Scifood
vol. 19, 2025, p. 61-78
https://doi.org/10.5219/scifood.5
ISSN: 2989-4034 online
https://scifood.eu

Received: 14.11.2024
Revised: 15.12.2024
Accepted: 19.12.2024
Published: 1.1.2025

Modeling of the qualitative state of oilseeds from soybean seeds by multifactorial analysis of factor areas

Igor Palamarchuk, Mikhailo Mushtruk, Volodymyr Piddubny, Nina Osokina, Andrii Chahaida, Vitalii Mihailik, Olena Herasymchuk, Hennadii Tkachenko

ABSTRACT

The production of oil products in Ukraine is a leader not only in the European but also in the world market of food and processing industry products, therefore, the priority areas of scientific research in this field are the effective assessment of the quality of the oil obtained. Existing methods for assessing this product by organoleptic characteristics are subjective and do not allow the use of parameters that require more complex measurement technologies; which in general makes it impossible to conduct a comprehensive analysis of the quality of the studied product. The purpose of this study was to develop and implement a mathematical modeling method for numerical analysis of the quality of soybean oil product varieties. Qualitative assessment of the studied oil varieties was carried out using such indicators as the mass fraction of fat, peroxide, and acid number; content of free fatty acids, phosphatides, moisture, and impurities; it allowed to perform a numerical analysis using dimensionless complexes regarding the condition of the studied oil product varieties and compliance with regulatory indicators. When processing experimental data and calculating the developed quality criteria, programming methods, Excel, and COMPASS mathematical environments were used, which allowed the construction of geometric quality models and the necessary assessment criteria. According to the results of the research, it turned out that the characteristics of the studied varieties "OAS Avatar", "ES Mentor", "Sigalia", "ES Mentor" and "Gallek" do not meet the requirements for compliance with the quality thresholds by 160 - 220%, however, their current characteristics, which were selected for assessment, are within the average normative indicators. The proposed mathematical models can be implemented for practical application in assessing the condition of any complex object of research using an unlimited number of characteristics. At the same time, the main requirements for these parameters are their breadth of coverage of the physical, mechanical, and chemical-biological properties of the product and the ability to provide an objective and thorough assessment of its condition.

Keywords: product quality, oil grades, soybean seeds, regulatory characteristics, geometric quality models

INTRODUCTION

In the current conditions of intensive development of the agro-industrial complex and global changes in the food industry, soybean cultivation and the production of products based on it are becoming one of the most relevant areas for many countries, including Ukraine **[1]**. Soybean oil is significant among other vegetable oils due to its availability, universal nutritional qualities, and wide possibilities for use in the food industry and bioenergy **[2]**. In addition, the demand for soybean products is constantly growing due to the high content of polyunsaturated fatty acids, proteins, and antioxidants **[3]**. However, ensuring the stable quality of these products remains an essential challenge for manufacturers since the processes of soybean oil production are complex and depend on many factors **[4]**.

In particular, the quality of soybean oil can vary depending on the soybean variety, agrotechnical measures, climatic conditions of cultivation, seed collection and storage, technological processes of oil extraction, etc. **[5]**. Considering these factors requires an integrated approach that will allow assessing their impact separately and in combination. Therefore, modern research focuses on developing mathematical models and statistical methods that help accurately predict product quality indicators at different stages of production **[6]**. One promising method to solve such problems is multifactorial factor area analysis. This method provides the ability to identify optimal production parameters, allowing optimisation processes to achieve stable, high product quality **[7]**.

This work aims to develop a model that will allow for an accurate assessment of the quality of soybean oilseed products through multifactor analysis of factor areas, which, in turn, will allow for the optimisation of technological production parameters. This model will consider not only the influence of individual variables but also allow for identifying relationships between them, which is critically important for predicting the product's final quality.

To achieve this goal, the main factors affecting the quality of soybean oil products were considered. The main ones are varietal characteristics, methods, technical means for harvesting seeds, storage conditions, duration, and pre-treatment methods **[8]**. In addition, technological parameters of the oil extraction process, such as temperature and pressure, significantly affect the oil yield and quality. Another important aspect is the control of the acid number of the oil, which is a key indicator of its quality and stability during storage **[9]** and **[10]**.

One of the main challenges in ensuring the stable quality of oil products is their dependence on the interaction of numerous variable factors, complicating the traditional analysis approach. Multivariate analysis allows not only to analysis of individual variables but also to assess of their mutual influence, which is essential for obtaining a more detailed picture of the factors determining the product's final quality. Thanks to this approach, it is possible to create a mathematical model that allows you to choose the optimal parameters of production and quality control at different stages of the technological process.

Special attention in the framework of the study requires the analysis of factor areas, which allows you to visualise and understand the relationships between individual factors and their impact on the quality of the final product. This approach will enable you to comprehensively consider the specifics of raw materials, the effect of technological parameters, and the possibility of adjusting these parameters to achieve the highest possible quality indicators. Multifactor analysis of factor areas aims to ensure production's sustainability and technological processes' adaptability to specific requirements for product quality.

In addition, the study includes an analysis of the main methods of pre-treatment of seeds and their impact on the oil quality. Given that pre-treatment of soybean seeds is one of the main stages affecting the quality of the final product, it is essential to determine the optimal methods for increasing the yield and quality of the oil. Thus, the study includes an analysis of the temperature regime, type of treatment, and other parameters that allow obtaining high-quality products.

In general, the results of this study can become the basis for developing recommendations for optimising the production of soybean oil products, which will significantly impact the quality and stability of products on the market. The developed model can also be helpful for further research on other vegetable oils or similar products, where quality depends on numerous factors. Therefore, this study has important practical significance for the food industry, biotechnology, and agro-industrial complex.

Scientific Hypothesis

The first scientific hypothesis states that the area of the geometric quality model, which is built according to the specified evaluation parameters, constitutes the factor space of the qualitative state of oil products. When developing and selecting quality assessment criteria, the hypothesis was used that the factor space of the parameters presented for evaluation allows assessing the qualitative state of the product, and the corresponding areas of the polygons make it possible to evaluate numerically this state in comparison with the normative characteristics.

Objectives

Primary objectives: To develop a model that reflects the dependence of the quality indicators of oil products on multiple factors that affect its formation. To investigate the influence of various parameters of growing, storing and processing soybean seeds on the final quality indicators of oil. To identify the key factors that most significantly affect oil products' quality for further optimisation.

Secondary objectives: To develop a methodology for conducting multifactor analysis using modern mathematical methods and computer modelling. Experimental studies will be conducted to validate the proposed model on real samples of soybean seeds. To assess the possibility of applying the developed methodology to improve oil quality management in production conditions.

Such objectives provide a comprehensive approach to solving the problem and emphasise the scientific and practical significance of the study.

MATERIAL AND METHODS

Samples

Samples description: For experimental research, 5 oil samples were used:

• soybean oil of the *"EU Mentor"* variety, obtained in laboratory conditions by cold pressing on an extruder press (not refined and not frozen);

• soybean oil of the *"Gallek"* variety, obtained in laboratory conditions by cold pressing on an extruder press (not refined and not frozen);

• soybean oil of the *"OAS Avatar"* variety, obtained in laboratory conditions by cold pressing on an extruder press (not refined and not frozen);

• soybean oil of the *"Arisa"* variety, obtained in laboratory conditions by cold pressing on an extruder press (not refined and not frozen);

• oil from soybean seeds of the *"Sigali"* a variety, obtained by cold pressing (not refined and not frozen), obtained in laboratory conditions by cold pressing on an extruder press (not refined and not frozen).

Samples collection: Samples were taken from the total volume of each soybean variety in 25 kg bags and temporarily stored at 18°C.

Samples preparation: To prepare soybean oil samples for experiments, it is important to follow several key steps:

• soybean seed samples were selected to reflect the average quality of the overall crop;

• seeds should be clean and intact, without signs of damage or foreign impurities;

• a mechanical pressing method was used to obtain oil samples;

• the obtained oil was filtered to remove solid particles and impurities that could affect the experimental results;

• oil samples were stored in sealed containers under controlled temperature and humidity conditions to prevent oxidation processes and ensure appropriate characteristics during laboratory studies.

This sample preparation sequence will ensure the reproducibility and accuracy of experimental data for further modelling of the quality state of the product.

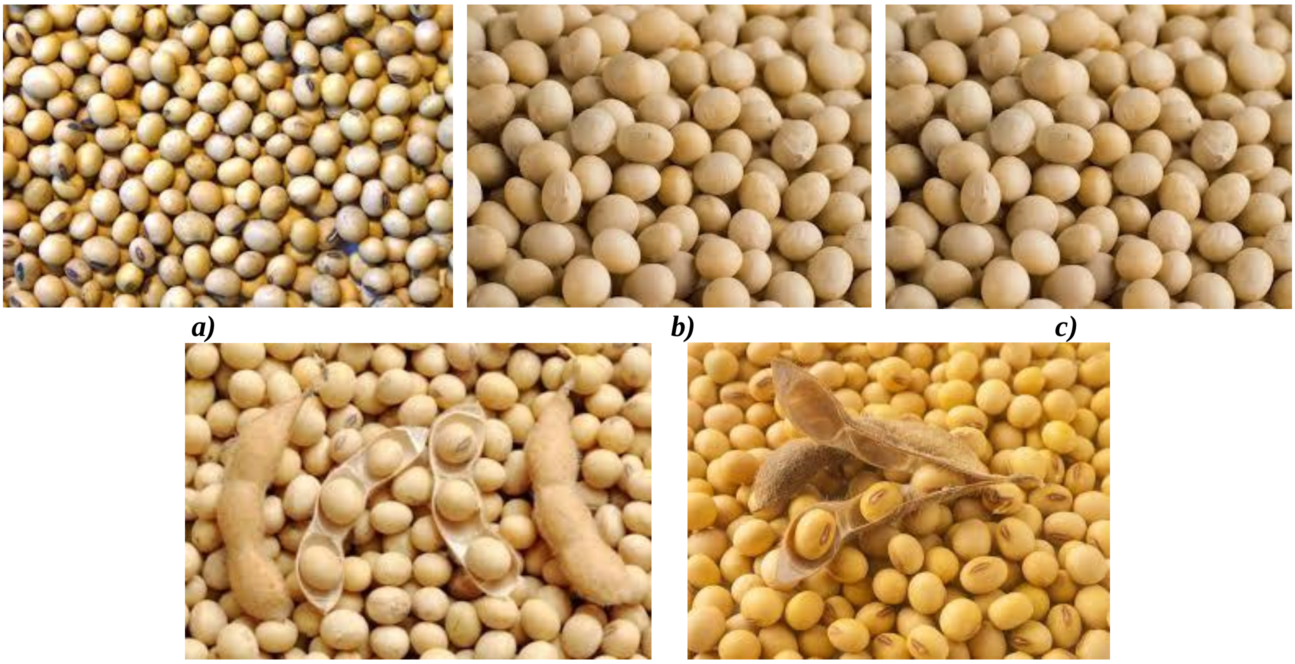
Number of samples analysed: 25 soybean oil samples were examined during experimental studies.

Chemicals

Sodium hydroxide, NaOH (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Sulfuric acid, H_2SO_4 (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Petroleum ether, H_3C-O-CH_3 (excise, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Anhydrous sodium sulfate, Na_2SO_2 (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Ethyl alcohol (96%), C_2H_5OH (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Diethyl ether, $C_4H_{10}O$ (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Phenolphthalein, $C_{20}H_{14}O_4$ (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Distilled water (supplier Limited Liability Company (Khimlaborreakt), Ukraine). Potassium iodide solution, KI (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Sodium thiosulfate solution, $Na_2S_2O_3$ (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine). Potassium hydroxide is a KOH solution in alcohol (supplier Limited Liability Company (Khimlaborreakt), Ukraine). Acetone, C_3H_6O (grade A, p.d.a, supplier Limited Liability Company (Khimlaborreakt), Ukraine).

Animals, Plants and Biological Materials

For experimental studies, the soybean seeds Figure 1 were used.



a) b) c) d) e)

Figure 1 Soybean seed test samples.
Note:
a – *"EU Mentor"* variety (supplier: Sofia Farm, Vinnytsia Region, Ukraine);
b – *"Gallek"* variety (supplier: Lito Farm, Kherson Region, Ukraine);
c – *"OAC Avatar"* variety (implemented by Agrofirm "Polissya LTD", Kyiv Region, Ukraine);
d – *"Arisa"* variety (implemented by Agrofirm "Skvyra", Kyiv Region, Ukraine);
e – *"Sigalia"* variety (implemented by Agrofirm "Petruk", Smila, Ukraine).

Instruments

Drying cabinet (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Muffle furnace (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Fat analyzer (SOX 406, producer (Khimlaborreaktyv) Limited Liability Company, China).

Mineralizer (Velp Scientifica, producer (Khimlaborreaktyv) Limited Liability Company, Italy).

Distiller for steam distillation (Velp Scientifica UDK 129 producer (Khimlaborreaktyv) Limited Liability Company, Italy).

Automatic penetrometer (K95500, producer (Khimlaborreaktyv) Limited Liability Company, USA).

pH meter (HI8314 HANNA, producer (Spectro lab) Limited Liability Company, Ukraine).

Thermometer (digital laboratory thermometer TH310 Milwaukee, producer (Spectro lab) Limited Liability Company, Ukraine).

Laboratory scales (AXIS BDM 3, (Spectro lab) Limited Liability Company, Ukraine).

Filter paper (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Single-screw laboratory extruder SJ25 (JC001) Extraction apparatus (Soxlet apparatus) (producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Magnetic stirrer with heating (LMM, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine). Burettes (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Flasks with stoppers (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Dispensers and pipettes (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Conical or volumetric flasks (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Centrifuge (SNOL, producer (Khimlaborreaktyv) Limited Liability Company, Ukraine).

Laboratory Methods

The evaluation of the physicochemical properties of the studied oil samples was carried out according to established protocols:

- Moisture content was determined using the drying method specified in DSTU ISO 1442:2005 **[11]**.
- Fat content was analyzed using the Soxhlet method by DSTU 8380:2015 **[12]**.
- Active acidity was studied by assessing pH levels according to DSTU ISO 2917:2001 **[13]**.

• The content of radionuclides was measured using the gamma spectrometric method **[14]**.
• The temperature of the samples was recorded using a TH310 Milwaukee thermometer.
• Sample weighing was carried out using AXIS BDM 3 scales.
• Acid value was determined by titration of the sample with an alkaline solution according to ISO 660 **[15]**.
• Peroxide value was determined according to ISO 3960 **[16]**.
• Free fatty acid content was determined by a method similar to the acid value determination, but the results are expressed as a percentage according to ISO 660 **[15]**.
• Phosphatide content was determined according to DSTU EN 12871:2004 **[17]**.

Description of the Experiment

Study flow: To study the qualitative composition of soybean oil, a multivariate analysis of different samples was conducted, which differed in growing, storage, and processing conditions. To obtain representative results, samples of soybean seeds of different varieties grown in different agroclimatic zones were selected. For each soybean oil sample, several qualitative characteristics were determined, including acid number, moisture content, free fatty acid content, peroxide number, phospholipid content, and other indicators that affect the quality of the final product. In the first stage, each oil sample was subjected to chemical analysis to determine the main physicochemical indicators critical for assessing the characteristics of the oil. Special attention was paid to the acid number and free fatty acid content, which characterise the level of hydrolysis and oxidation during storage. The next stage included using multivariate analysis to construct factorial plots, which allowed us to identify the dependencies between various parameters of the oil samples and their impact on product quality. All samples were divided into several groups according to characteristics, and for each group, a correlation model between quality parameters was built. This allowed us to identify the main factors influencing the stability and quality of the oil, in particular, to determine which indicators have the most significant impact on the formation of oxidative processes. After the analysis, the models were validated on independent samples of soybean oil, which ensured the accuracy of quality prediction.

Quality Assurance

Number of repeated analyses: The study was repeated 5 times, with the experimental data processed using mathematical statistics.

Number of experiment replications: Each study was conducted five times, with five samples, resulting in 25 replicate analyses.

Reference materials: -

Calibration: Each instrument was calibrated before each experiment, and calibration checks were performed regularly to maintain measurement accuracy. Each instrument was calibrated before each experiment, and calibration checks were performed periodically to maintain measurement accuracy.

Laboratory accreditation: The experiments were conducted at the "Ukrainian Laboratory of Quality and Safety of Agricultural and Industrial Complex Products", the management of which is carried out through the implementation of a management system built (since 2007) by the requirements of DSTU EN ISO/IEC 17025:2019 (EN ISO/IEC 17025:2017, IDT; ISO/IEC 17025:2017, IDT) and confirmed by the Accreditation Certificate of the National Accreditation Agency of Ukraine.

Data Access

The data supporting the findings of this study are not publicly available.

Statistical Analysis

A set of statistical processing methods was used to analyse the data obtained, which allowed us to investigate the influence of various factors on the quality of soybean oil. At the initial stage, data preprocessing was carried out, including checking for outliers, missing values, and normalisation of indicators to ensure the correctness of further analysis.

The primary statistical analysis used multivariate regression to assess the relationships between oil quality parameters and factors such as acid value, free fatty acid content, peroxide value, and moisture content. The regression model allowed us to identify the main factors that significantly affect the quality of the final product. The significance of the factors was determined using the F-test and p-values, where $p \leq 0.05$ was accepted as the significance level.

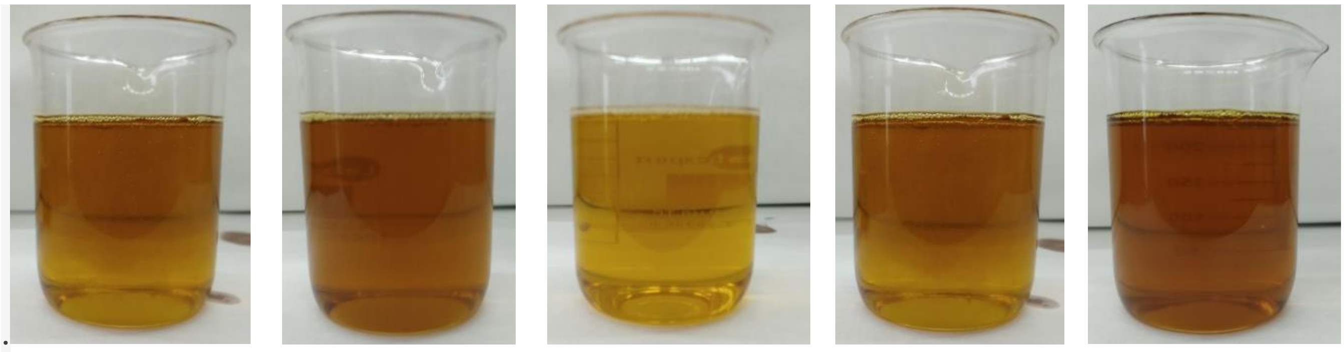
The variance factor (VIF) was used to detect multicollinearity between independent variables. In cases where a high level of correlation between variables was observed, the principal components method was used to reduce the dimensionality of the data, which allowed the impact of multicollinearity to be reduced and the accuracy of the model improved.

After creating the regression model, its adequacy was assessed using the coefficient of determination (R^2), which showed the percentage of variation in oil quality parameters explained by the model. Additionally, cross-validation was performed to check the robustness of the model and assess its ability to predict the quality of new samples.

To test the influence of individual factors on the quality indicators of the oil, an analysis of variance (ANOVA) was also conducted, which allowed assessing the significance of differences between groups of samples. The analysis of variance confirmed the significance of the selected factors and their contribution to the change in product quality indicators. Thus, the statistical analysis allowed us to describe in detail the relationship between various parameters and identify key factors affecting the quality of soybean oil, which is important for optimising the production process and improving the characteristics of the final product.

RESULTS AND DISCUSSION

Experimental studies were conducted with the following types of oilseeds (Figure 2):



a) *b)* *c)* *d)* *e)*

Figure 2 Experimental samples of soybean oil.
Note:
a) soybean oil of the *"EU Mentor"* variety,
b) soybean oil of the *"Gallek"* variety,
c) soybean oil of the *"OAS Avatar"* variety,
d) soybean oil of the *"Arisa"* variety,
e) soybean oil of the *"Sigalia"* variety,

The initial data for modelling were used according to the results of experimental studies of oilseeds, contained in Table 1. To conduct a qualitative and comparative assessment of the studied samples of edible oilseeds, the evaluation criteria were selected according to the two-sided interval of normalised values according to DSTU 4534:**2006 (Table 1).**

Table 1 Main characteristics of unrefined sunflower oil from soybeans.

No.	Indicator	Soybean seed oil of the appropriate grade					
		according to DSTU 4534:2006	EU Mentor	Gallek	OAC Avatar	Arisa	Sigalia
1	Mass fraction of fat, %	99.5 – 99,8	99.6	99.7	99.5	99.3	99.8
2	Acid number, mg KOH/g	≤ 0.6	0.5	0.6	0.45	0.7	0.55
3	Peroxide value, mEq/kg	≤ 10	8	7	5	9	10
4	Free fatty acid content, %	≤ 0.05	0.04	0.06	0.045	0.03	0.025
5	Phosphatidide content, %	1.0 – 1.5	1.1	1.2	1.05	1.2	1.3
6	Moisture and impurity content, %	≤ 0.05	0.04	0.035	0.05	0.04	0.03

At the first stage of modelling, the parameters presented in Table 1 were converted into dimensionless units by using the values of the ratios between the normative and current values of the parameters. In this case, the value of the normative indicators was numerically represented through a dimensionless unit, and the current ones through its fraction, i.e., the partial values of R, and were determined as the ratio of the values of the actual i-th parameter to its normalised value **[18]** and **[19]**.

Considering that these characteristics determine the qualitative state of the studied oil varieties from soybean raw materials, the geometric area, built according to the specified parameters, constitutes the factor space of the qualitative state of the oil product. This statement constitutes the basic scientific hypothesis when performing mathematical modeling.

When constructing quality characteristics, their values are plotted across the diagonals of the polygon faces. Since the values of the normalized characteristics are equal to a conventional unit, the factor space corresponding to the normative or recommended quality state is a regular polygon, the number of faces of which is determined by the number of quality criteria **[20]**. The determined partial values of the experimental parameters of the studied oils were plotted along the diagonals of the normative regular polygon. The area formed according to the experimental characteristics of the studied oil product samples is displayed in the form of an irregular polygon. Accordingly, this area constitutes the factor space of the quality state of the studied product. Then the algebraic ratio of the normative and actual areas of the polygons was used in the given mathematical modeling as quality criteria, which constitutes the second scientific hypothesis **[21]**.

In the drawing of the constructed graphic model, the sought area is outlined in blue (Figure 3). Considering that according to Table 1, the normalized characteristics according to DSTU 4534:2006 are presented in the form of an acceptable interval, a two-sided estimate of each of the studied parameters was used in the modeling. Then the determined factor space of each current parameter should approach the normalized one, which is presented in black in the form of a regular polygon. As a result, this geometric model allows for a visual assessment of qualitative characteristics, and its mathematical description allows you to determine the necessary calculation data for mathematical evaluation.

The modeling used the hypothesis that the factor space of the parameters presented for evaluation allows us to assess the quality state of the product, and the corresponding areas of the polygons make it possible to numerically assess this state compared to the normative characteristics **[22]**. When calculating the areas of irregular polygons, the method of dividing the figure into triangles was used, using a compiled calculation program.

The areas of regular polygons on the displayed computational graphic models demonstrate the normalized parameter space during the evaluation of the corresponding sample of oilseed, i.e. $S_N = S_H$.

To determine these areas (S_N), we used the well-known formula (1) for the area of a regular polygon:

$$S_N = \frac{ma^2}{4tg\left(\frac{180}{m}\right)} \tag{1}$$

Where:
m – number of angles or sides of a polygon;
a – the magnitude of the side of the polygon that can be found in terms of the semi-diagonal *R* how: $a = 2R\sin(180/m)$.

Then the desired value of the area of the polygon is:

$$S_N = 0.5 \cdot m \cdot R^2 \sin(360/m) \tag{2}$$

Given that the angle α =360/*m*, then formula (2) was finally reproduced as:

$$S_N = S_H = 0.5 \cdot m \cdot R^2 \sin\alpha \tag{3}$$

According to formula (3), the areas of polygons were determined according to normalized parameters for all studied spaces, i.e. for a 6-factor estimation space:

$$S_{н6} = 0{,}5 \cdot 6 \cdot \sin 60 = 2{,}598\ con.un^2$$

As a result of the mathematical calculation, it turned out that for an irregular 6-gon, the total desired area is (3):

$$S_{06} = 0.5 \cdot \sin\alpha \cdot \left[R_1 \cdot R_2 + R_2 \cdot R_3 + R_3 \cdot R_4 + R_4 \cdot R_5 + R_5 \cdot R_6 + R_6 \cdot R_1\right] \tag{4}$$

To assess possible deviations of product characteristics from the limit (maximum) standard or recommended values, the proposed *coefficient of compliance with the standard quality limit was used.*

$$k_{VN} = \frac{\sum f_i}{n} \tag{5}$$

Where:
F_i – Valid value of the current parameter;
F_{max} – maximum value of the normalized parameter (Table 2);
$f_i = F_i / F_{max}$; *n* – number of current parameters to be evaluated.

For a two-sided assessment using the characteristics presented in Table 1, a *coefficient of compliance with a given quality interval was developed and proposed.*

$$k_{VQ} = \frac{S_i}{S_c} \tag{6}$$

Where:
S_c – average value of the normalized interval;
S_i – factor space of current parameters.

This evaluation criterion shows how close the complex of product sample quality indicators is to the standard quality interval, which is regulated for the studied sample of oilseed products under a certain factor space, determined algebraically when the result is approached one or geometrically by the asymmetry of the obtained area of the polygon relative to the regular, i.e. normalized.

According to experimental data for oilseeds from soybean seeds, "EC Mentor" calculated the main quality parameters for the construction of a mathematical model (Table 2), using 6 main characteristics of the studied product sample.

Table 2 Calculation of quality parameters of a sample of soybean seed oil of the "EU Mentor" variety according to the main characteristics of products during bilateral evaluation.

No.	Indicator	Norm			Product Sample Quality Characteristics					
		F_c	R, con. un	F_{max}	f_i	R_i, con. un	S_c, con. un^2	S_i, con. un^2	k_{VQ}	k_{VN}
1	Mass fraction of fat, %	99.65	99.6	99.8	0.998	0.999	2.598	4.9	0.827	1.886
2	Acid number, mg KOH/g	0.3	0.5	0.6	0.833	1.667				
3	Peroxide value, mEq/kg	5.0	8	10	0.8	1.6				
4	Free fatty acid content, %	0.025	0.04	0.05	0.8	1.6				
5	Phosphatidide content, %	1.25	1.1	1.5	0.733	0.88				
6	Moisture and impurity content, %	0.025	0.04	0.05	0.8	1.6				

Note: The following parameters were used in the table: F_c – the average value of the normalized parameter evaluated; F_{max} – maximum value of the normalized parameter; R = 1,0 – the value of the normalized parameter in conventional units; F_i – the valid value of the current parameter; R_i – the current parameters presented in con. un.; S_i – factor space of current parameters, determined by the area of the irregular polygon, con. un^2; S_H – normative factor space: for two-way evaluation $S_H = S_c$, con. un^2; k_{VQ} – coefficient of compliance with a given quality interval; k_{VN} - coefficient of compliance with the maximum quality standards.

Using the calculated values of the current Ri parameters (Table 2), a geometric quality model of the studied control sample of soybean seed oil of the "EU Mentor" variety was constructed based on bilateral evaluation (Figure 3).

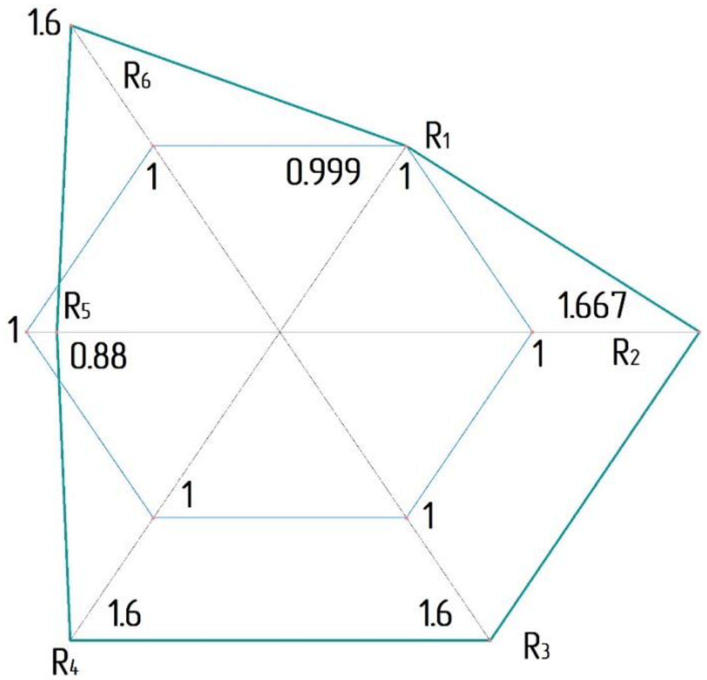


Figure 3 Mathematical model of the quality of the studied sample of soybean seed oil of the "EU Mentor" variety according to the product's main characteristics during bilateral evaluation.

According to the experimental data for oilseeds from soybean seeds of the Gallek variety, the calculation of the leading quality parameters for the construction of a mathematical model was carried out (Table 3), using 6 main characteristics of the studied product sample.

Table 3 Calculation of quality parameters of a sample of soybean seed oil of the "Gallek" variety according to the main characteristics of products during bilateral evaluation.

No.	Indicator	Norm			Product Sample Quality Characteristics					
		F_c	*R, con. un*	F_{max}	f_i	*R_i, con. un*	*S_c, con. un^2*	*S_i, con. un^2*	k_{VQ}	k_{VN}
1	Mass fraction of fat, %	99.65	99.7	99.8	0.999	1.001	2.598	5.72	0.89	2.202
2	Acid number, mg KOH/g	0.3	0.6	0.6	1	2				
3	Peroxide value, mEq/kg	5.0	7	10	0.7	1.4				
4	Free fatty acid content, %	0.025	0.06	0.05	1.2	2.4				
5	Phosphatidide content, %	1.25	1.2	1.5	0.8	0.96				
6	Moisture and impurity content, %	0.025	0.035	0.05	0.7	1.4				

Using the calculated values of the current Ri parameters (Table 3), a geometric quality model of the studied control sample of oil from soybean seeds of the Hallek variety was constructed based on a two-sided assessment (Figure 4, b).

According to experimental data for oilseeds from soybean seeds of the "OAC Avatar" variety, the calculation of the main quality parameters for the construction of a mathematical model (Table 4) was carried out using 6 main characteristics of the studied product sample.

Table 4 Calculation of quality parameters of a sample of soybean seed oil of the "**OAC** Avatar" variety according to the main characteristics of products during bilateral evaluation.

No.	Indicator name	Norm			Product Sample Quality Characteristics					
		F_c	*R, con. un*	F_{max}	f_i	*R_i, con. un*	*S_c, con. un^2*	*S_i, con. un^2*	k_{VQ}	k_{VN}
1	Mass fraction of fat, %	99.65	99.5	99.8	0.99	0.998	2.598	4.32	0.76	1.663
2	Acid number, mg KOH/g	0.3	0.45	0.6	0.75	1.5				
3	Peroxide value, mEq/kg	5.0	5	10	0.5	1				
4	Free fatty acid content, %	0.025	0.045	0.05	0.9	1.8				
5	Phosphatidide content, %	1.25	1.05	1.5	0.42	0.84				
6	Moisture and impurity content, %	0.025	0.05	0.05	1	2				

Using the calculated values of the current Ri parameters (Table 4), a geometric quality model of the studied control sample of soybean seed oil of the OAC Avatar variety was constructed on the basis of a two-sided assessment (Figure 4, a).

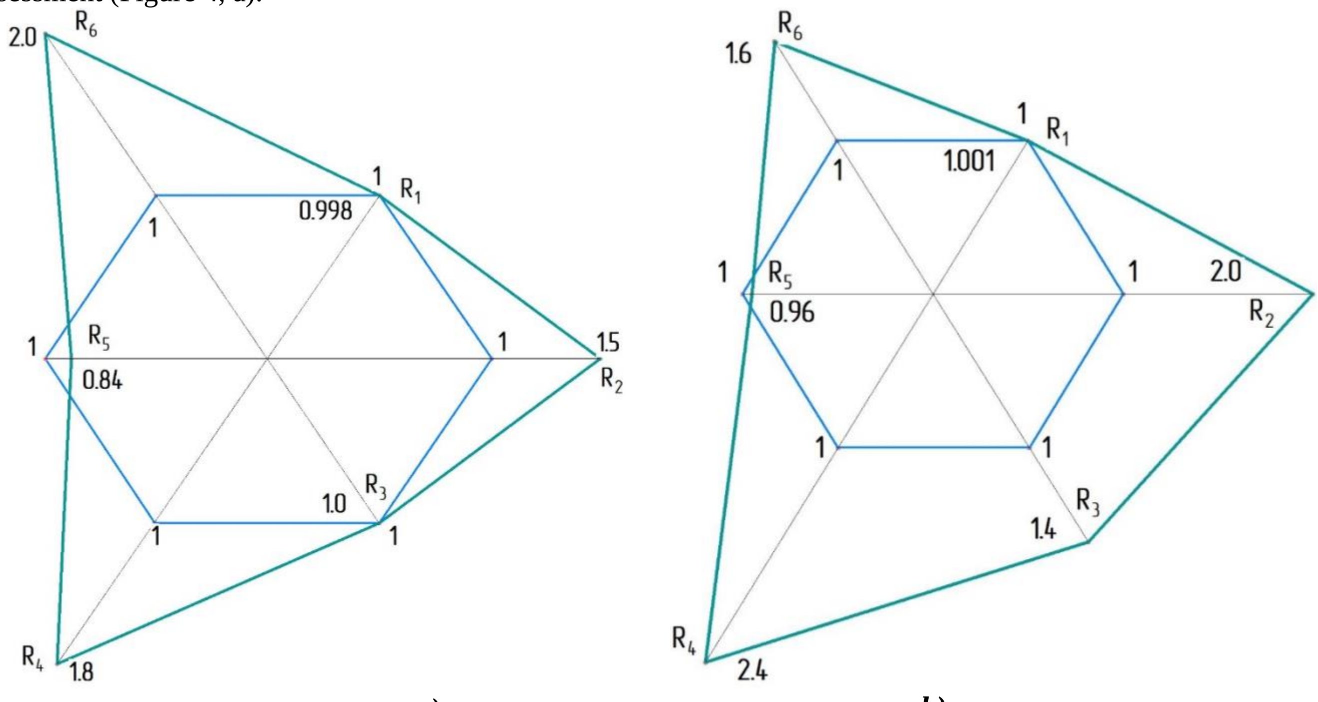


Figure 4 Mathematical model of the quality of the studied sample of soybean seeds of the varieties "OAC Avatar" (*a*) and "Gallek" (*b*) according to the main characteristics of products during bilateral evaluation.

Similar to the calculation methodology described above and per experimental data, the accepted evaluation criteria for oilseed products of the varieties "Arisa" and "Sigalia" were determined. Using the calculated values of the current parameters of R_i, geometric models of the quality of the studied control sample of soybean seed oil of the varieties "Arisa" (Figure 5, a) and "Sigalia" were constructed (Figure 5, b) based on a two-way assessment.

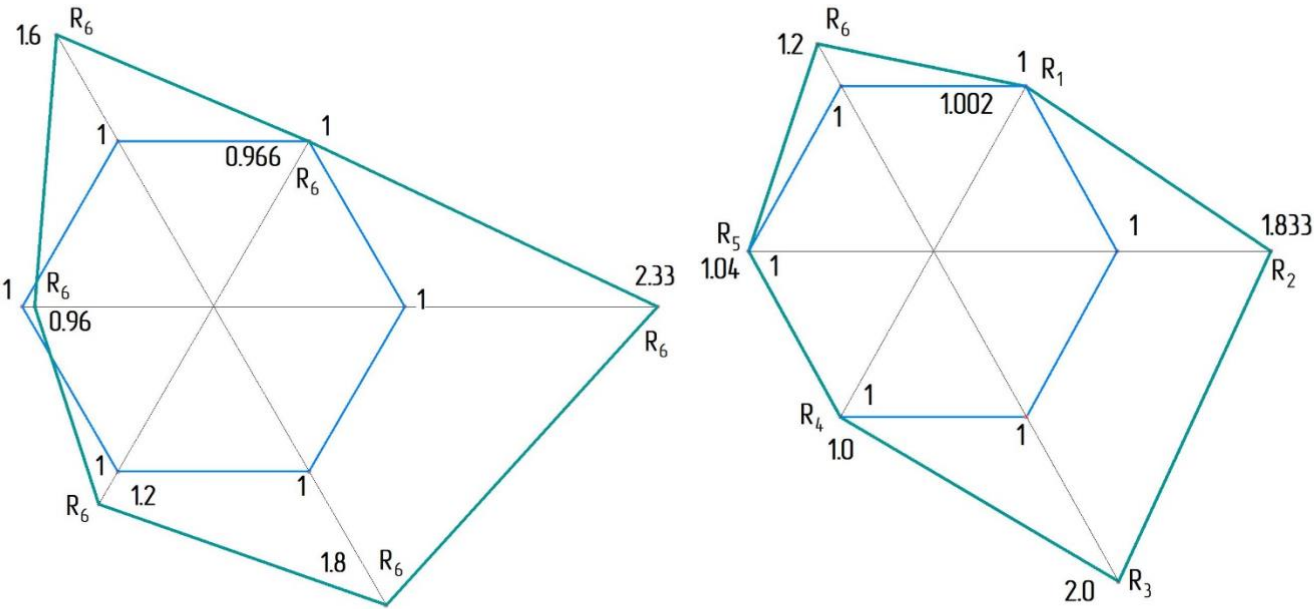


Figure 5 Mathematical model of the quality of the studied sample of soybean seed oil of the varieties "Arisa" (*a*) and "Sigalia" (*b*) according to the main characteristics of products during bilateral evaluation.

It is evident that according to the results of the assessment of the quality properties of soybean seed oil according to the main characteristics of the products during the two-sided evaluation, the best characteristics were found in the sample of the OAC Avatar brand, and the worst – for the sample of the Hallek brand. Thus, for the last grade of oilseed products, the coefficient of compliance with the normative limit exceeds 2.2 times the maximum limit of marginal quality, and the coefficient of compliance of the quality interval is within the limits of the average normative indicator by 89%. The evaluation of the "OAC Avatar" brand sample revealed that the maximum limit of marginal quality was exceeded by 1.663 times, and the average product quality interval was satisfied by 76.1%. The varieties "EU Mentor" and "Sigalia" showed similar characteristics of oilseed products. Thus, it was observed that the characteristics of all of the studied samples of oilseeds from soybean seeds do not meet the requirements for compliance with the quality limit indicators by 160 – 220%: Although all the studied samples are within the average normative assessment indicators according to the characteristics used.

Using the results of mathematical modelling using the method of factor spaces, the obtained criteria for assessing the quality of the studied samples of oilseeds from soybean seeds were placed in Table 5.

Table 5 Criteria for assessing the quality of the studied samples of oilseed products from soybean seeds.

No.	Product Brand	Factor area		Factor area	
		S_H, con. un^2	S_N (S_c), con. un^2	k_{VQ}	k_{VN}
1	"EU Mentor"	2.598	4.9	0.827	1.886
2	Halleck	2.598	5.72	0.89	2.202
3	"OAC Avatar"	2.598	4.32	0.761	1.663
4	"Arisa"	2.598	5.61	0.877	2.16
5	"Sigalia"	2.598	4.76	0.814	1.832

Based on the data of Table 4, a comparative graph-analytical analysis of changes in the criteria for assessing the quality of the studied samples of soybean seed oil, which are placed in Figure 6, was carried out.

The coefficient of compliance with the k_{VN} quality standards *of* soybean seed oil samples of the brands "EU Mentor", "Gallek", "OAC Avatar", "Arisa", and "Sigalia" fluctuates around *the value of* k_{VN} = 2.0 in both directions, which indicates that they exceed the limit normative indicators by 1.6 – 2.2 times (Figure 6). There is an almost linear nature of the change in the coefficient of compliance of the quality interval k_{VQ} for all brands of oilseed products, and all their values do not exceed the average standard characteristics (Figure 6).

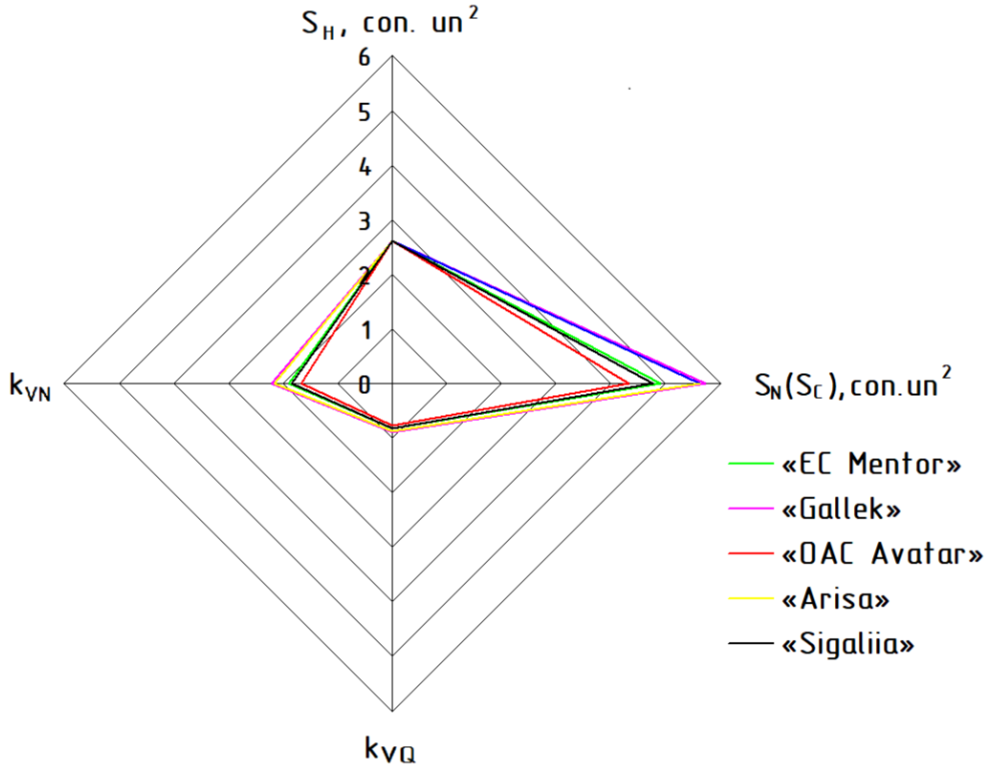


Figure 6 A generalised graphical interpretation of the mathematical model of the quality of the studied samples using a two-sided assessment of the factor space by the content of fatty acids.

The fluctuating nature of the change in the factor area according to the used characteristics of oilseed products is traced, the values of which for the studied samples are 1.5 – 2 times higher than the factor area according to the standard quality parameters, which are 2.598 u.u^2 (Figure 6). Thus, according to these evaluation criteria, none of the studied samples of soybean seed oil meet the limited characteristics of regulatory requirements.

M. Ryabovol **[23]** modelled the quality of recipes of boiled sausages with different amounts of a herbal additive according to such characteristics as consistency, colour, juiciness, taste, smell, shape, size, and dressing, which were built on a 9-point scale along the diagonals of a hexagon.

N. Golembowska, in her work **[24]**, investigated the change in organoleptic characteristics of assessing the quality of carp meat, namely, appearance, consistency, colour, taste, and smell, which were deposited along the diagonals of the pentagon according to a 5-point assessment.

The general negative characteristics of these quality models are their subjective choice and justification of point assessment, the limitation of the number of evaluation parameters by purely organoleptic indicators, and the impossibility of using parameters that require more complex measurement technologies, which in general, makes it impossible to comprehensively analyse the qualitative state of the studied products **[25]** and **[26]**.

The results of our study confirmed the significant influence of chemical parameters such as acid number, free fatty acid content, and peroxide number on the organoleptic properties of soybean oil, which are critical for its consumer qualities. These indicators are the primary markers of hydrolysis and oxidation, which directly affect the oil's taste, aroma, and colour characteristics. High values of acid and peroxide numbers correlate with changes in taste, odour, and colour, consistent with the results of several other studies that describe similar degradation processes in vegetable oils **[27]** and **[28]**.

In the context of taste properties, the study's results indicate that an increase in the content of free fatty acids, which are formed by the hydrolysis of triglycerides, leads to a deterioration in the palatability of the oil. As indicated in the works of the authors, **[29]** and **[30]**, high levels of free fatty acids cause the appearance of an undesirable bitter or rancid taste, which we have also confirmed for samples with high acid numbers. Changes in taste properties are associated with the accumulation of oxidation products that affect consumers' perception of oil. In scientific studies **[31]** and **[32]**, it has been established that the control of free fatty acids can be an essential factor in maintaining the taste of the oil at the proper level.

The analysis of the effect of the peroxide number, which is an indicator of the initial stages of oxidation, also confirmed the importance of this indicator as a predictor of organoleptic quality **[33]**. An increase in the peroxide number is associated with the formation of primary oxidation products, which cause the appearance of an unpleasant odour and deterioration of aroma. In the works of the authors **[34]** and **[35]**. It has been proven that as oxidative processes progress, aldehydes and ketones accumulate, significantly changing the smell and making it rancid and unpleasant for consumers. Our study found a clear correlation between high peroxide numbers and odour intensity, a strong argument for controlling this indicator during oil storage.

Regarding the colour of the oil, the results confirmed that the seeds' moisture content affects the final product's shade. Samples with a higher moisture content showed a darker colour, possibly due to the acceleration of oxidative reactions and polymerisation of oxides in the presence of moisture. Studies by authors' teams **[36]** and **[37]** showed that the darker colour in oils is generally associated with the accumulation of secondary oxidation products and the appearance of pigments resulting from long-term or unstable storage. Our results suggest that controlling moisture levels in raw materials during storage can minimise oxidation and maintain a lighter shade.

The principal component method used to analyse multifactorial data made it possible to identify key factors that significantly affect organoleptic indicators, such as taste, smell, and colour, and to reveal hidden relationships between them. The multifactorial approach made it possible to conclude that the combination of high acid and peroxide numbers is an important indicator of the deterioration of the organoleptic properties of the oil **[38]**. This approach also made it possible to reveal more subtle relationships. In particular, it showed that certain factors have an amplifying influence on each other in the processes of degradation. It is a well-known fact that oxidation and hydrolysis are synergistic processes, and our results indicate that simultaneous control of several critical parameters, such as moisture content, acid, and peroxide numbers, can significantly improve the stability and organoleptic properties of the oil **[39]** and **[40]**.

Compared to traditional regression models used in several previous studies **[41]** and **[42]**, our multivariate approach to dimensionality reduction using the principal component method allows for multicollinearity between indicators, an essential condition for more accurate quality prediction. For example, some authors **[43]** and **[44]** Used simple linear regression analysis methods to model oil quality based on individual chemical indicators. However, such methods need to consider the complex relationships between parameters and tend to overestimate the influence of particular variables, which can reduce the accuracy of models. One of the disadvantages of such approaches is the limited ability to consider the impact of a complex set of factors on the organoleptic and chemical properties of the oil, especially in the presence of nonlinear relationships.

Several researchers **[45]** and **[46]** have used classification methods such as cluster analysis or discriminant analysis to predict the quality of vegetable oils. Such approaches have the advantage of determining groups of samples by similar characteristics. Still, they cannot accurately estimate quantitative changes in quality when parameters change, which is essential for modelling oil properties. An additional disadvantage of such methods is their limited applicability in cases when it is necessary to assess the continuous effect of quantitative parameters on organoleptic properties and not only to assign samples to specific categories **[47]**. Our approach, which combines multivariate analysis and regression modelling, allows us to assess the effect of each of the indicators more accurately, mainly changes in acid and peroxide numbers, which are critical for the stability of the oil.

Scientific papers **[48]** and **[49]** have used artificial intelligence techniques such as neural networks and genetic algorithms to predict oil quality. Although these methods allow for the creation of highly accurate models, they have certain drawbacks, including difficulty interpreting the results and the risk of overlearning, especially when working with limited data samples **[50]**. In addition, such models require large amounts of data for testing, which is only sometimes available in real-world production and quality control conditions. In our study, we used more interpretive approaches that allowed us to track each factor's impact, simplifying the application of the results in industrial settings.

Thus, considering the main components, our multivariate analysis method has several advantages over traditional approaches, mainly, due to greater forecasting accuracy and the ability to consider interactions between parameters. The disadvantages of many conventional models, such as the limited ability to account for complex dependencies and the problem of multicollinearity, have been successfully eliminated by using our approach. This not only improves the quality assessment of soybean oil but also contributes to the further optimisation of production and storage technologies, which is especially important for the stability of products in the market.

Therefore, the study's results emphasise the importance of an integrated approach to soybean oil quality control, which considers the relationship between physicochemical parameters and their effect on organoleptic properties. This study confirms the importance of individual chemical parameters and proposes a multifactorial methodology that can contribute to the optimisation of production processes and storage conditions to ensure stable oil quality and maintain its attractive organoleptic characteristics.

CONCLUSION

The application of the method of mathematical modelling for the qualitative assessment of soybean seed oil by such indicators as the mass fraction of fat, peroxide, and acid numbers; the content of free fatty acids, phosphatides, moisture, and impurities which made it possible to create a numerical assessment of the qualitative state of the studied varieties of oilseed products has been scientifically substantiated. Such an assessment is purely objective and allows one to comprehensively analyse the quality of the studied products with any number of evaluation parameters.

According to the assessment results, the worst quality indicators were found for the "Gallek" brand sample, evidenced by the excess of the maximum limit of marginal quality according to DSTU 4534:2006 by 2.2 times. Evaluation of samples of oilseed varieties "OAC Avatar", "EU Mentor", and "Sigalia" determined the excess maximum limit of marginal quality by 1.663 times, and the average product quality interval was satisfied by 76.1%, which in general shows a particular potential for a possible change in the average standard level. The varieties "ES Mentor" and "Sigalia" demonstrated similar characteristics of oilseed products.

The fluctuating nature of the change in the factor area of the current parameters of the evaluation of the studied samples of soybean seed oil revealed the maximum approximation to the standard area of the "OAC Avatar" variety, as well as its excess for the rest of the varieties. Thus, the results of the studies revealed that the characteristics of all of the studied samples of oilseeds from soybean seeds do not meet the requirements of compliance with the quality limit indicators by 160 – 220%. Still, their current characteristics, which were selected for evaluation, are within the average normative indicators.

REFERENCES

1. Shanina, O., Minchenko, S., Gavrysh, T., Sukhenko, Y., Sukhenko, V., Vasyliv, V., Miedviedieva, N., Mushtruk, M., Stechyshyn, M., & Rozbytska, T. (2020). Substantiation of basic stages of gluten-free steamed bread production and its influence on the quality of the finished product. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 14, pp. 189–201). HACCP Consulting. https://doi.org/10.5219/1200
2. Mushtruk, M., Bal-Prylypko, L., Slobodyanyuk, N., Boyko, Y., & Nikolaienko, M. (2022). Design of Reactors with Mechanical Mixers in Biodiesel Production. In Lecture Notes in Mechanical Engineering (pp. 197–207). Springer International Publishing. https://doi.org/10.1007/978-3-031-06044-1_19
3. Palamarchuk, I. P., Mushtruk, M. M., Palamarchuk, V. I., Deviatko, O. S., Wójcik, W., Kalizhanova, A., & Kozbakova, A. (2021). Physical-mathematical modelling of the process of infrared drying of rape with vibration transport of products. In Mechatronic Systems 1 (pp. 243–253). Routledge. https://doi.org/10.1201/9781003224136-21
4. Hudzenko, M., Vasyliv, V., Zheplinska, M., Burova, Z., & Sarana, V. (2022). Research the effectiveness of means for intensifying oil compression in twin-screw extrusion presses. In Animal Science and Food Technology (Vol. 13, Issue 4. pp. 7-18). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal.13(4).2022.7-18
5. Tsyhanskyi, V., Tsyhanska, O., & Didur, I. (2023). Influence of biologisation of the nutrition system on the transformation of biological nitrogen and formation of soybean productivity. In PLANT AND SOIL SCIENCE (Vol. 14, Issue 4, pp. 86–97). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/plant4.2023.86
6. Hnatiuk, T., Kravchenko, O., Abarbarchuk, L., Churilov, A., & Chobotar, V. (2023). Influence of drugs produced by electropulse ablation methods on the development of soybean phytopathogenic bacteria. In PLANT AND SOIL SCIENCE (Vol. 14, Issue 3, pp. 22–34). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/plant3.2023.22
7. Palamarchuk, I., Mushtruk, M., Vasyliv, V., Stefan, E., Priss, O., Babych, I., Karpovych, I., & Pushanko, N. (2024). Modelling the centrifugal mixing process of minced meat to optimise the production of chopped meat semi-finished products. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 18, pp. 297–312). HACCP Consulting. https://doi.org/10.5219/1959
8. Mokrienko, V., Kalenska, S., & Andriec, D. (2024). The effectiveness of intercropping in the Forest-Steppe zone of Ukraine. In PLANT AND SOIL SCIENCE, (Vol. 15, Issue 3, pp. 68–80). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/plant3.2024.68
9. Liu, Y., Li, J., Cheng, Y., & Liu, Y. (2020). Volatile components of deep-fried soybean oil as indicator indices of lipid oxidation and quality degradation. In European Food Research and Technology (Vol. 246, Issue 6, pp. 1183–1192). Springer Science and Business Media LLC. https://doi.org/10.1007/s00217-020-03475-2

10. Vieira, B., Nadaleti, W. C., & Sarto, E. (2021). The effect of the addition of castor oil to residual soybean oil to obtain biodiesel in Brazil: Energy matrix diversification. In Renewable Energy (Vol. 165, pp. 657–667). Elsevier BV. https://doi.org/10.1016/j.renene.2020.10.056
11. DSTU ISO 1442:2005. Meat and meat products. Method for determining moisture content (control method) (ISO 1442:1997, IDT). Amended. *Quality management systems – Requirements*
12. DSTU 8380:2015. Meat and meat products. Method for determining moisture content (control method) (ISO 1442:1997, IDT). Amended. *Quality management systems – Requirements*
13. DSTU ISO 2917:2001. Meat and meat products. Method for determining moisture content (control method) (ISO 1442:1997, IDT). Amended. *Quality management systems – Requirements*
14. ISO 20042:2019. Measurement of radioactivity. Gamma-ray emitting radionuclides. Generic test method using gamma-ray spectrometry.*Quality management systems – Requirements*
15. ISO 660. Animal and vegetable fats and oils. Determination of acid value and acidity. *Quality management systems – Requirements*
16. ISO 3960. Animal and vegetable fats and oils. Determination of peroxide value. *Quality management systems – Requirements*
17. DSTU EN 12871:2004. "Animal and vegetable fats and oils. Determination of phosphorus. Spectrometric method" *Quality management systems – Requirements*
18. Palamarchuk, I., Palamarchuk, V., Sarana, V., Heipel, Y., & Borodych, B. (2022). Technical and economic substantiation of the process of semi-fluidisation treatment of fruit and berry products. In Animal Science and Food Technology (Vol. 13, Issue 2, pp. 35-43). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal.13(2).2022.35-43
19. Bali Swain, R., & Yang-Wallentin, F. (2019). Achieving sustainable development goals: predicaments and strategies. In International Journal of Sustainable Development & World Ecology (Vol. 27, Issue 2, pp. 96–106). Informa UK Limited. https://doi.org/10.1080/13504509.2019.1692316
20. Palamarchuk, I., Shtonda, O., Semeniuk, K., Topchii, O., & Petryna, A. (2023). Physical and mathematical modelling of the massing process of marinated pork and beef preparation technology. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 17, pp. 929–944). HACCP Consulting. https://doi.org/10.5219/1926
21. Palamarchuk, I. (2024). Evaluation of the Energy Efficiency of the Process of Vibratory Mixing of Multicomponent Bulk Raw Material of Food Industries. In PRZEGLĄD ELEKTROTECHNICZNY (Vol. 1, Issue 6, pp. 114–117). Wydawnictwo SIGMA-NOT, sp. z.o.o. https://doi.org/10.15199/48.2024.06.21
22. Rogovskii, I. L., Palamarchuk, I. P., Voinash, S. A., Troyanovskaya, I. P., Butenko, A. F., & Sokolova, V. A. (2020). Engineering of constructive parameters of vibroaspiration separator of oil-containing grain seeds. In Journal of Physics: Conference Series (Vol. 1679, Issue 4, p. 042034). IOP Publishing. https://doi.org/10.1088/1742-6596/1679/4/042034
23. Riabovol, M. (2022). Mathematical modelling of the process of vibration mixing of minced sausage. In Animal Science and Food Technology (Vol. 13, Issue 2 pp. 53-62). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal.13(2).2022.53-62
24. Holembovska, N., Slobodianiuk, N., & Israelian, V. (2021). Improvement of technology of fish semi-finished products with addition of non-conventional raw materials. In ANIMAL SCIENCE AND FOOD TECHNOLOGY (Vol. 12, Issue 2, pp. 14–23). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal2021.02.002
25. Majumder, P., Sinha, A., Gupta, R., & Sablani, S. S. (2021). Drying of Selected Major Spices: Characteristics and Influencing Parameters, Drying Technologies, Quality Retention and Energy Saving, and Mathematical Models. In Food and Bioprocess Technology (Vol. 14, Issue 6, pp. 1028–1054). Springer Science and Business Media LLC. https://doi.org/10.1007/s11947-021-02646-7
26. Alabi, K. P., Olalusi, A. P., Olaniyan, A. M., Fadeyibi, A., & Gabriel, L. O. (2022). Effects of osmotic dehydration pretreatment on freezing characteristics and quality of frozen fruits and vegetables. In Journal of Food Process Engineering (Vol. 45, Issue 8). Wiley. https://doi.org/10.1111/jfpe.14037
27. Rosu, L., Varganici, C., Mustata, F., Rosu, D., Rosca, I., & Rusu, T. (2020). Epoxy Coatings Based on Modified Vegetable Oils for Wood Surface Protection against Fungal Degradation. In ACS Applied Materials & Interfaces (Vol. 12, Issue 12, pp. 14443–14458). American Chemical Society (ACS). https://doi.org/10.1021/acsami.0c00682
28. Lozano-Castellón, J., Rinaldi de Alvarenga, J. F., Vallverdú-Queralt, A., & Lamuela-Raventós, R. M. (2022). Cooking with extra-virgin olive oil: A mixture of food components to prevent oxidation and degradation. In Trends in Food Science & Technology (Vol. 123, pp. 28–36). Elsevier BV. https://doi.org/10.1016/j.tifs.2022.02.022

29. Simsek, S., & Uslu, S. (2020). Determination of a diesel engine operating parameters powered with canola, safflower and waste vegetable oil based biodiesel combination using response surface methodology (RSM). In Fuel (Vol. 270, p. 117496). Elsevier BV. https://doi.org/10.1016/j.fuel.2020.117496
30. Obajuluwa, O. V., Sanwo, K. A., Akinola, O. S., Sobukola, O. P., Adeola, A. V., & Faloye, O. R. (2020). Effect of unconventional marinades on beef quality. In Nigerian Journal of Animal Production (Vol. 47, Issue 1, pp. 90–99). Nigerian Society for Animal Production (NSAP). https://doi.org/10.51791/njap.v47i1.193
31. Suárez, M., Gual-Grau, A., Ávila-Román, J., Torres-Fuentes, C., Mulero, M., Aragonès, G., Bravo, F. I., & Muguerza, B. (2021). Oils and Oilseeds in the Nutraceutical and Functional Food Industries. In Oil and Oilseed Processing (pp. 219–243). Wiley. https://doi.org/10.1002/9781119575313.ch11
32. Piddubnyi, V., Sabadosh, A., Mushtruk, M., Chahaida, A., Fedorov, V., Kravcheniuk, K., Krasnozhon, S., & Radchenko, I. (2024). Innovative thermodynamic modeling for enhanced yeast dough mixing: energy perspectives and applications. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 18, pp. 251–267). HACCP Consulting. https://doi.org/10.5219/1951
33. Trabelsi, N., Marotta, S. M., Giarratana, F., Taamali, A., Zarrouk, M., Ziino, G., & Giuffrida, A. (2018). Use of Tunisian flavored olive oil as an isakicidal agent in industrial anchovy marinating process. In Journal of the Science of Food and Agriculture (Vol. 98, Issue 9, pp. 3446–3451). Wiley. https://doi.org/10.1002/jsfa.8857
34. Stefani Juncos, N., Florencia Cravero, C., Rubén Grosso, N., & Horacio Olmedo, R. (2024). Integral oxidation Value used as a new oxidation indicator for evaluation of advanced stages of oxidative processes: Intox value. In Microchemical Journal (Vol. 204, p. 111186). Elsevier BV. https://doi.org/10.1016/j.microc.2024.111186
35. Yılmaz, B., Şahin, T. Ö., & Ağagündüz, D. (2023). Oxidative Changes in Ten Vegetable Oils Caused by the Deep-Frying Process of Potato. In E. H. Sakar (Ed.), Journal of Food Biochemistry (Vol. 2023, pp. 1–11). Hindawi Limited. https://doi.org/10.1155/2023/6598528
36. Cherednichenko, O., & Bal-Prylypko, L. (2019). Modern condition and development of the specialized enterprises – rape producers. In IOP Conference Series: Earth and Environmental Science (Vol. 315, Issue 2, p. 022018). IOP Publishing. https://doi.org/10.1088/1755-1315/315/2/022018
37. Mushtruk, M., Mushtruk, N., Slobodyanyuk, N., Vasyliv, V., & Zheplinska, M. (2024). Enhanced energy independence: converting animal fat into biodiesel. In International Journal of Environmental Studies (Vol. 81, Issue 1, pp. 134–144). Informa UK Limited. https://doi.org/10.1080/00207233.2024.2314860
38. Zhang, X., Li, C., Zhou, Z., Liu, B., Zhang, Y., Yang, M., Gao, T., Liu, M., Zhang, N., Said, Z., Sharma, S., & Ali, H. M. (2023). Vegetable Oil-Based Nanolubricants in Machining: From Physicochemical Properties to Application. In Chinese Journal of Mechanical Engineering (Vol. 36, Issue 1). Springer Science and Business Media LLC. https://doi.org/10.1186/s10033-023-00895-5
39. Vasyliv, V., Mushtruk, M., Zheplinska, M., Mukoid, R., & Tkachenko, S. (2021). Method of Electrohydraulic Activation of Water-Lime Suspension in Sugar Production. In Lecture Notes in Mechanical Engineering (pp. 664–673). Springer International Publishing. https://doi.org/10.1007/978-3-030-91327-4_64
40. Mateos, P. S., Navas, M. B., Morcelle, S. R., Ruscitti, C., Matkovic, S. R., & Briand, L. E. (2021). Insights in the biocatalyzed hydrolysis, esterification and transesterification of waste cooking oil with a vegetable lipase. In Catalysis Today (Vol. 372, pp. 211–219). Elsevier BV. https://doi.org/10.1016/j.cattod.2020.09.027
41. Costa, M. J., Silva, M. R. L., Ferreira, E. E. A., Carvalho, A. K. F., Basso, R. C., Pereira, E. B., de Castro, H. F., Mendes, A. A., & Hirata, D. B. (2020). Enzymatic biodiesel production by hydroesterification using waste cooking oil as feedstock. In Chemical Engineering and Processing - Process Intensification (Vol. 157, p. 108131). Elsevier BV. https://doi.org/10.1016/j.cep.2020.108131
42. Naveen, S., Gopinath, K. P., Malolan, R., Ramesh, S. J., Aakriti, K., & Arun, J. (2020). Novel Solar Parabolic Trough Collector cum Reactor for the Production of Biodiesel from Waste Cooking Oil using Calcium Oxide catalyst derived from seashells waste. In Chemical Engineering and Processing - Process Intensification (Vol. 157, p. 108145). Elsevier BV. https://doi.org/10.1016/j.cep.2020.108145
43. Forero-Hernandez, H., Jones, M. N., Sarup, B., Jensen, A. D., Abildskov, J., & Sin, G. (2020). Comprehensive development, uncertainty and sensitivity analysis of a model for the hydrolysis of rapeseed oil. In Computers & Chemical Engineering (Vol. 133, p. 106631). Elsevier BV. https://doi.org/10.1016/j.compchemeng.2019.106631
44. Tavares, F., Sackser, P. R., Borba, C. E., & Silva, E. A. (2021). Rapid enzymatic hydrolysis of crambe oil catalyzed by castor seeds lipases. In Industrial Crops and Products (Vol. 171, p. 113890). Elsevier BV. https://doi.org/10.1016/j.indcrop.2021.113890

45. Stadnyk, I., Bodnarchuk, O., Kopylova, K., Petrov, P., Bal-Prylypko, L., & Narizhnyy, S. (2021). Modification of the properties of milk-fat emulsions with the phase structure of "oil in water" in the dependence on the mass part of the lipoid and the stabilizing systems. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 15, pp. 741–748). HACCP Consulting. https://doi.org/10.5219/1389

46. Sukhenko, Y., Sukhenko, V., Mushtruk, M., & Litvinenko, A. (2018). Mathematical Model of Corrosive-Mechanic Wear Materials in Technological Medium of Food Industry. In Lecture Notes in Mechanical Engineering (pp. 507–514). Springer International Publishing. https://doi.org/10.1007/978-3-319-93587-4_53

47. Mushtruk, M., Palamarchuk, I., Palamarchuk, V., Gudzenko, M., Slobodyanyuk, N., Zhuravel, D., Petrychenko, I., & Pylypchuk, O. (2023). Mathematical modelling of quality assessment of cooked sausages with adding vegetable additives. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 17, pp. 242–255). HACCP Consulting. https://doi.org/10.5219/1845

48. Choubey, S., & Karmakar, G. P. (2020). Artificial intelligence techniques and their application in oil and gas industry. In Artificial Intelligence Review (Vol. 54, Issue 5, pp. 3665–3683). Springer Science and Business Media LLC. https://doi.org/10.1007/s10462-020-09935-1

49. Yaro, N. S. A., Sutanto, M. H., Habib, N. Z., Napiah, M., Usman, A., & Muhammad, A. (2022). Comparison of Response Surface Methodology and Artificial Neural Network approach in predicting the performance and properties of palm oil clinker fine modified asphalt mixtures. In Construction and Building Materials (Vol. 324, p. 126618). Elsevier BV. https://doi.org/10.1016/j.conbuildmat.2022.126618

50. Mustafa, H. M., Mustapha, A., Hayder, G., & Salisu, A. (2021). Applications of IoT and Artificial Intelligence in Water Quality Monitoring and Prediction: A Review. In 2021 6th International Conference on Inventive Computation Technologies (ICICT) (pp. 968–975). 2021 6th International Conference on Inventive Computation Technologies (ICICT). IEEE. https://doi.org/10.1109/icict50816.2021.9358675

Funds:

This research received no external funding.

Acknowledgments:

We would like to thank you to Dr. for I. Palamdrchuk.

Competing Interests:

No potential conflict of interest was reported by the author(s).

Ethical Statement:

This article does not contain any studies that would require an ethical statement.

AI Statement:

Artificial intelligence was not used in the article.

Contact Address:

Igor Palamarchuk
Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Control of Agricultural Products, Department of Processes and Equipment for Processing of Agricultural Production, Heroes of Defense Str., 12 B, 03040, Kyiv, Ukraine
Tel.: +38(067)754-44-93
E-mail: vibroprocessing@gmail.com
ORCID: https://orcid.org/0000-0002-0441-6586
Author contribution: project administration

Mikhailo Mushtruk
Affiliation: National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Control of Agricultural Products, Department of Processes and Equipment for Processing of Agricultural Production, Heroes of Defense Str., 12 B, 03040, Kyiv, Ukraine
Tel.: +38(098)941-26-06
E-mail: mixej.1984@ukr.net
ORCID: https://orcid.org/0000-0002-3646-1226
Author contribution: writing – review & editing

Volodymyr Piddubny
Affiliation: Ukrainian Research Institute for Alcohol and Biotechnology Food Products, Senkivskyi Lane Str., 3 m. 03190, Kyiv, Ukraine
Tel.: +38(067)401-70-96
E-mail: profpod@ukr.net
ORCID: https://orcid.org/0000-0002-1497-7133
Author contribution: validation

Nina Osokina
Affiliation: Uman National University of Horticulture, Department of Food Technologies, Institutska Str., 1, 20300, Uman, Ukraine
Tel.: +38(067)867-09-45
E-mail: ninaosokina1953@gmail.com
ORCID: https://orcid.org/0000-0002-2822- 2989
Author contribution: methodology

Andrii Chahaida
Affiliation: Zhytomyr Polytechnic State University, Department of Tourism and Hotel and Restaurant Business, Chudnivska Str., 103, 10005, Zhytomyr, Ukraine
Tel.: +38(096)988-99-24
E-mail: andrey11081968@ukr.net
ORCID: https://orcid.org/0000-0003-1826-9545
Author contribution: formal analysis

Vitalii Mihailik
Affiliation: State University of Trade and Economics, Department of restaurant and craft technologies, Kyoto Str., 19, 02154, Kyiv, Ukraine
Tel.: +38(068)355-49-03
E-mail: v.mykhaylyk@knute.edu.ua
ORCID: https://orcid.org/0000-0001-7604-4403
Author contribution: software

Olena Herasymchuk
Affiliation: Uman National University of Horticulture, Department of Food Technologies, Institutska Str., 1, 20300, Uman, Ukraine
Tel.: +38(097)087-93-11
E-mail: elena.gerasim4uk@ukr.net
ORCID: https://orcid.org/0000-0003-0973-832X
Author contribution: resources

Hennadii Tkachenko
Affiliation: Uman National University of Horticulture, Institutska Str., 1, 20300, Uman, Ukraine
Tel.: +38(068)816-39-85
E-mail: tkachenkogenady@ukr.net
ORCID: https://orcid.org/0000-0002-3438-938X
Author contribution: writing – original draft

Corresponding author: **Mikhailo Mushtruk**