw

in Ukraine, but also in Canada, the USA, Egypt, Northern Ireland, Finland, Poland, the Russian Federation, and the Republic of Belarus [3—5, 10].

Thus, in advanced economies of Europe, the USA, and Canada, there are no standards for assessing the quality of raw bast material. In these countries, thee factories have been using the organoleptic method for assessing the quality of oil flax straw. The quality of raw materials is controlled by highly skilled certified specialists who have a license for these works. They assess the oil flax straw quality on the field before mowing, at the request of processing factory and representatives of the sowing operator. The main parameters for the straw are bast output, technical (productive) length to total length ratio, color of the straw, and impurity content.

In the case of more detailed assessment of the quality of raw materials, at the request of factory, additional parameters such as average diameter of the stalks, which determines the intensity of their machining, total length of the stalks, and technical length to total length ratio are taken into consideration.

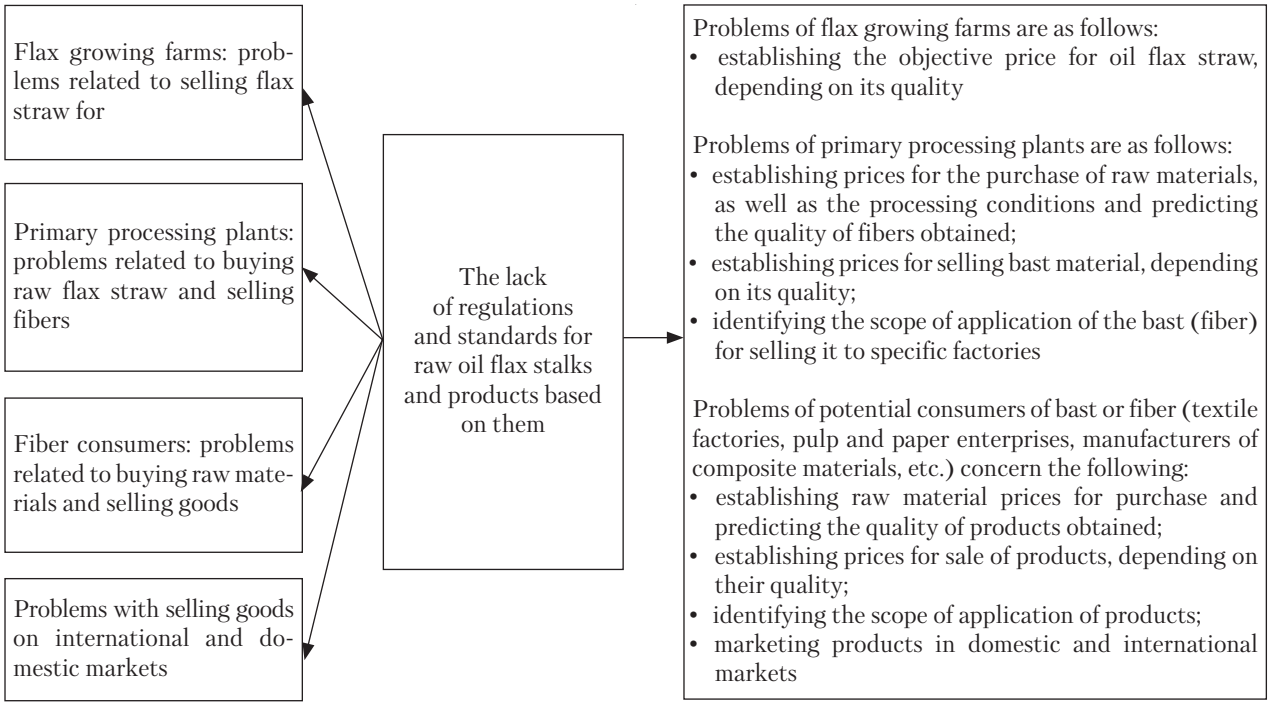


Fig. 3. Relevance of quality management system at all stages of oil flax straw processing

Based on expert assessment, the farmer and the processing factory make a verbal agreement (or official contract, at the request of one or both parties) on sale/purchase of straw, which clearly identifies the price of raw material and the terms for its delivery to the processing factory. When the oil flax straw comes to the processing plant, the technologists measure the moisture content in the stalks and check the material for the presence of unusable (rotten) stalks affected by fungal diseases (rust, fusariosis, polysporosis, anthracnose, bacteriosis, etc.). It should be noted that in the absence of standards for this raw material, in fact, the result of quality assessment depends on the subjective opinion of the expert, which is a significant disadvantage of such assessment [3—5, 11].

In the CIS countries (Russia, Belarus, and Ukraine), the oil flax straw quality is assessed in accordance with the applicable standards for fiber flax [13, 14]. At the same time, because of significant differences in the morphological and anatomical characteristics and, consequently, in the technological properties of the stalks of these two types of flax, it is inexpedient to use fiber flax standards for assessing the quality of oil flax straw. For example, such parameters as sheave extension, strick length, suitability, color, and stalk diameter are used for scoring the fiber flax straw. However, these quality characteristics cannot be used for assessing the quality of oil falx straw that is formed only after combine harvesting of seeds, which significantly changes the morphological parameters of the stalks. It should be kept in mind that oil flax straw is a fundamentally new raw bast material. Therefore, to assess its quality, it is necessary to develop and to approve appropriate standards. Thus, for the time being, the problem of general methodology and principles for assessing the quality of oil flax straw has remained unsolved.

In order to develop a promising system for oil flax straw quality control, the authors have done a research aiming at a detailed analysis of all the peculiarities of the structure of the stalks of the

Table 1

Methods for Assessing the Quality of Raw Materials and Basic Quality Indicators of Flax Straw Used by World R&D Centers and Oil Flax Processing Factories

Country	Factories and R&D centers	Basic quality indicators of flax straw
	Oil flax straw quality assessment without the use of standards (the organoleptic method)	
Canada	Primary processing of stalks, 6 factories: *FlaxStalk / SWM* (Manitoba), *Biolin* (Saskatchewan), *Stalkergy* (Ontario), *Crailar Flax Fiber* (British Columbia), *Stalkia*, and *Vegreville Decortication* (Alberta); fiber processing for manufacture of consumer goods; boon processing for manufacture of bioenergy products, 2 factories; *FibreCity* innovation center	Bast output from the stalks; technical length to total length; color of straw; moisture content; impurity content; average diameter; technical length
USA	Stalk processing and product manufacturing plants in Minnesota, Montana and North Dakota; Russell R&D Center (Athens, Georgia) under the direction of Dr. Denney E. Akin	Bast output from the stalks; color of straw; moisture content; impurity content
Egypt	National Research Center, Cairo (D. M. El Hariri and M.S. Hasaneinb); Field Crops Research Institute (Amna Hafiz Hassan EL-Sweify)	Bast output from the stalks; color of straw; total length; technical length
Northern Ireland	Royal University (Belfast) (Sharma); Department of Agriculture (G. J. Focha)	Bast output from the stalks; stalk length; stalk diameter
Finland	Agricultural R&D Center of Finland (C. Sankari)	Bast output from the stalks; color of straw; moisture content; impurity content
Poland	Stalk processing stems and fiber recycling plants Madex, Ekotex; Institute of Natural Fibers and Medicinal Plants (Poznan) (E. Mankowski and A. Kubaki)	Bast output from the stalks; color of straw; Weeds per total bast crop area
	OAssessment of quality of oil flax based on standards for fiber flax (long-stalked flax)	
Russian Federation	*LenTechmash* (Novosibirsk Region, Moscow Region, Volokolamsk); Kostroma State Technical University (Kostroma) (Fedosova N.M., Pashin E.L., Novikov E.V.) Central Research Institute of Complex Automation of Light Industry, Federal State Budget Research Institute of Mechanization of Flax (Tver) GOST 28285-89	Bast output from the stalks; color of straw; impurity content
Republic of Belarus	*RadaLen* Ltd. (Minsk Oblast); OJSC Shklovsk Flax Plant (Mogilev Oblast); OJSC Orekhovsk Flax Plant (Vitebsk Oblast); Institute of Flax (Vitebsk Oblast). The organoleptic method and GOST 28285-89	Bast output from the stalks; color of straw; impurity content; moisture content; technical length; total length
Ukraine	Kherson National Technical University (Chursina L.A., Tikhosova G.A., Putintseva S.V., Gorach O.O., Boyko G.A., Golovenko T.M., Bobir S.V., Menyaylo -Basysta I.O.); Askaniske, the NAAS of Ukraine (Kherson Oblast); Experimental station of barn crops of the Institute of Agriculture of the North East of Ukraine (Sumy Oblast); Institute of Irrigated Agriculture of the NAS of Ukraine (Kherson Oblast). GOST-14897-69 and GOST 28285-89	Bast output from the stalks; total length; technical length; technical length to total length; color of straw; moisture content; impurity content; average diameter

abovementioned crop and the identification of those properties based on which the technological value of raw materials can be predicted [6, 10, 15]. The results of theoretical studies on the identification of such morphological and anatomical parameters, the chemical composition of oil flax stalks, as well as their main technological properties, are summarized in Tables 2—5.

The critical analysis of world and domestic practice in the processing of oil flax straw and deep theoretical studies of all qualitative indicators of oil flax stalks have showed that solving the problems of mechanical processing of oil flax stalks for obtaining the products of multi-sectoral application largely depends on the technological indices (Table 5). The limit values of the indices significantly influence the quality of oil flax straw as industrial raw material.

To substantiate the draft documents, the abovementioned technological characteristics of oil flax straw were experimentally studied in order to determine the ranges of variation of individual quality indicators.

Table 2

Morphological Parameters of Oil Flax Stalks

Parameter	Oil flax group	
	Intermediate flax	Crown flax
Biologic and economic indicators		
Average height of oil flax plant, cm	57—90	25—78
Stalks from one root, pcs	57.0—90.0	25.0—78.0
Branches in the inflorescence, pcs	1—2	4—5
Number of seed boxes, pcs	12—14	12—18
Vegetation period, days	15—26	32—50
Average output of straw, %	92—95	98—102
Average seed output, %	55.0—65.0	60.0—77.0
Weight of 1000 seeds, g	20.0—25.0	21.0—27.0
Average oil output per seed, %	3.5—6.8	3.7—7.3
Average weight of stalk, g	38.0—40.0	38.0—48.0
Technical parameters (generalized for the two groups)		
Length:		
total length of stalks, cm	25.0—90.0	
technical length of stalks, см	15.0—78.0	
technical length to total length, %	60.0—86.0	
Thickness (diameter), mm:		
in the middle of the upper third;	1.01—1.10	
in the middle of flax plant;	1.20—2.04	
in the middle of the lower third	2.00—4.10	
Length to width ratio	260—645	123

Table 3

Anatomical Properties of Oil Flax Stalks

Parameters	Average parameter for		
	In the middle of the upper third	In the middle of flax plant	In the middle of the lower third
Wood content, %	51.6	40.8	69.8
Content of epidermis and parenchyma, %	31.1	24.6	17.9
Bast layer content, %	4.0	34.1	5.6
Bast bunches in the stalk cross section, pcs	14—26	37—45	21—38
Elementary fibers in the bunch, pcs	15—21	19—27	12—19
Elementary fibers in the cross section, pcs	210—546	703—1215	252—722
Length of elementary fibers	9.5 mm		

Table 4

Chemical Composition of Products Made of Oil Flax Stalks

Parameters	Average parameter of certain products, %		
	Bast	Fiber	Bleached fiber
Cellulose	54.58—67.33	61.28—73.17	92.40—98.45
Lignin	1.89—2.09	1.24—4.25	0.5—0.84
Pectic substances	8.85—12.18	6.26—7.65	residues
Waxy substances	n/a	2.5—3.0	n/a
Tannins	n/a	2.0	n/a
Ash content	n/a	1.0	n/a
Pigments (chlorophyll and carotenoids)	Green, yellow, or orange		

Note: n/a – parameters have not been studied.

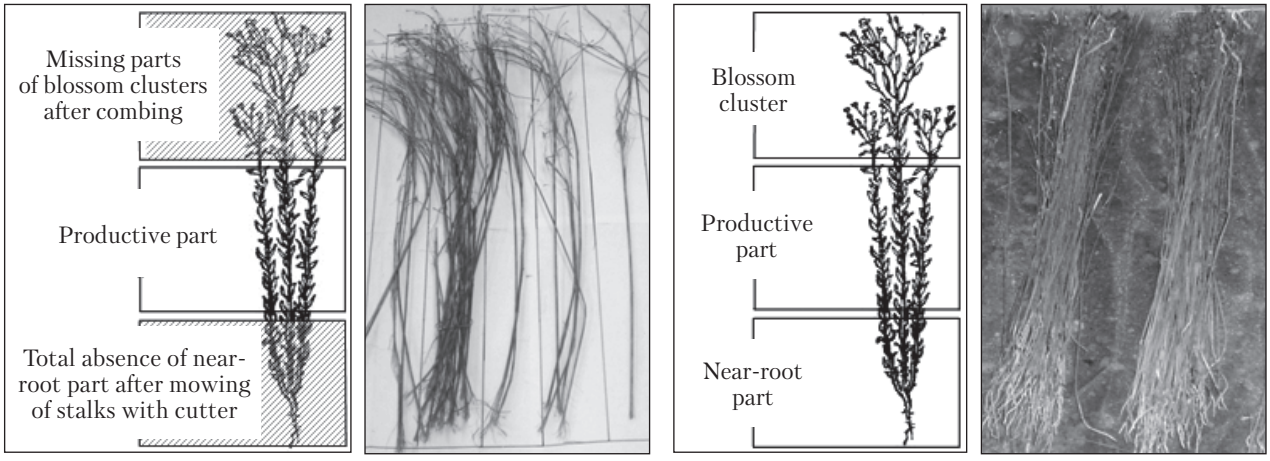


Fig. 4. Schematic and natural appearance of oil flax straw and stalks: *a* — straw after combine harvesting of seeds; *b* — stalks after manual harvesting

The object for practical research is oil flax straw obtained by combine harvesting of seeds and stalks after manual harvesting. Since, in the case of manual harvesting, the morphological structure of stalks is not damaged and, consequently, their biological, economic, and technical properties are not affected. Unlike, after harvesting of seeds by combined harvester, the oil flax stalks undergo significant changes: as a result of combing the seeds by reaper, the upper part of the stalk loses its primary morphological features and almost does not remain on the stalk. Fig. 4 shows a schematic and natural appearance of the general shape of oil flax straw and stalks harvested in different ways.

Table 5

Technological Properties of Oil Flax Stalks (Straw)

Parameters	Limit
Technological moisture content, %	6.0—8.0
Standard moisture content, %	19.0
Impurity content, %	5.0—20.0
Bast output from stalks, %	11.0—40.0
Straw color group	I, II, III
Total length, cm	22.0—90.0
Technical length, cm	15.0—78.0
Diameter, mm	1.0—4.1
Technical length to total length, %	60.0—86.0

For sampling of oil flax stalks and straw there were used the three varieties: *Iceberg*, *Debut*, and *Lyrina*, at the stage of yellow maturity in field conditions. To determine the limits of technological properties of raw materials (oil flax stalks and straw) it is necessary to make a detailed study for different methods of harvesting.

The results of research can be used as framework for the creation of standards for determining the oil flax straw quality, which will have practical application in the industrial and research spheres.

The parameters of oil flax stalks and straw quality have been experimentally studied at the research laboratory for bast crops processing of the Department for Merchandizing, Standardization, and Certification of the Kherson National Technical University. The experiments were repeated five times, and the obtained quality indicators of the studied oil flax varieties have been generalized. The calculations have been made in order to establish the average values of physical and mechanical parameters of oil flax straw as industrial raw material. This enables to disregard a particular variety or kind of oil flax, since processing factory can receive raw materials of different composition, in particular, straw of several varieties or kinds. The generalized results of experimental

studies of physical and mechanical parameters of oil flax straw and stalks are given in Table 6.

Below, the values of qualitative parameters of oil flax straw and stalks obtained by theoretical (Table 5) and experimental (Table 6) research are generalized. In addition, the technological properties of oil flax straw and stalk are divided into the primary and the secondary ones, with their limit values specified (Table 7).

Consequently, according to the theoretical studies, it has been found that oil flax straw should be processed at a technological moisture content of 6.0—8.0% and input at processing plant at a standard moisture content of 19%. The total length of the stalks is specified as maximum values, since it is impossible to get accurate values of minimum length for oil flax straw after combine harvesting of seeds. The maximum permissible impurity content is up to 20%, based on the theoretical analysis of the world experience of cultivating oil and grain crops according to which the impurity content shall not exceed 20—25%.

The next task of the research is to determine the dependence of the general straw quality on its primary technological properties. According to the results of the study, a general methodology and basic principles for determining the general quality of oil flax straw need to be developed, which will make it possible to estimate the feasibility of its processing for the purpose of industrial application and to determine the functional purpose of the resulting products. This can be done with the help of qualimetry methods [16, 17].

Since the authors studied oil flax straw for which there were no basic (standardized) values, an expert method with the mathematical and statistical processing of the obtained expert assessments was used to assess the straw quality [16]. The procedure for assessing the oil flax straw quality by experts was carried out using elements of the combined method. In order to determine the importance of the quality indicators of the straw stalks, the opinion of experts who are highly skilled specialists in this field is really important. Eight well-known specialists in processing oil flax straw, employees of the laboratories of the DPDG *Askaniyske* and the Institute of Irrigated Agriculture of the NAS of Ukraine were engaged in the expert assessment. To determine the quality of oil flax straw, the indicators given in Table 7 were selected. with the technological and standard moisture content combined into one qualitative parameter — moisture content.

Table 6

Average and Limit Values of Physical and Mechanical Parameters of Oil Flax Straw and Stalks Harvested by Different Methods

Parameters	Straw		Stalks	
	Limit	Average	Limit	Average
Impurity content, %	5.29—6.63	5.66	0.0	0.0
Bast output from stalks, %	34.2—38.5	36.57	15.3—29.1	23.3
Straw color group	II	II	I—II	II
Total length, cm	22.0—36.5	27.5	50.0—73.0	57.0
Technical length, cm	20.0—34.8	24.8	31.0—57.0	39.7
Technical length to total length, %	69.4—83.3	76.60	58.5—78.1	68.9
Diameter, mm	2.4—3.0	2.6	1.6—4.0	2.7

Table 7

Technological Properties of Oil Flax Straw

Parameter	Value
Primary technological properties	
Technological moisture content, %	6.0—8.0
Standard moisture content, %	19.0
Impurity content, %	5.0—20.0
Bast output for stalks, %	11.0—40.0
Straw color group	I, II, III
Secondary technological properties	
Total length, cm	22.0—90.0
Technical length, cm	15.0—78.0
Diameter, mm	1.0—4.1
Technical length to total length, %	60.0—90.0

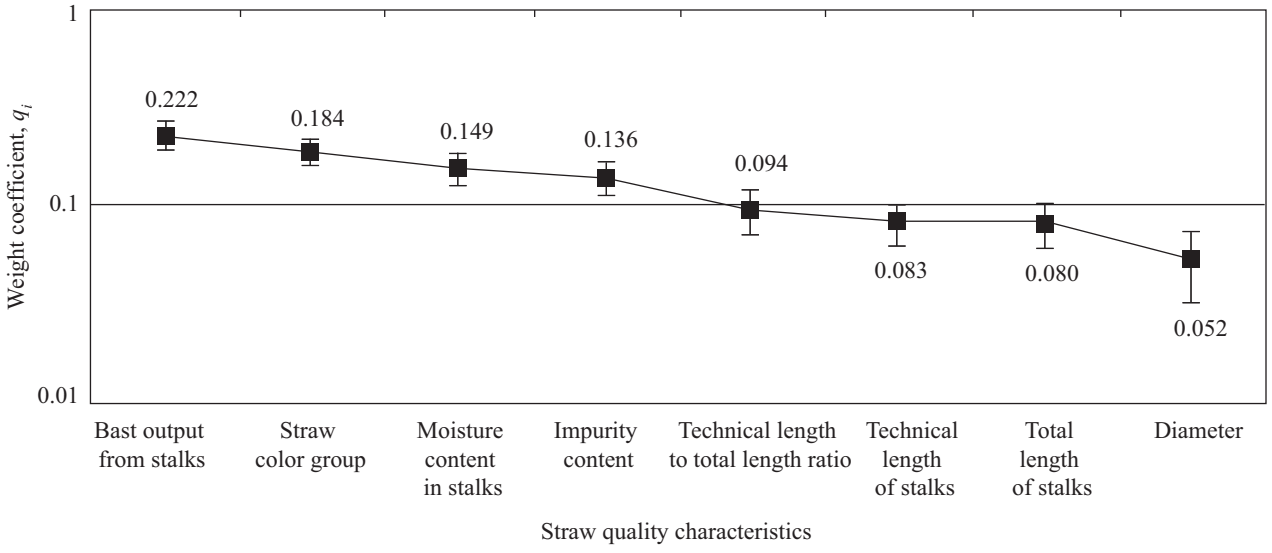


Fig. 5. Weighting coefficients of oil flax straw quality indices

For processing the data obtained from the expert assessment of the technological characteristics of oil flax straw, the scoring method has been chosen, and the total score R_i has been calculated (Table 8).

Analysis of data given in Table 8 has shown that the majority of experts believes the main criteria of oil falx straw suitability for industrial application are as follows: bast output from stalks, straw color, impurity content, and moisture content. The plausibility of expert assessment has been confirmed by mathematical and statistical methods of squared deviation for each parameter (Δ_i^2), squared deviation sum (S), and concordance coefficient (Ku) (Table 9).

The weighting coefficients q_i for each quality indicator have been determined based on relative importance, which enables to select significant qualitative characteristics of straw important for its primary processing. The weight of each index

Table 8

Scoring of Technological Properties of Oil Flax Straw

Quality indicators of oil flax straw	Expert score of quality indicators								R_i
	1	2	3	4	5	6	7	8	
Bast output from stalks	8	8	8	8	8	8	8	8	64
Impurity content	4	5	5	3	5	6	6	5	39
Straw color group	6	7	7	5	7	7	7	7	53
Moisture content	5	6	6	4	6	5	5	6	43
Technical length to total length	1	4	3	6	2	2	4	2	24
Technical length	3	2	4	7	3	3	2	3	27
Total length	2	3	2	1	4	4	3	4	23
Diameter	7	1	1	2	1	1	1	1	15
Total	36	36	36	36	36	36	36	36	288
Average score (T):	36								
Control score Σx_{ij}	36								

has been calculated as arithmetical mean of its weights assigned by all experts. The results of mathematical calculations are shown in Fig. 5.

Having analyzed the results of the calculations, one can conclude that the most significant of the above indicators are those with the highest weighting factors: bast output from stalks (q_i = 0.222), impurity content (q_2 = 0.184), straw color group (q_3 = 0.149), and moisture content (q_4 = 0.136)). These are just those that showing the quality of oil flax straw as a raw material for industrial use [16, 17]. Thus, as a result of the research, it has been established that the general level of oil flax straw quality shall be assessed based on the three most important indicators: bast output from stalks, impurity content, and straw color group. This general indicator of quality assessment is referred to as "oil flax straw index", while moisture content is regarded separately. According to preliminary theoretical studies [2, 4, 6, 10], it has been established that oil flax straw shall be processed at a technological moisture content of 6.0—8.0% and input at a standard moisture content of 19%, which affects the actual weight of batch.

Table 9

Statistical Processing of Oil Flax Straw Properties Scoring Results

Oil flax straw quality indicators	Parameter		
	R_i	Δ_i	Δ_i^2
Bast output from stalks	64	28	784
Impurity content	39	3	9
Straw color group	53	17	289
Moisture content	43	7	49
Technical length to total length	24	–12	144
Technical length	27	–9	81
Total length	23	–13	169
Diameter	15	–21	441
Total		288	
Squared deviation sum, *S*		1966	
Concordance coefficient, *Ku*		0,731	

Consequently, during the input of raw materials for industrial production, it is necessary to take into account the two factors: moisture content and straw index (as established based on bast output from stalks, impurity content, and straw color group, the limit values of which are given above). Since the quality that is determined by the straw index depends on these indicators, they have been ranked according to the five levels: 5, 4, 3, 2, 1. For example, the straw having an index of 5 is characterized by the highest quality parameters, while the straw indexed 1 has the lowest quality. Table 10 contains the indexes of oil flax straw and their permissible values for assessing the feasibility of industrial processing of oil flax straw.

The detailed analysis of world and Ukrainian theoretical and practical research, as well as the results of abovementioned experiments have shown that the bast output from the stalks of studied raw material varies from 11 % to 40 %, while the impurity content in the straw ranges from 5% to 20%. Therefore, to get more precise assessment of oil flax quality using the differential met-

Table 10

Oil Flax Straw Quality Indicators

Quality indicators	Value
Primary	
Moisture content, %	Technological — 6,0–8,0 Standard — 19,0 Actual: rolled straw — 20.0, at most baled straw — 25.0, at most
To measure the index of straw	
Bast output from stalks, %	11.0–40.0
Impurity content, %	5.0–20.0
Straw color group	I, II, III
Secondary	
Total length, cm	22.0—90.0
Technical length, cm	15.0—78.0
Diameter, mm	1.0—4.1
Technical part in total length, %	60.0—90.0

hod [16], relative values of these indicators have been scored. The results of mathematical processing of impurity content and bast output values are given in Tables 11, 12.

Based on the sum of scores of relative impurity content and bast output from stalks, with straw color taken into consideration, the oil flax straw index is determined according to Table 13.

Table 11

Relative Impurity Content in Oil Flaw Straw (score)

Impurity content in the straw		Impurity content in the straw	
%	score	%	score
5	100.0	13	38.5
6	83.3	14	35.7
7	71.4	15	33.3
8	62.5	16	31.3
9	55.5	17	29.4
10	50.0	18	27.7
11	45.4	19	26.3
12	41.7	20	25.0

Table 12

Relative Bast Output from Oil Flax Stalks (score)

Bast output from stalks		Bast output from stalks	
%	score	%	score
11	27.5	26	65.0
12	30.0	27	67.5
13	32.5	28	70.0
14	35.0	29	72.5
15	37.5	30	75.0
16	40.0	31	77.5
17	42.5	32	80.0
18	45.0	33	82.5
19	47.5	34	85.0
20	50.0	35	87.5
21	52.5	36	90.0
22	55.0	37	92.5
23	57.5	38	95.0
24	60.0	39	97.5
25	62.5	40	100.0

The oil flax straw index determined for the sample characterizes the entire batch.

The introduction of any measures to improve the quality of products should be economically justified. Therefore, an important component of the quality management system is economic efficiency of quality improvement [17]. As a result of the economic analysis, it has been established that Ukraine has a sufficient amount of raw materials to ensure all-year uninterrupted operation of oil flax straw processing factories. According to official data, in 2016, oil falx plantations covered 66.8 thousand hectares in Ukraine (Fig. 1). With an average straw yield of 1 t / ha, 66.8 thousand tons of oil flax straw was produced in Ukraine, in 2016. The annual capacity of the designed flax processing mini-plant being 1113.6 tons, it can continuously operate all the year round using domestic raw materials. The results of economic calculations are shown in Table 14.

Table 13

Oil Flax Straw Index Determination

Straw index	Quality Score for straw by color, in points		
	I group	II group	III group
5	200—132	—	—
4	131—98	200—110	—
3	97—79	109—82	200—90
2	78—64	81—65	89—66
1	63—53	64—53	65—53

Table 14

Economic Efficiency of Oil Flax Straw Processing

Economic indices	At a bast output of 11 %	At a bast output of 30 %
Proceeds from sales, UAH:	3 723 800,45	7 270 583,04
a) bast	2 237 144,45	6 101 303,04
b) boon	1 486 656,00	1 169 280,00
Profit from sales, UAH	1 815 931,26	5 362 713,85
Profitability, %	95,18	281,08
Payback period, year	1,05	0,36

The analysis of Table 14 data testifies to the economic efficiency of oil flax straw processing for the purpose of obtaining raw materials (bast and boon) suitable for the production of innovative products: composite materials of various functional purposes, pulp and paper products, and fuels in the form of briquettes, pellets, and boon briquettes, which have undeniable advantages over the counterparts.

CONCLUSIONS

As a result of comprehensive theoretical and experimental research, a method for assessing the oil flax straw quality has been developed. The obtained results have shown that using this method it is possible to reliably assess the quality of oil flax straw and, based on this assessment, the expediency of processing oil flax straw primary and using the obtained products in various industries. Based on the results of theoretical and experimental research, technical specifications TU U 01.1-2303511525 — 001:2016 *Oil Flax Straw. Specifications* have been developed and approved at *Kherson Standartmetrology*. This technical documentation for assessing the oil flax straw quality has enabled to introduce industrial processing of this raw material at domestic factories. Certified raw materials can be used for the production of competitive products of various functional purposes.

According to the calculations, the cost of products made of domestic raw oil flax has been established to be significantly lower than that of products from imported raw materials. So, at a minimum bast output from the stalks of 11%, the net annual profit from the sale of products (bast and boon) reaches UAH 18,15931.26. The profitability of straw processing is 95.18%, and the payback period is 1.05 years. At a bast output of 30%, the net annual profit from sale of oil flax straw products (bast and boon) amounts to UAH 5362713.85; the profitability of straw processing is 281.08%, and the payback period is 0.36 years. Therefore, burning of oil flax straw in the field is economically unfeasible.

REFERENCES

1. State Statistics Service of Ukraine. Kyiv, 2018. URL: http://www.ukrstat.gov.ua/ (Last accessed: 20.04.2018).

2. Golovenko, T. N., Boyko, G. A., Diaghilev, A. S., Shovkomod, A. V. (2017). Industrial use of oilseed flax straw, both in the world and in Ukraine. *Young scientist*., 1(41), 37—40 [in Ukrainian].

3. Flax Council of Canada: Flax straw and fibre past and present uses. Canada, 2015. URL: http://flaxcouncil.ca/growing-flax/chapters/flax-straw-and-fibre/ (Last accessed: 17.02.2018).

4. Saskatchewan Flax Development Commission. Canada, 2015. URL: http://www.saskflax.com/ (Last accessed: 06.10.2017).

5. Hennink, S., Van Soest, L. J. M., Pithan, K., Hof, L. (Eds.). (April, 1994). *Alternative oilseed and fibrecrops for cool and wet regions of Europe*. Proceedings of the COST 814 Workshop. Wageningen, Netherlands, 1994.

6. Tihosova, G. A, Chursina, L. A, Gorach, O. O, Yayyuk, T. I. (2011). *Scientific bases of complex processing of oilseed flax stems and seeds*. Kherson: Oldi-plius.

7. Golovenko, T. N., Tihosova, G. A, Chursina, L. A, Meniylo-Basista, I. A. (2014). *Innovative technologies for the production of nonwoven and cellulosic materials from oilseed flax*. Kherson: Grin DS.

8. Putintseva, S. V. (2015). *Properties of filter paper based on cellulose from oilseed flax*. PhD (Techn.). Lutsk [in Ukrainian].

9. Boiko, G. A. (2014). *Merchandizing analysis of mixed yarn with fibers of oilseed flax for knitted products*. PhD (Techn.). Lutsk [in Ukrainian].

10. Fedosova, N. M. (2012). *Investigation of the properties of flax-mezheouk and the justification of the method for predicting its technological value*. PhD (Techn.). Kostroma [in Russian].

11. Golovenko, T. N., Tihosova, G. A., Bartkiv, L. G., Kniazev, A. V., Yanyuk, T. I. (2017). The necessary of development of the standardization system for the new products from oilseed flax straw. *National Science Review*, 3(1) (4), 335—342 [in English].

12. Golovenko, T. N., Tihosova, G. A., Chursina, L. A., Bartkiv, L. G., Shovkomod, A. V. (2017). Current methods standardization of oilseed flax straw in Ukraine for its industrial application. *Engineering Computations*, 34, 8(2), 2534—2541 [in Ukrainian].

13. GOST 14897-69 Straw linen. Technical specifications: [Introduced 1969-08-15]. Moscow: Publishing House of Standards, 1989.

14. GOST 28285-89 Straw linen. Requirements blanks: [Introduced 01/07/1990]. Moscow: Publishing House of Standards, 1990.

15. Golovenko, T. N., Boiko, G. A., Ivanenko, E. A., Shovkomod, A. V. (2016). General characteristics of parameters oilseed flax to manufacture innovative products. *Young scientist*, 5(32), 218—222 [in Ukrainian].

16. Bozhenko, L. I., Gutta, O. Yo. (2001). *Quality management, fundamentals of product standardization and certification*. Lviv: Textbook.

17. Innovative commodity policy. Economic essence of the determination of the level of product quality. Kyiv, 2002. URL: https://uchebnik-online.net/book/619-tovarna-innovacijna-politika-navchalnij-posibnik-kardash-v-ya-pavlenko-i-a-shafalyuk-o-k/15-33-ekonomichnij-zmist-viznachennya-rivnya-yakosti-produkciyi.html (Last accessed: 27.03.2018).

Received 12.10.18

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ПЕРСПЕКТИВНІ МЕТОДИ Й СИСТЕМИ КОНТРОЛЮ ЯКОСТІ ІННОВАЦІЙНОЇ ЛУБ'ЯНОЇ СИРОВИНИ

Вступ. У економічно розвинених країнах світу льон олійний розглядається не лише як культура для отримання насіння, а й як джерело додаткової високоякісної текстильної сировини. Для України льон олійний — це єдиний вітчизняний сировинний ресурс, який може стати альтернативою імпортованим бавовні та льону-довгунцю для використання в текстильній, целюлозно-паперовій промисловостях та для виробництва армованих композиційних матеріалів.

Аналіз стану стандартизації на продукцію зі стебел льону олійного свідчить про відсутність нормативних документів для визначення їх якості, а, відповідно, розробка останніх є актуальним питанням сьогодення, оскільки організація переробки та реалізація зазначеної продукції в умовах сучасного ринку й вимог споживача неможливі без відповідної стандартизації та сертифікації.

Проблематика. Необхідність розробки стандартів на продукцію зі стебел льону олійного для визначення якості та надання їй товарознавчої характеристики є, нагальною, оскільки затвердження такої технічної документації на державному рівні стимулює створення ринків реалізації соломи льону олійного як сировини для одержання волокон широкого промислового застосування з метою її первинної переробки.

Мета. Розробка вітчизняних нормативних документів для контролю якості луб'яної сировини «нового покоління» — соломи льону олійного, з урахуванням вимог сучасного споживача.

Матеріали й методи. Методами кваліметрії створено комплексну методологію визначення загального рівня якості соломи льону олійного, як промислової сировини.

Результати. Розроблено та затверджено в Державному підприємстві «Херсонстандартметрологія» технічні умови ТУ У 01.1-2303511525 — 001:2016 «Солома льону олійного. Технічні умови».

Висновки. Сертифікована вітчизняна сировина із стебел льону олійного, а саме солома, може бути використана текстильними, целюлозо-паперовими та іншими виробництвами України для виготовлення інноваційної конкурентоспроможної продукції різного функціонального призначення.

Ключові слова: солома, льон олійний, якість, технічні умови.

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ПЕРСПЕКТИВНЫЕ МЕТОДЫ И СИСТЕМЫ КОНТРОЛЯ КАЧЕСТВА ИННОВАЦИОННОГО ЛУБЯНОГО СЫРЬЯ

Введение. В экономически развитых странах мира лен масличный рассматривается как культура не только для получения семян, но и как источник дополнительного высококачественного текстильного сырья. Для Украины лен масличный — это единственный отечественный сырьевой ресурс, который может стать альтернативой импортному хлопку и льну-долгунцу для использования в текстильной, целлюлозно-бумажной промышленностях и для производства армированных композиционных материалов.

Анализ состояния стандартизации на продукцию из стеблей льна масличного свидетельствует об отсутствии нормативных документов для определения их качества, а, соответственно, разработка последних является актуальным вопросом современности. Поскольку организация переработки и реализация указанной продукции в условиях современного рынка и требований потребителя невозможны без соответствующей стандартизации и сертификации.

Проблематика. Необходимость разработки стандартов на продукцию из стеблей льна масличного для определения качества и предоставления ей товароведческой характеристики является насущной, поскольку утверждение такой технической документации на государственном уровне стимулирует создание рынков реализации соломы льна масличного как сырья для получения волокон широкого промышленного применения, с целью ее первичной переработки.

Цель. Разработка отечественных нормативных документов для контроля качества лубяного сырья «нового поколения» — соломы льна масличного, с учетом требований современного потребителя.

Материалы и методы. Методами квалиметрии создана комплексная методология определения общего уровня качества соломы льна масличного как промышленного сырья.

Результаты. Разработаны и утверждены в Государственном предприятии «Херсонстандартметрология» технические условия ТУ У 01.1-2303511525 - 001: 2016 «Солома льна масличного. Технические условия».

Выводы. Сертифицированное отечественное сырье из стеблей льна масличного, а именно солома, может быть использована текстильными, целлюлозно-бумажными и другими производствами Украины для изготовления инновационной конкурентоспособной продукции различного функционального назначения.

Ключевые слова: солома, лен масличный, качество, технические условия.