INNOVATIVE METHODOLOGY AND SOFTWARE FOR QUALITY CONTROL OF NEW BAST RAW MATERIAL WITH OILSEED FLAX

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Abstract: *The scientific novelty of this work is to create an innovative approach to the assessment of oilseed flax straw and retted straw, on the basis of which technical specifications are declared; nomenclatures of quality characteristics of straw and retted straw as industrial raw materials and their limit values are defined, the software to improve and accelerate the process of determining the quality of new raw materials was developed. This stems from the fact that nowadays oilseed flax is a technical agricultural crop that can play a strategically important role in the formation of the domestic market of bast raw material as well as of ready-made competitive ecological products. This is a very important issue for Ukraine, as most state enterprises operate on imported raw materials, a high price of which reduces the competitiveness of finished goods in the domestic and world markets.*

Keywords: *oilseed flax, straw, retted straw, quality, computer system, methodology, technical specifications.*

1 INTRODUCTION

So far, in today's conditions of the development of advanced technologies, the directions of application of bast raw materials have increased significantly and in its list, in practice, such unconventional crop as oilseed flax has been introduced. Economically developed countries such as Canada, the USA, Germany, Sweden, Italy and France have been using this flax group for over 11 years, not just for seeds. Fibers derived from stems of oilseed flax now occupy a niche of bast raw material of the "new generation" for the production of a wide range of products of various industrial uses [1].

Oilseed flax, provided it is in sufficient amount in our country [2], acts as the main source of natural raw materials for various industries in the conditions of their full raw material import dependence. Therefore, processing of oilseed flax stems at the enterprises of Ukraine and the production of innovative products on the basis of the use of natural raw materials of high quality is a step towards the future.

The scientists of Kherson National Technical University (further - KNTU) developed resource-saving technologies for complex processing of oilseed flax stems [3]. Under these technologies, in laboratory and production conditions, the samples of innovative products of various functional uses were created: filter paper [4], blended yarn [5], cellulose-containing semi-finished products, composite products and non-woven materials of such types as flax batting, upholstery cloth and nonwoven cloth [6]. These products have a great economic importance, but there are other obstacles in organizing the industrial complex for processing oilseed flax stems in Ukraine. This is due to the lack of targeted regulatory documents for the assessment of products from oilseed flax stems. After all, industrial processing of raw materials, the manufacture of innovative products, as well as their implementation in the domestic and world markets are impossible without the basics of standardization, certification and the use of its methods and means [7].

2 LITERATURE REVIEW

All over the world, the latest technologies and equipment for the complex processing of oilseed flax stems for the manufacture of innovative products are being developed and implemented. At the same time, the system for assessing the quality of straw, retted straw and oilseed flax stems has significant drawbacks. It stems from the fact that the enterprises of Canada, the USA, Germany, Sweden, Italy, France and Poland are assessing oilseed flax straw and retted straw by organoleptic methods, which are carried out by certified highly

skilled specialists and the fibers are assessed according to the current regulatory documents for determining the quality of long-stalked flax, cotton and other textile fibers of natural or chemical origin [8-13]. In Russia, Belarus and Ukraine, the determination of some qualitative indicators of straw, retted straw and oilseed flax fiber is carried out according to the existing regulatory documents for long-stalked flax: GOST 28285-89, GOST 24383-89, DSTU 4149:2003, GOST 9394-76, DSTU 5015:2008, TU 17 U 00306710.079 – 2000, TU.U. 05495816.005 – 2000 [3, 5-7].

As a result of systematized experimental research carried out by the scientists of KNTU it is proved that straw, retted straw and oilseed flax fibers present fundamentally new bast raw material since they differ significantly by morphological, anatomical, chemical composition and technological properties from the features of long-stalked flax [3, 6]. Therefore, it is incorrect to use the aforementioned regulatory documents for assessing the quality of products from oilseed flax stems.

Thus, based on the foregoing, the topical issue of today is the creation of a targeted methodology for determining the quality level of new bast raw material from oilseed flax: straw, retted straw and fibers. The results of the scientific work should be declared in regulatory documents and approved at the state level.

3 RESEARCH METHODOLOGY

In the course of detailed analysis of the world and domestic experience of industrial use, scientific research, as well as the principles for assessing the products of oilseed flax stems, a nomenclature of all the quality characteristics of straw and retted straw has been determined and their range from a minimum to a maximum value has been generalized [8-14]. The summary of results is shown in Tables 1 and 2.

The obtained results of scientific research are an important theoretical basis when creating a new methodology for assessing the quality of straw, retted straw and oilseed flax fibers, taking into account all modern requirements of consumers.

Subsequently, it was necessary to determine which indicators (Tables 1 and 2) affect the quality level of raw materials and predict the feasibility of its primary processing. Therefore, in order to solve the tasks set, the existing methods of qualimetry are analyzed, which are now widely used to determine the general level of quality of a certain product [15, 16].

In our case, standardization objects - straw, retted straw and fiber from oilseed flax stems are ambiguous, because they can act as raw materials and products and also do not have basic (standardized) values. Thus, in order to determine the importance of the characteristics of the quality of oilseed flax straw and retted straw, it is expedient to use an expert method with the mathematical and statistical processing of the expert estimates obtained.

Table1 Quality characteristics of oilseed flax straw and their limit values

№ of position	Quality characteristics of straw	Limit values
1.	Moisture content [%]	technological 6.0-8.0 standardized 19.0 actual: in rolls - not < 20.0 in bales - not < 25.0
2.	Bast yield from stems [%]	11.0-40.0
3.	Impurity [%]	5.0-20.0
4.	Straw color group	I, II, III
5.	Technical part in total length [%]	60.0-90.0
6.	Technical length [cm]	15.0-78.0
7.	Total length [cm]	up to 90.0
8.	Diameter [mm]	1.0-4.1

Table 2 Quality characteristics of oilseed flax retted straw and their limit values

№ of position	Quality characteristics of retted straw	Limit values
1.	Moisture content [%]	technological 6.0-8.0 standardized 19.0 actual: in rolls - not < 20.0 in bales - not < 25.0
2.	Fiber yield [%]	11.0-40.0
3.	Degree of retted straw maturation (separation, unit/intensity of reflected light flux, lux)	- mature (4.1 and more/less than 23) - immature (from 3.1 to 4.0/23-27) - straw (3.0 and less/more than 27)
4.	Fiber color index (retted straw color group)	1.0-4.0 (I, II, III, IV)
5.	Impurity of retted straw [%]	5.0-20.0
6.	Technical part in total length [%]	60.0-90.0
7.	Technical length [cm]	15.0-78.0
8.	Total length [cm]	up to 90.0
9.	Diameter [mm]	1.0-4.1

The procedure for straw and retted straw assessment was carried out by experts using the elements of the mixed method [15, 17]. For the processing of expert estimates, the method of ranking was used, after that the sum of ranks *Ri* was calculated. The results of the experiment are shown in Tables 3 and 4.

Table 3 Matrix ranking of technological characteristics of oilseed flax straw

№ of position	Quality characteristics of straw	Ranked estimate of quality indicator								R_i
		1	2	3	4	5	6	7	8	
1.	Bast yield from stems	8	8	8	8	8	8	8	8	64
2.	Impurity	4	5	5	3	5	6	6	5	39
3.	Straw color group	6	7	7	5	7	7	7	7	53
4.	Moisture content	5	6	6	4	6	5	5	6	43
5.	Technical part in total length	1	4	3	6	2	2	4	2	24
6.	Technical length	3	2	4	7	3	3	2	3	27
7.	Total length	2	3	2	1	4	4	3	4	23
8.	Diameter	7	1	1	2	1	1	1	1	15
Sum of ranked estimate of each j-expert Σm_{ij}		36	36	36	36	36	36	36	36	-
Total sum of ranks ΣR_i		-								288
Average sum of ranks T		36								
Control sum of ranks Σx_{ij}		36								

Table 4 Matrix ranking of technological characteristics of oilseed flax retted straw

№ of position	Quality characteristics of retted straw	Ranked estimate of quality indicator								R_i
		1	2	3	4	5	6	7	8	
1.	Fiber yield	7	9	8	9	8	8	9	9	67
2.	Impurity	4	6	5	3	5	6	7	5	41
3.	Fiber color group	8	5	7	5	7	5	6	7	50
4.	Separability	9	8	9	8	9	9	8	8	68
5.	Moisture content	5	7	4	4	6	7	5	6	44
6.	Technical part in total length	6	4	3	7	4	4	3	2	33
7.	Technical length	3	3	6	6	2	3	4	3	30
8.	Total length	1	2	2	1	3	2	1	4	16
9.	Diameter	2	1	1	2	1	1	2	1	11
Sum of ranked estimate of each j-expert Σm_{ij}		45	45	45	45	45	45	45	45	-
Total sum of ranks ΣR_i		-								360
Average sum of ranks T		40								
Control sum of ranks Σx_{ij}		45								

The sum of ranks of each quality indicator R_i was calculated by the following formula:

$$R_i = \sum_{j=1}^{n} m_{ij} \quad (1)$$

where: m_{ij} - rank of *i*-quality indicator, set by j-expert; n - number of experts.

The verification of the correctness of the matrix compilation was performed on the basis of the calculation of the control sum $\sum x_{ij}$ (2) and the average sum of ranks T (3):

$$\sum x_{ij} = \frac{(1+m)\cdot m}{2} \quad (2)$$

where: m - number of expert assessment objects (indicators).

$$T = \frac{\sum R_i}{m} \quad (3)$$

The sums in the columns of the matrix are equal to each other and the control sum of ranks, and therefore, the matrix is composed correctly [15].

The high relevance and reliability of the received expert estimates (ranks) is confirmed by the mathematical and statistical method (Tables 5 and 6) according to which the degree of coincidence of experts' estimates, expressed by the coefficient of concordance K_u (4), the total sum of the squares of deviations S (5) and the square of deviations for each parameter Δ_i^2 (6) were determined:

$$K_u = \frac{12 \cdot S}{n^2(m^3 - m)} \quad (4)$$

$$S = \sum_{i=1}^{m} \Delta_i^2 \quad (5)$$

$$\Delta_i = R_i - T \quad (6)$$

where: S is the sum of the squares of deviations of the sum of the ranks of each object of examination from the average sum of the ranks.

Further work with expert estimates is only feasible if the coefficient of concordation is greater than or equal to 0.4 [15]. In our case, the coefficient of concordation K_u of the characteristics of the quality of oilseed flax straw is 0.731 and that of retted straw is 0.832, which indicates the presence of a high degree of consistency of expert opinions and allows assessing the agreement of experts' decisions as “satisfactory". Subsequently, on the basis of the expert estimates obtained, according to the scale of relative significance, the weight coefficients q_i were determined for each characteristic of the quality of straw and retted straw, according to the following formula:

$$q_i = \frac{R_i}{\sum R_i} \quad (7)$$

Table 5 Mathematical and statistical processing of the results of the ranking of technological characteristics of the oilseed flax straw

№ of position	Quality characteristics of straw	Mathematical processing of data		
		Ri	Δ_i	Δ_i^2
1.	Bast yield from stems	64	28	784
2.	Impurity	39	3	9
3.	Straw color group	53	17	289
4.	Moisture content	43	7	49
5.	Technical part in total length	24	-12	144
6.	Technical length	27	-9	81
7.	Total length	23	-13	196
8.	Diameter	15	-21	441
Total		288	-	-
Total sum of the squares of deviations *S*		-	-	1966
Coefficient of concordance K_u		0.731		

Table 6 Mathematical and statistical processing of the results of the ranking of technological characteristics of the oilseed flax retted straw

№ of position	Quality characteristics of retted straw	Mathematical processing of data		
		Ri	Δ_i	Δ_i^2
1.	Fiber yield	67	27	729
2.	Impurity	41	1	1
3.	Fiber color group	50	10	100
4.	Separability	68	28	784
5.	Moisture content	44	4	16
6.	Technical part in total length	33	-7	49
7.	Technical length	30	-10	100
8.	Total length	16	-24	576
9.	Diameter	11	-29	841
Total		360	-	-
Total sum of the squares of deviations *S*		-	-	3196
Coefficient of concordance K_u		0.832		

Then, to the ordinal scale conduct a direct measurement of the weight coefficients, the sum of which must be equal to one. This will allow to distinguish from all *m* indicators the most significant indicators for which the condition $q_i > 1/m$ is fulfilled. Since $\Sigma\ qi = 1$, then the weight coefficients of meaningful indicators must be calculated according to the formula:

$$q_{i0} = q_i^* / \sum_{i=1}^{m} q_i^* \quad (8)$$

Determination of weight coefficients makes it possible to select significant qualitative characteristics of oilseed flax straw and retted straw stems, which in aggregate testify to the expediency of their primary processing. According to the research results, scales of relative importance of the characteristics of oilseed flax straw and retted straw were created, which are presented in Figures 1 and 2 in accordance.

Experts estimated the weight of each indicator according to the scale of relative significance. The total of all properties was taken as 1. Therefore, the most weighting coefficients will be those that are as close as possible to one.

Analyzing all the calculations obtained by the expert method, it can be claimed that the most important quality characteristics are those with the highest weight coefficients. That is, for straw they are bast yield stems, impurity, the group of straw color and moisture content, and for retted straw they include fiber content, the degree of retted straw maturity, fiber color indicator and its impurity. It is these characteristics that indicate the general level of quality of straw and retted straw as industrial raw materials.

A summary quality assessment is proposed to name "the number of oilseed flax straw" and "the number of oilseed flax retted straw". Since the quality level, that is the number of straw and retted straw, depends on the values of certain characteristics of quality, they were distributed to different degrees. As a result, for the first time, it is proposed to determine the number of oilseed flax straw and retted straw by five levels of quality: 5, 4, 3, 2, 1. For example, straw (retted straw) No. 5 is characterized by the best values of quality indicators, and straw (retted straw) No. 1 by the worst ones. A detailed analysis of the world and domestic works of scientific and practical nature (Tables 1 and 2) shows that the bast yield from stems and the fiber yield from the retted straw of this group of flax can vary in the range from 11 to 40%, the impurity of straw and retted straw from 5 to 20% and the color indicator of the retted straw fiber from 1.0 to 4.0. Therefore, for a more accurate evaluation

of the quality of straw and retted straw, it was suggested to calculate the relative values W_i, of the above-mentioned characteristics in scores by differential method [7]. Relative values were calculated by the following formulas:

$$W_i = \frac{P_i}{P_{iv}} \cdot 100 \quad (9)$$

,

$$W_i = \frac{P_{iv}}{P_i} \cdot 100, \quad (10)$$

where: P_i - the value of the single quality indicator being evaluated; P_{iv} – the value of the best quality indicator from the available single indicators being evaluated; $i = 1, 2,..., n$ - number of single quality indicators.

The formula (9) is used to assess the performance, an increase in the numerical value of which indicates an improvement in quality.

The formula (10) is used for comparison of indicators, reducing the numerical value which ensures the improvement of product quality. The differential evaluation reflects the linear relationship between the analyzed properties.

To determine the number of oilseed flax straw and retted straw for the first time, tables with fixed ranges of score values have been developed that correspond to a certain level of quality of raw materials, that is, the number.

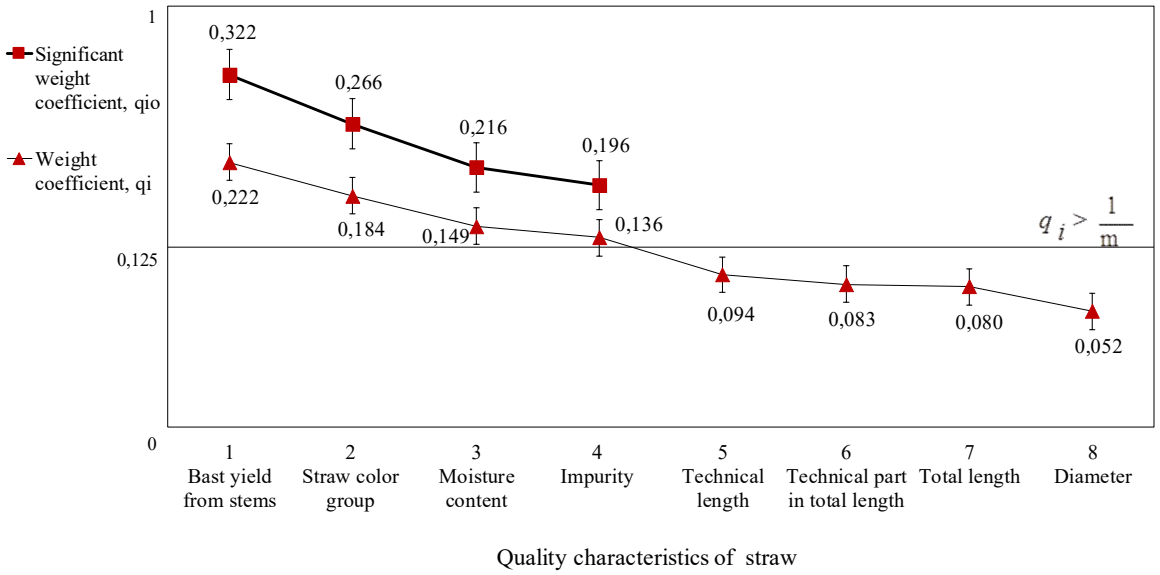

Figure 1 Scales of the ordinal for determining the significant of weight coefficients of the quality of oilseed flax straw

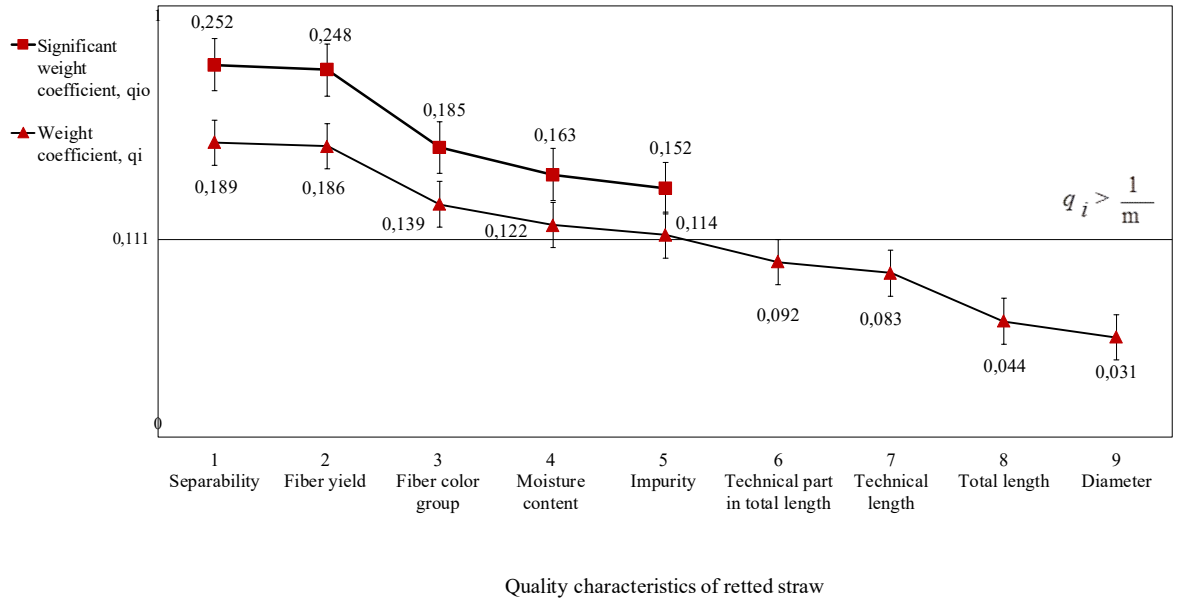

Figure 2 Scales of the ordinal for determining the significant of weight coefficients of the quality of oilseed flax retted straw

The result of the theoretical and experimental research was the development and approval of the technical specifications of TU U 01.1-2303511525 - 001: 2016 "Oilseed flax straw" at the State Enterprise "Kherson standart matrologia. Technical specifications" (Figure 3A) and TU U 01.1-05480298-001: 2017 "Oilseed flax retted straw, Technical specifications" (Figure 3C). In this case, the technical specifications are accompanied by the software “CQ Soilseed Flax” (Figure 3B) and “CQ Roilseed Flax” (Figure 3D) for straw and retted straw respectively.

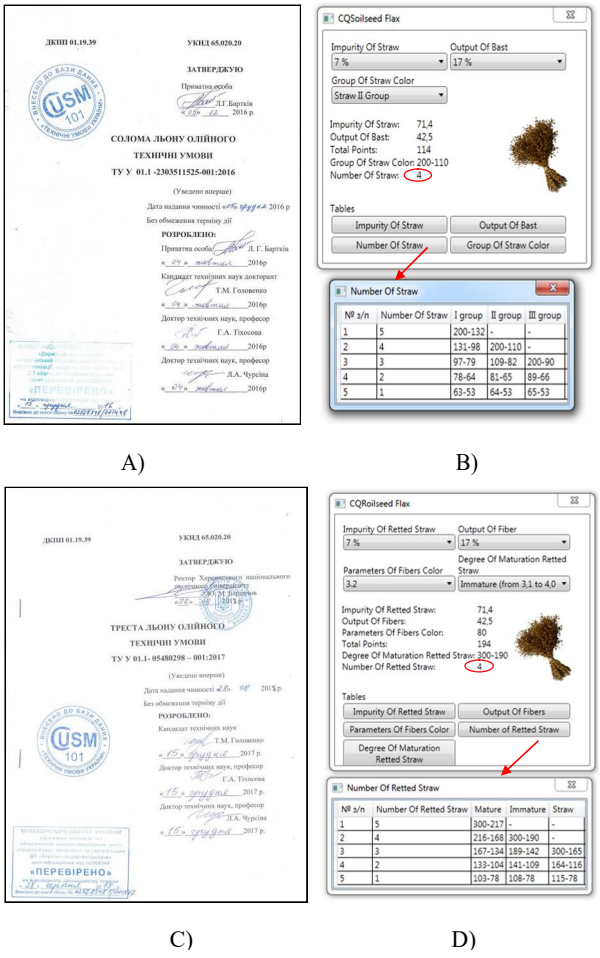

Figure 3 Technical specifications and the interface of the software for determining the quality of straw (A, B) and retted straw (C, D) of oilseed flax

These normative documents regulate the quality of oilseed flax straw and retted straw I and the expediency of their primary processing and industrial application. The use of automated systems can facilitate and accelerate the process of assessing raw materials at its entry to industrial production.

Software developed by KNTU scientists in a convenient standard interactive graphical interface that facilitates its mastering and can be used by consumers of any level of computer literacy. The program is designed for one user and does not involve simultaneous operation of many users.

The software operation requires a personal computer running MS Windows XP SP3 and above. Computer systems are written in a high-level C# programming language using the Microsoft Visual Studio 2010 development environment.

This software calculates the number of oilseed flax straw and retted straw. For all input data there are tables that correspond to the indispensable characteristics of quality and their values obtained by the instrumental calculation. Input data are set through the drop down list, which makes it easier to work with the program.

Thus, when receiving oilseed flax straw or retted straw at an industrial plant, the moisture content and the number of raw materials will be taken into account. To determine the number of oilseed flax straw, the relative values of straw impurity and bast yield from stems are summarized. By the resulting score, which is rounded to an integer, taking into account the color group, according to the table given on the interface B in Figure 3, the number of oilseed flax straw is determined. To determine the number of oilseed flax retted straw, the relative values of retted straw impurity, fiber content and fiber color indicator are summarized. Based on the score rounded to an integer, taking into account the level of the maturity of retted straw, according to the table given on the interface D of Figure 3, the number of oilseed flax retted straw is determined.

4 RESULTS

A necessary condition for the effective functioning of the mechanism of self-regulation of a market economy is competition. It is an important driving force for the development and success of any enterprise. Increasing the competitiveness of products is possible only under the condition of increasing its quality in comparison with an analogue. To date, flax oil is the only cheap, compared to imported analogues, bast-fiber raw material in Ukraine, the volumes of which can meet the needs of domestic enterprises for the production of cellulose-paper, technical, textile products and composite goods.

In order to organize the processing complex of oilseed flax stems and with the aim of the certification of products obtained on their basis, a methodology for assessing the straw and retted straw of this group of flax was developed. This methodology became the basis for the technical specifications, which are approved at the state level. These normative documents regulate the quality of oilseed flax straw and retted straw and their general level of quality is a number indicating the expediency of industrial processing and the functional purpose of the obtained products;

give an opportunity to create new markets of cheap certified raw materials in Ukraine; they allow agricultural producers correctly determine the cost of straw and retted straw when it is sold to industrial facilities, increasing profits from growing this crop as a whole; rationally and economically consume raw materials of a certain quality and determine the functional purpose of potential products.

In order to automate the quality assessment of the new bast raw material, software was developed that improves and accelerates the processing of data obtained by instrumental methods.

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