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ELECTROTECHNICAL TOOLS AND COMPUTER IMAGE ANALYSIS IN ASSESSING THE QUALITY OF MAIZE GRAIN DURING STORAGE

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ABSTRACT

The study of qualitative characteristics is becoming increasingly important due to determination of the purchase price and further use of seeds. An important problem of the modern sustainable agriculture is the production of seeds and products with appropriate quality parameters. The research carried out so far proves that the technology of harvesting, transport, and drying conditions as well as storage have an impact on the quality of seeds, determining their usefulness for the industry. The smallest irregularities can cause irreversible changes and significantly reduce the technological value of seeds and their processing products. The use of tools in the field of supporting electrical engineering enables detection and highlighting of image elements so that it becomes readable to the human eye. The aim of the research was to develop technology for evaluating grain in storage using electrotechnical tools and computer techniques.

Introduction

The study of qualitative characteristics is becoming increasingly important due to the low purchase price and further production of seeds. Important technical research relates to the production of seeds and products which have quality parameters. Current research proves that regardless of the harvesting technology, transport, and drying conditions, as well as the impact on the quality of seeds, their suitability for industry is crucial. The smallest benefits may come from irreversible changes and may take into account the reduction in the technological value of seeds and their processing products (Alexandratos and Bruinsma, 2012).

The task of the grain industry is, in addition to processing, to care for the storage to ensure the effect of the properties and taste of the seeds. To achieve such a result, the industry uses a number of technologies and innovationsFor this reason, it is important to control the quality of raw materials and food products during storage, and processing. The method of classifying the ingredients and applying the quality control method should also be used. For example, different quality characteristics should be taken into account for vegetables and different for fruits, or sources that should be found only for processing, e.g., cereal grains or legumes (Broda and Grajek, 2009).

The factors relating to the sources of origin are primarily the characteristics of the product, such as: color, shape, degree of protection against pests, degree of special mechanical origin, accordingly Therefore, the development of the development of the developed method prove on the basis of these characteristics in a simple, quick and accessible way.

The analysis of the results shows that 20% of the world's textbooks on cereal of the storage method. The main causes of losses are: transport of seeds, activity of transport transports, adaptation of storage conditions and transport.

Using assistive tools allows you to detect and enhance image elements so that they become a problem for the human eye. During the computer analysis of the image, many, often frequency and abstract transformations of repetitive multiples are used. Computer analysis is used to extract information from the image to confirm information for us (Abdullah et al., 2005; Godfray and Granett, 2014). The evaluation of products is important for the consumer because it determines the price of the final product (Dworczak and Szalasa, 2001). Developing quick and effective methods is most effective, allowing you to make movement and quick research without any additional extra mode of operation. Computer image analysis and neural modeling are visible in the food industry and agriculture.

Material and Methods

The research was conducted in the grain storage company. Maize grain stored in cereal warehouses with a usable area of 1217.3 m^2, 885 m^2 and 1173 m^2 was examined. Chemical conservation was used for care treatments accompanying the storage of cereals. This operation was performed during the transfer of grain from the chamber to the chamber. During the tests, it was not necessary to carry out, for example, grain ventilation or transfer from chamber to chamber. In the research, grain contamination was determined by microscopy of the seed coat using the "Biolar" microscope. The size of a single sample is 50 g with an accuracy of 0.01 g. The samples were taken in accordance with PN-EN ISO 24333:2012. The bulk sample for the study consisted of incremental samples taken from 25 locations in the grain store. Samples were collected using a multi-chamber probe. The research was conducted in the months of June-September. Samples were taken twice a day at the same hours (7am and 7pm). In order to carry out the research, samples were taken from the stored maize grains. 10 series of tests were carried out. 150 samples were taken in each series. During the experiment, grain moisture, temperature and density were tested. Grain density and temperature were measured using a mini GAC Plus moisture meter. The bulk sample for the study consisted of incremental samples taken from 25 locations in the grain store. The samples were collected using a manual cylindrical probe (single slot holder with a filling hole).

The grain warehouse in which the research was conducted is a floor warehouse. The number of sampling sites was calculated from the formula:

$$n_{sp} = 0.5\sqrt{V} \tag{1}$$

where:
V – volume of the tested unit in m^3,
n_{sp} – is rounded to the nearest whole number.

According to the calculations, 50 samples should be taken from 10,000 m^3 of the tested material. Samples were taken from different layers of the heap. The samples were taken with a probe at a depth of 120 cm. Samples were taken from 25 places in the heap. In total, 50 samples were taken from the heap each time. It is not possible to present a sample collection pattern from the heap due to the fact that it is a floor warehouse, and the heap is irregular. An important element is to determine the number of trials. Samples are taken with a special sampling probe, which is divided into 6 sectors at a length of 120 cm.

Sensor parameters: AM2302 (DHT22) sensor, supply voltage: 3.3 V to 5.5 V, no additional external components required, connecting cable included, module dimensions: 40 x 15 x 10 mm, temperature, measuring range: -40°C to +80°C, resolution: 8-bit (0.1°C), accuracy: ± 0.5°C, measuring range: from 0% to 100% RH, resolution: 8-bit (±0.1% RH).The test performed with the use of the prepared probe is carried out in accordance with the following procedure: connecting the probe to the control, starting the set (approx. 40 s), penetration of the probe in the grain mass, starting the measurement, picking grain, pulling the sampler out of the grain mass, pouring grain into the container, end of measurement. Steps 3-7 are repeated many times over the entire warehouse area. After the test is completed, the control element should be connected to the computer network, after which the data will be sent to the FTP server. The data is processed in an external statistical tool such as Statistica, Tableau or in a spreadsheet application.

The use of image analysis in the study of the quality characteristics of agri-food products is not a new approach. The main advantage of this method is its extraordinary accuracy and repeatability. However, this method is demanding in terms of image acquisition conditions. The most important is lighting in terms of color temperature and intensity. The construction of the light source is also important, so that the tested object is illuminated evenly, with the smallest possible share of shadows and reflections. As regards the preparation of the image acquisition station, it was decided to adopt a compact solution, i.e., allowing the observation of objects with a maximum size of 20x20 cm.

The prototype station consists of a closed chamber in which the influx of external light has been eliminated. The chamber is made of white MDF board. The front wall is opened. The working size is 20 x 20 cm, with the specific surface of the bottom plate 28x26.5 cm. The color of the chamber was chosen because it does not absorb any light in the visible spectrum. Another element is the LED lighting system. The lighting system is based on the ANDURINO controlled board, which controls 1 RGB LED lighting system. This solution allows you to control the lighting in terms of its color in the RGB space. Changing the color of the lighting allows for better highlighting of the characteristics of the tested object. This is similar to applying filters. Thanks to modern technology, they can be performed already at the stage of image acquisition. A serial port is used for communication, on which the device listens for incoming messages in the format of 3 numbers in the range from 0 to 255. Messages with the content and format other than those assumed are rejected by the system. The prototype device uses a 5 Mpx image acquisition system. To build the prototype, a USB500WO2M camera (Aptina, Chiny) with the parameters listed in Table 1 was used.

Due to the prototype nature of the work, it was decided to leave the possibility of manipulating the installed components. They have been placed and secured in the upper part of the acquisition chamber, with the possibility of direct access and possible replacement in the event of a failure. It is expected that a protective cover will be added after about 6 months of operation, i.e., after the time allowing for the confirmation of obtaining the appropriate parameters of the device.

Tabela 1.
Parameters of the USB500WO2M camera [source: ELP]

Module	ELP-USB500W02M-AF60
Sensor	OV5640 (1/4")
Resolution	2592 (H) *1944 (V)
Sensitivity	600mV/Lux-sec
Pixel size	1.4μm x1.4μm
Image size	3673.6μmx2738.4μm
Maximum image transfer	2592x1944@ 15fps MJPEG / 2048x1536@ 15fps MJPEG 1600x1200@ 15fps MJPEG / 1920x1080@ 15fps MJPEG 1280x1024@15fps MJPEG/ 1280x720@ 30fps MJPEG 1024 x 768@ 30fps MJPEG/ 800 x 600@ 30fps MJPEG 640x480@ 30fps MJPEG / 320x240@ 30fps MJPEG
Camera assembly technique	SMT (ROSH)
Focus method	Auto
Acquisition distance	5CM-100M
Resolution	600LW/PH (Center)
High speed	USB 2.0 High Speed
Protocol	USB Video Class（UVC）
S/N Ratio	36dB
Dynamic Range	68dB
Shutter	Rolling shutter/ frame exposure
AGC/AEC/AWB/ABF	Auto
Data format	YUYV/MJPEG
Control parametrs	Brightness Contrast Hue Saturation Sharpness Gamma White Balance Exposure Focus
Pack	LQFN-40pin
Lens parametres	Size: 1/4, Iris: F2.8, Focus: 3.2mm, FOV: 60Degree Relative Illumination (Sensor): 70% IR Filter: 650±10nm
Power control	Support 2P-2.0mm socket
Power	USB BUS POWER 4P-2.0mm socket
Voltage	DC5V
Power consumption	150mW （VGA）；200mW （QSXGA）；
Module	38mm × 38mm （compatible 32X32mm）
Allowable temperature	-20°C to 70°C
Temperatura zdjęć	0°C to 60°C

Supported	Win XP/Vista/Win7/Win8 / Linux with UVC（above linux-2.6.26） MAC-OS X 10.4.8 or later/Android 4.0 or above with UVC
Certicications	FCC and CE

The proposed method is based on automatic image analysis. Therefore, there are some basic issues to consider in research where graphical images are the input information. The first stage is to define the purpose of research and to select methods and tools to support its implementation. In this regard, it was determined that the parameters of the grain collection (sample) will be figured out, which will then be used to assess its quality. The focus was on two types of parameters. The first group includes parameters based on the analysis of color distribution on the surface of the tested object (sample). It should be noted here that there are known studies in which the distribution of colors in a sample was used, and they mainly concerned the determination of the share of grains of various cereals in heterogeneous mixtures (Tukiendorf, 2005; Tukiendorf et al., 2006). The second group consists of morphological features that can be obtained for individual objects in the sample, i.e., grains.

Image acquisition is the first stage of the proposed method, and it is an operation consisting in introducing a digital representation of the tested object into the computer system. The most commonly used method is the use of visible (light) radiation to illuminate the sample and detect the reflected light using a suitable sensor. It is worth emphasizing here the need to exercise diligence and comply with the rules of correct acquisition of graphic images. In particular, this applies to the proper illumination of the sample, i.e., the one where the light intensity, the angle of inclination of the light rays falling on the sample and the spectral temperature of this light are correctly selected. Possible errors made at this stage have serious consequences in terms of the correctness of the measurement and the amount of information that can be obtained from the image. In particular, attention should be paid to the repeatability of the measurement, which is of key importance for the presented method and is an absolute condition for the metrological correctness of the measurements performed. Attention should also be paid to the optimal use of the brightness level ranges of the light sensor, so that the resulting image is characterized by the highest possible use of all brightness levels for achromatic images and the intensity levels of RGB components for chromatic images (Mladenov and Dejznov, 2004). It is very important that the illuminated sample does not generate additional artifacts in the form of e.g., shadows or areas of increased brightness (blinks), which during the analysis may distort the image and suggest the existence of additional elements or change the shape of the observed object. In the aspect of shadows, multi-point lighting with diffused light with possibly homogeneous distribution of light sources in the entire observed area is proposed (Gonzales-Barron and Butler, 2006; Iqbal et al., 2010).

After acquisition, the image needs to be processed. Image processing is an operation where there is an image both as input and output. A processing operation can be performed for many reasons. In the described problem, one of the first activities is image processing aimed at removing possible distortions (Kręcidło and Krzyśko- Łupnicka, 2015). These disturbances can have many different sources and can be characterized by different features. A description of all potential interference resulting from the imperfection of the acquisition method is beyond the scope of this study.

The basic task is to isolate the tested object from the background. This operation is called segmentation. Due to the nature of the planned method of morphological analysis (Szwedziak, 2019; Liu et al., 2005), the image will be binarized, i.e., transformed from a color image to a binary one. In addition to the trivial threshold method, the applied tool (APR), described in the next section, has an implemented segmentation algorithm that enables segmentation based on the selection of any number of areas (Majumdar et al., 1999; Manickavasagab, et al., 2008).

Each of the areas is represented by the indicated rectangle, in which there are pixels subject to averaging in the range of all components. Thus, a single pixel value is created, which is the basis for determining the color distance between this pixel and all pixels of the analyzed area. The software allows you to select the metric in which the distance is calculated, and after selecting it, the image is automatically segmented into as many areas as the reference areas. After segmentation, using simple methods available in APR, it is possible to remove all pixels except for pixels with specific component values, and then binarization will be carried out. The image processed in this way is the input data for the morphological analysis procedure (Szwedziak, 2019; Mohan et al., 2004).

In the first stage of the analysis of pollutants, however, the focus was on verifying the shares of individual types of identified classes in the images of samples. For each type of sample (maize, canola, wheat) 3 classes were identified: background (omitted in the analysis), granule (with a possible division into characteristic elements such as furrow, etc.), artefacts.

Each of the samples was subjected to morphological analysis in accordance with the procedure described in (Szwedziak, 2019a). The basic results of the analysis for each identified object was a set of attributes: objects number, filled surface, empty surface, number of holes, edge adherent, centre of gravity, start pixel, length of external edge x, length of internal edge, length of all edges, number of edges, internal edges.

The developed application is used to analyze, process, and recognize images. Its main feature is the ability to build image processing scripts. For this purpose, a scripting language has been built in that allows you to perform a number of graphical operations. In addition, it is possible to enter commands directly in the command line. Some of the operations are available from the panel containing the appropriate communication interface with the user. The main application window allows you to work on multiple images in separate workspaces. Operations in each space can be performed independently of others by means of commands, scripts or an auxiliary panel with dialog elements facilitating interaction with the program. Image windows have their own menus, tabs, information bar, and help pane. After pressing the image save or image button, the appropriate dialog box appears in which you can select the file. The program is adapted to read and write images in standard graphic formats (BMP, JPEG).

Scripting is the primary method for image processing in this application. Individual commands can also be issued by typing them in the command line. The Lua language, which is an efficient scripting programming language, was adopted to handle program commands. Commands should be typed with the name of the image to which they apply. A number of mechanisms have been introduced to facilitate programming. One of them is the default of some parameters, which significantly reduces the time of writing scripts.

Basic and advanced image manipulation commands are an integral part of the APR application, which includes specialized and unique proprietary solutions, e.g., in the field of binary scene morphological analysis. The choice of APR was driven by the considerations of maintaining consistency with the research conducted so far and the efficiency of this tool. APR has interfaces that allow you to create your own functions in C++. APR is designed with computational efficiency in mind and a strong focus on real-time applications. It was written in C ++ in a way that enables efficient analysis and processing of complex scenes and even video sequences. As already mentioned, the main window of the program may contain several images. Operations on each of the images can be performed using commands, scripts or an auxiliary panel with dialog elements facilitating interaction in the program. Image windows have their own menus, tabs, information bar, and help pane. After pressing the image save or image button, the appropriate dialog box appears in which you can select the file. The program is adapted to read and write images in BMP and JPG formatScripting is the primary method for image processing in this application. Individual commands can also be issued by typing them in the command line. The developed language has a number of commands that relate to image handling (reading, writing, etc.), image processing and analysis. Commands should be typed with the name of the image to which they apply. Several mechanisms have been introduced to facilitate programming. One of them is the default of some parameters, which significantly reduces the time of writing scripts. Commands should be typed using the following syntax:

[<window_name>] COMMAND <parameters>

For commands that apply to all windows or the entire program, the window name is omitted. This applies, for example, to the commands: EXIT, WINCASCADE, WINVERTICAL, WINHORIZONTAL.

The letters are not case sensitive, which means that the WINCASCADE command is equivalent to the wincascade command. However, it is recommended that you write your scripts in upper case, which greatly improves readability.

The names of the command parameters are in brackets < >. The commands themselves are presented exactly as you type them. A line starting with // indicates a comment.

The syntax element enclosed in square brackets is optional, i.e., it may or may not appear in the expression. For example:

NEW [<name>]

means that the NEW command may have a name parameter, but it is not required. Therefore, both the command. The commands are described according to the following scheme: command name, syntax, example of use, parameter description, command description. For example:

NEW

Syntax: NEW [<name>]

Example: NEW window1

<name> - Name of the window. The window is identified by this name.

The NEW command creates a new window in the main window and assigns it the name given in the <name> parameter.

All available procedures are described in the help files available directly from the program menu. Below is an example of using the object parameterization function in a binary scene:

GETOBJECTS

Syntax: <window> GETOBJECTS

Example: IM1 GETOBJECTS

<window> - Name of the window.

The GETOBJECTS command finds objects in the scene and calculates their basic parameters.

The following script loads the image from the MONOREG.BMP file and then calculates the global and local parameters shown below the script (Fig.1)

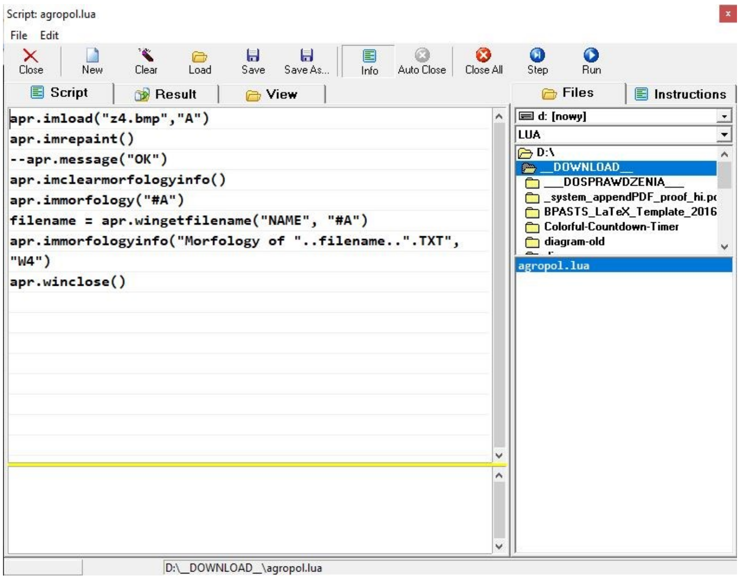
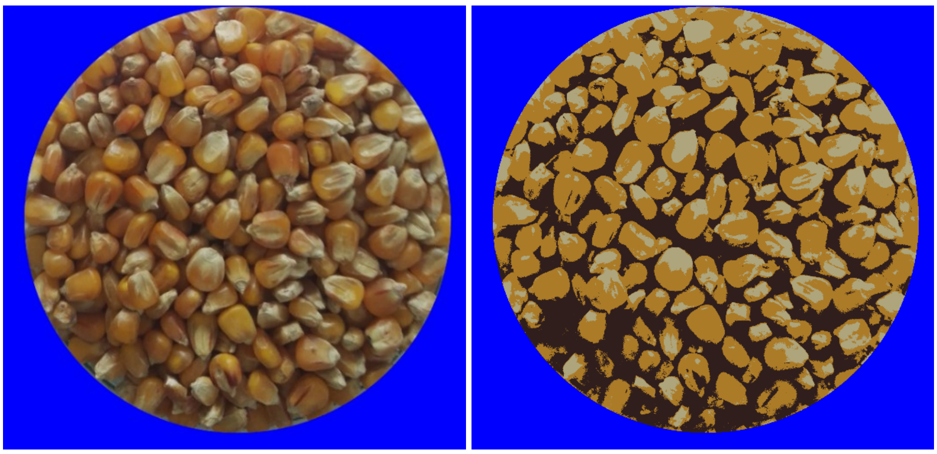


Figure 1. Segmentation share window



	X	Y	Red	Green	Blue	Pixels	Share
	861	394	171	123	39	1888205	34,617 %
	465	143	0	0	255	1660046	30,434 %
	705	718	48	30	28	1311314	24,041 %
	1090	731	174	165	124	595027	10,909 %

Figure 2. Image before segmentation, after segmentation and counting classes

Each of the areas is represented by the indicated rectangle, in which there are pixels subject to averaging in the range of all components. Thereby, a single pixel value is created, which is the basis for determining the color distance between this pixel and all pixels of the analyzed area. The software allows you to select the metric in which the distance is calculated, and after selecting it, the image is automatically segmented into as many areas as the reference areas. After segmentation, using simple methods available in APR, it is possible to remove all pixels except for pixels with specific component values, and then binarization will be carried out. The image processed in this way is the input data for the morphological analysis procedure (Szwedziak, 2019b). At the first stage of the analysis of pollutants, however, the focus was on verifying the shares of individual types of identified classes in the images of samples. For each type of sample, 3 classes were identified: background (omitted in the analysis), granuloma (with possible division into characteristic elements such as a furrow, etc.), artifacts (Fig.2).

Results and Discussion

As part of the conducted conventional tests, in order to assess the quality of the raw material - maize, at the time of acceptance for storage, as well as during the entire storage process at all stages, individual parameters were assessed: moisture, temperature, density. To verify the obtained results, a statistical analysis was performed (Tab. 2). Figures 3-6 show the correlation of moisture, temperature, and corn grain density.

Tabela 2.
Descriptive statistics for the results of individual tested corn grain variables

Variable	Nimportant	mean	Tust 95%	median	minimum	maximum	Lower quaetlle	Upper quartile	variance
Moisture	50	13.38	13.51	13.3	12.8	14.2	13	13.8	0.22
Temperature	50	20.29	20.43	20.4	19.5	21.0	19.9	20.7	0.24
Density	50	74.96	75.10	74.9	74.1	75.9	74.5	75.3	0.27

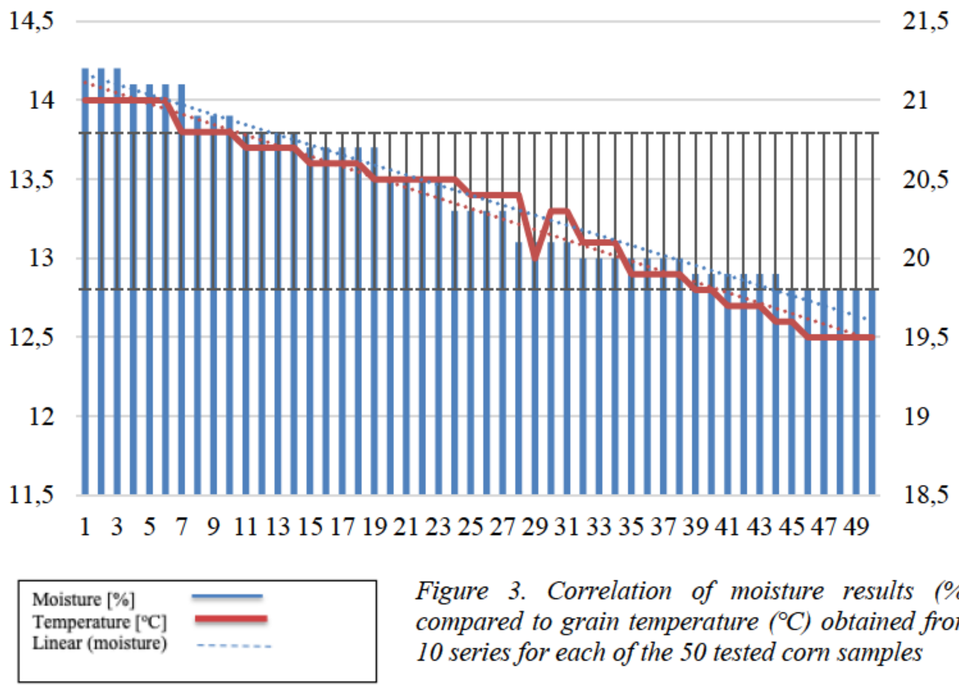


Figure 3. Correlation of moisture results (%) compared to grain temperature (°C) obtained from 10 series for each of the 50 tested corn samples

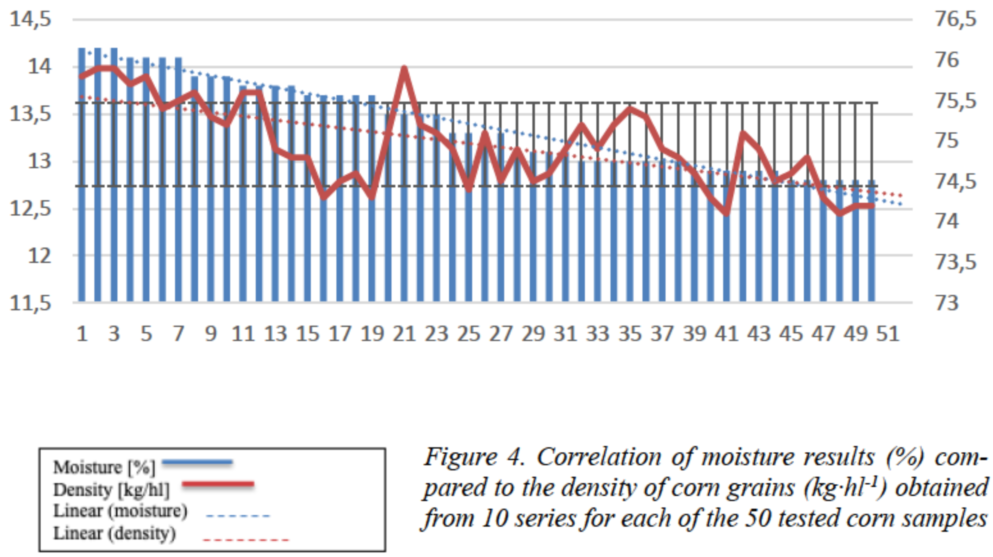


Figure 4. Correlation of moisture results (%) compared to the density of corn grains ($kg \cdot hl^{-1}$) obtained from 10 series for each of the 50 tested corn samples

Analyzing the presented test results it can be observed that all the data obtained are within the normal limits and do not exceed 14.5% of the permissible humidity. The temperature of corn grains was closely related to moisture, which decreased depending on the temperature. The lowest maize density obtained was 74.1 kg h·L^{-1} in tests 41 and 48, and the highest in tests 2, 3 and 21 was 75.9 kg h·L^{-1}. The most common data in the field of fluctuations in the scope of research ranged from 74.5 to 75.5 kg h·L^{-1} . To confirm the obtained results, Fig. 5 shows the scatter diagram of moisture and temperature for the tested corn grains.

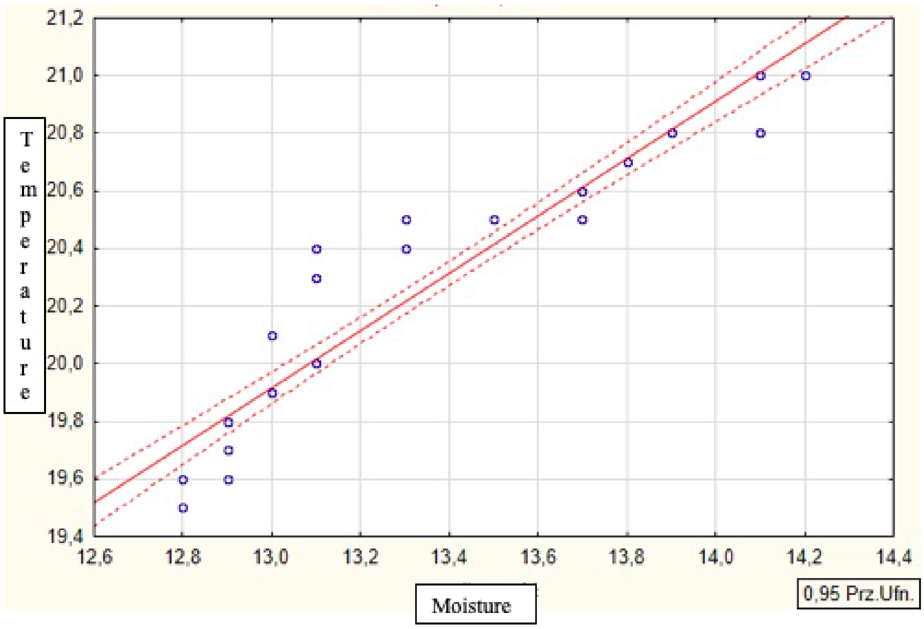


Figure 5. Scatter plot of moisture and temperature correlation for the tested corn grains

As part of the conducted computer analysis studies, two types of results were also obtained. The first concerned the participation of designated colors in the scene. For this purpose, supervised segmentation of the sample images was performed and the values of the occupied area for the appropriate classes were determined. The results for individual samples. Mladenov and Dejanov (2004) focused their attention on the use of image analysis to assess germinating seeds. In their research, they used the RGB color description model. Manickavasagan et al. (2008) in their work on the comparison by illumination of classes identifying wheat through monochrome images used a vision machine that recorded images of wheat samples analyzing their color and texture. Wheat grains with different moisture content (11%, 14%, 17%, 20%) were tested. 9,600 photos were taken. 32 shades of gray recorded on wheat samples were used for the evaluation. The mean gray values were significantly different within each illuminant and with different illumination. The average value of the gray level was also dependent on grain moisture. Visen et al. (2004) used image analysis using a digital camera to identify different types of grain. The tests were carried out on 5 types of grain: barley, oats, rye, wheat, and durum wheat. The obtained images from the digital camera were processed by a computer program that analyzed the data on the basis of color and texture. The results showed the correctness of classification over 90% for all types of grain. Li et al. (2007) used image analysis to classify rapeseed. The color, which was determined using the HSV model, and the shape of the seeds were used for the assessment. Majumdar et al. (1999) used digital image analysis based on the RGB model in their study to evaluate and classify wheat, barley, oat, and rye samples. The accuracy of the method used was 98.6%. Mohan et al. (2004) used digital image analysis for the volumetric classification of oilseeds and pulses. Gonzales-Barron and Butler (2006) used image analysis to assess the texture of breadcrumbs. The research showed a differentiation in the texture of breadcrumbs due to the type of flour from which the bread was baked. The accuracy of the results was 93%. Liu et al. (2005) in their research used image analysis and neural networks to classify rice varieties based on morphological features and color. Białobrzewski used neural networks to estimate the value of relative humidity of atmospheric air based on its temperature (Białobrzewski, 2005; Bałobrzewski et al., 2005). Based on the performed tests, the author concluded that the model values obtained for a one-way neural network with a time-delayed multi-layer perceptron topology, using the back-propagation error algorithm, reflect the nature of empirical changes in relative humidity of atmospheric air. In the further part of the research, the author showed that the learning algorithm, Bayesian regularization, turned out to be one of the best in terms of all analyzed parameters for assessing predicted temperature values (Qian et al., 2017).

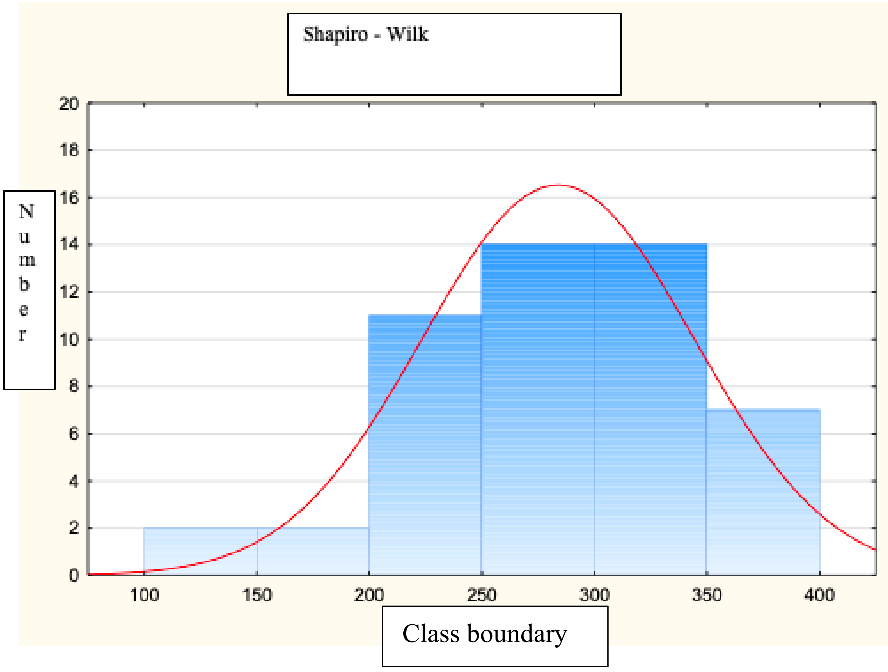


Figure 6. Histogram with the expected normal distribution for the surface area counted in pixels in the tested maize grains

Conclusions

The results obtained from conventional tests on the quality of the selected parameters of the raw material, such as: moisture, grain temperature, density, present normalized results within the limits of the established imperatives, which prove that the process of storing and storing the grain subjected to computer analysis tests is correct.

The results of further computer analysis of grain quality indicate that the adopted research direction is promising. The biggest problem in the area survey was a relatively low quality of the photos resulting from the adopted methodology, according to whose photos were of a bulk sample placed in a petri dish. When developing the method, a different solution should be adopted, in particular, the one in which the sample to be acquired would contain at most one layer of grain placed on a contrasting background (preferably blue R0G0B255). Regardless of these difficulties, corn kernels, a relatively small dispersion of the measured values could be observed. In order to prepare the participatory method for implementation, a procedure should be defined that would solve the problems of measurement repeatability:

1. Appropriate arrangement of the sample (one layer, background)
2. Appropriate lighting - tests for changing the color of light
3. Calibration of the station to determine the absolute unit (mm, cm), and not to build standardized measures in relation to the image characteristics (pixels)
4. Determination of repeatable colors of classes characteristic for maize

In terms of research on the morphology of kernels, the results should be considered satisfactory. At the same time, it should be noted that there are currently no standards or detailed studies regarding the unequivocal reference of the results of the morphological analysis performed on the image of a kernel to the assessment of its quality. Based on the analysis of the results obtained for maize, it can be concluded that the proposed use of normalized measures relating to the symmetry and circularity of objects corresponds to the given problem, i.e., it allows testing the homogeneity of the shape of kernels in the sample.

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NARZĘDZIA ELEKTROTECHNICZNE I KOMPUTEROWA ANALIZA OBRAZU W OCENIE JAKOŚCI ZIARNA KUKURYDZY PODCZAS PRZECHOWYWANIA

Streszczenie. Badanie cech jakościowych nabiera coraz większego znaczenia ze względu na ustalanie ceny skupu oraz ze względu na dalsze wykorzystanie nasion. Ważnym problemem współczesnego rolnictwa zrównoważonego jest produkcja nasion i produktów o odpowiednich parametrach jakościowych. Z dotychchczasowych badań wynika, że technologia zbioru, warunki transportu i suszenia oraz przechowywania mają wpływ na jakość nasion, decydując o ich przydatności dla przemysłu. Najmniejsze nieprawidłowości mogą spowodować nieodwracalne zmiany i znacznie obniżyć wartość technologiczną nasion i produktów ich przetworzenia. Wykorzystanie narzędzi z zakresu wspomagania elektrotechniki pozwala na wykrywanie i podkreślanie elementów obrazu tak, aby stał się on czytelny dla ludzkiego oka. Celem badań było opracowanie technologii oceny ziarna w magazynie z wykorzystaniem narzędzi elektrotechnicznych i technik komputerowych.

Słowa kluczowe: analiza jakości, magazyn zboża, komputerowa analiza obrazu, elektrotechnika