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COMPUTER IMAGE ANALYSIS IN THE ASSESSMENT OF GRAIN SIZE COMPOSITION OF GRANULAR MATERIALS

Summary

The aim of the study was to determine the potential and possibilities of use of computer analysis and image processing in the agri-food industry in Poland, with particular emphasis on the agricultural sector. The paper presents the results of tests of selected physical parameters of agricultural and horticultural fertilizers present on the Polish retail market. The study was performed with the use of AnalySis FIVE, a computer program that enables image analysis and is able to work with a variety of external devices (cameras, scanners, photo cameras, etc.). The steps involved in the process of performing measurements using computer image analysis were described. A method of measurement was developed, which consisted in creating a laboratory procedure for the preparation of samples for microscopic observation and defining the parameters characterizing the dimensions of the tested products. The results are presented in graphical and tabular forms and findings on the method of measurement are presented. Attention was drawn to a novel method for measuring the characteristic dimensions of agricultural and horticultural fertilizers which have an impact on the technological quality of applications.
***Key words**: computer image analysis, measurement, fertilizers, agricultural and horticultural, grain size*

KOMPUTEROWA ANALIZA OBRAZU W OCENIE SKŁADU GRANULOMETRYCZNEGO MATERIAŁÓW ZIARNISTYCH

Streszczenie

Celem pracy było określenie potencjału oraz możliwości zastosowania komputerowej analizy i przetwarzania obrazu w przemyśle rolno-spożywczym w Polsce, ze szczególnym uwzględnieniem sektora rolniczego. W pracy przedstawiono wyniki badań dotyczących wybranych parametrów fizycznych nawozów rolniczych i ogrodniczych obecnych na Polskim rynku handlowym. W badaniach posłużono się programem komputerowym: AnalySis FIVE umożliwiającym analizę obrazów, mogącego współpracować z różnymi urządzeniami zewnętrznymi (kamery, skanery, aparaty fotograficzne itd.). Opisano etapy składające się na proces wykonywania pomiarów za pomocą komputerowej analizy obrazu. Opracowano metodę pomiaru, która polegała na utworzeniu laboratoryjnej procedury przygotowania próbek do obserwacji mikroskopowych, zdefiniowania parametrów charakteryzujących wymiary badanych produktów. Otrzymane wyniki przedstawiono w formie graficznej i tabelarycznej. Przedstawiono wnioski charakteryzujące metodę pomiaru. Zwrócono uwagę na nowatorską metodę pomiaru charakterystycznych wymiarów nawozów rolniczych i ogrodniczych, wpływających na jakość technologiczną aplikacji.
***Słowa kluczowe:** komputerowa analiza obrazu, pomiar, nawozy rolnicze i ogrodnicze, granulometria*

1. Introduction

Agricultural technology involves dealing with granular materials such as grains and their milling products, seeds of other arable crops, industrial fodders, or sugar, among many others. A granular material consists of individual solid particles in contact with one another. An important aspect from the point of view of the course of various technological processes connected with processing of granular materials, i.e. transport, storage, or sieving, are characteristic dimensions of grains such as: hydraulic diameter, maximum diameter, circumference, surface area, form factor, etc. [5, 20].

Determining the geometric dimensions of a granular material can be carried out in various manners. When measuring instruments such as the calliper or micrometre are used, typical dimensions of grains in different planes can be measured. Such measurements are tedious, lengthy, and often marred by subjective conditions of the measuring process (e.g. readout method) [13].

Measurement by means of optical, electrical, and electron devices is the most modern method of measurement of particle size. The possibility of quick measurement of the size and shape of grains is extremely important in the case of many bulk materials, e.g. mineral resources (fine aggregates, gravel, coarse sands), coal, plant seeds, food pellets, and plastics, including agricultural and horticultural fertilizers [12, 15].

Computer image analysis is an invaluable tool for performing granulometric analysis [6].

This method makes use of image analysis software by means of which geometric parameters of the analysed objects are determined. The software makes it possible to perform measurements of objects easily in a relatively short period of time and simple unambiguous imaging of results. It also allows to remove all erroneous measurements resulting from cohesion of the analysed particles [18]. This method works especially well in granulometric analyses of fine crystalline powders susceptible to cohesion [1]. In times of rapid industrial development, present also in the agri-food industry, computer image analysis may prove a useful tool for analysis of the condition of the quality of agricultural and food products [9, 14, 19].

The results of granulation analyses obtained by means of computer image analysis are presented graphically in the

forms of histograms, cumulative curves, and by means of numerical characteristics of distribution [11].

The group of granular materials subject to computer image analysis consists of agricultural and horticultural fertilizers. The size of pellets has an influence mainly on retaining repeatability of the dose of fertilizer during its application with the use of a manual applicator. The accuracy of dosing depends on the percentage share of its different fractions in the fertilizer [10].

2. Research aim

The aim of the study is to assess the granulometric composition of agricultural and horticultural fertilizers through computer analysis, which would allow to accurately determine dimensions characteristic for the tested fertilizers (determining the hydraulic diameter of a granular raw material).
This action will facilitate the process of fertilizer spreading, e.g. in horticultural orchards or steep green terrain, by means of a fertilizer dispenser (application) where the maximum diameter of the applied fertilizers is the key operation parameter.

3. Research methodology

Agricultural and horticultural fertilizers available on the Polish retail market were used for the purpose of the tests (Table 1):

a) agricultural fertilizers (numbers from no. 1 to no. 9),
b) horticultural fertilizers (numbers from no. 10 to no. 15).

Table 1. Fertilizers used during the tests
Tab. 1. Nawozy użyte podczas badań

Type of tested fertilizer	Fertilizer variety	Release rate of nutrients
agricultural 1	granulated fertilizer	immediate
agricultural 2	granulated fertilizer	immediate
agricultural 3	coated fertilizer	not stated
agricultural 4	granulated fertilizer	immediate
agricultural 5	coated fertilizer	2-3 months
agricultural 6	granulated fertilizer	immediate
agricultural 7	coated fertilizer	1-1.5 months
agricultural 8	granulated fertilizer	immediate
agricultural 9	granulated fertilizer	immediate
horticultural 10	granulated fertilizer	immediate
horticultural 11	granulated fertilizer	immediate
horticultural 12	granulated fertilizer	immediate
horticultural 13	granulated fertilizer	immediate
horticultural 14	coated fertilizer	2-3 months
horticultural 15	coated fertilizer	4-6 months

Source: own work / Źródło: opracowanie własne

The tests were carried out by means of the Kodak EasyShare C913 digital camera and a computer with software for computer image analysis, AnalySIS 5, installed, which enables measurement of many geometric values of the tested particles, including: maximum, minimum, and average grain diameter; grain circumference; grain radius; grain elongation, etc. It is also possible to analyse all the parameters simultaneously.

Computer image analysis consists of the stages presented in fig. 1.

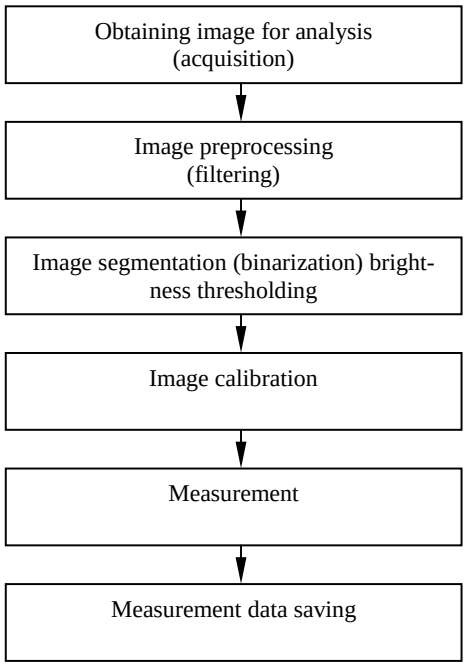
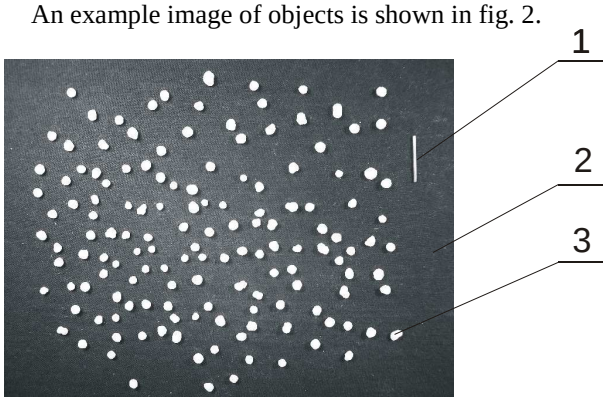


Fig. 1. Scheme of computer image analysis [23]
Rys. 1. Schemat komputerowej analizy obrazu [23]

The images for the tests were obtained according to the procedure presented in fig. 1. Selecting the appropriate lighting and position of the acquisition device is a very important element of acquisition [3]. Image acquisition is carried out by means of a photo camera and its aim is to adjust its resolution and contrast [17].

An example image of objects is shown in fig. 2.

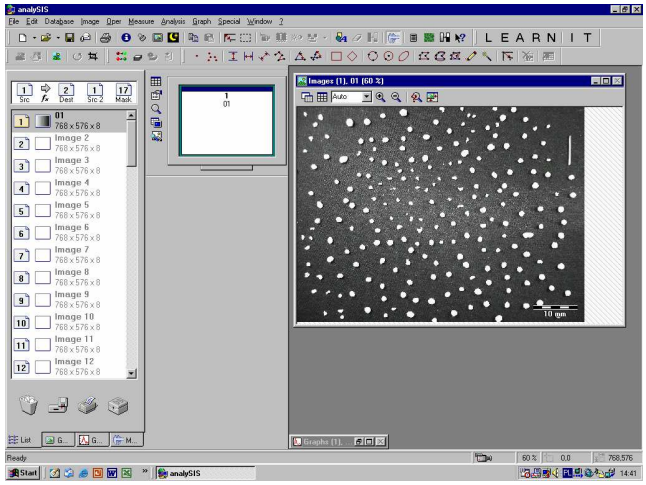


Source: / Źródło: [17]

Fig. 2. Image of objects recorded as 256 levels of brightness: 1 - length template, 2 - measurement plate, 3 - the tested fertilizer
Rys. 2. Obraz obiektów zapisany w postaci 256 poziomów jasności: 1 - wzornik długości 2 - blat pomiarowy, 3 - badany nawóz

The aim of image preprocessing is to obtain appropriate contrast between the analysed particles and the background. In digital analysis, a table with 256 levels of brightness (grey levels) is the one most commonly used for saving the image on the hard drive. This allows to adjust brightness and contrast of the photo (fig. 3) [23].

The aim of image preprocessing (filtering) is to reduce distortions of the image obtained in the acquisition process [18].



Source: / Źródło: [23]

Fig. 3. Photo of pelleted fertilizers as seen on the computer screen
Rys. 3. Zdjęcie nawozów granulowanych na ekranie komputera

The next stage consisted in selecting objects for measurement. Image segmentation consists in dividing the image into separable areas with specific characteristics [23]. In the discussed case, the purpose of segmentation was to separate the structures that would be subject to further analysis from the background. This was achieved through separation of white particles from the dark background with the use of a grey level histogram.

An important matter is also that the photographed objects are assigned to a certain scale that characterizes the magnification at which they were obtained. This was achieved through image calibration, which consisted in measuring the length of the template placed on the measurement plate next to the tested fertilizer. In this way, the image was scaled for measurement of geometric parameters of particles.

Owing to this, a fine-scale computer image corresponding to the real dimensions of the tested fertilizers, which enables later measurement of their linear characteristics, was obtained.

Initial examination of the analysed particles allowed to determine that their shape is circular, hence the parameter selected for measurement during the computer image analysis was maximum particle diameter. The results of these measurements were saved and subject to further analysis with the use of statistical software.

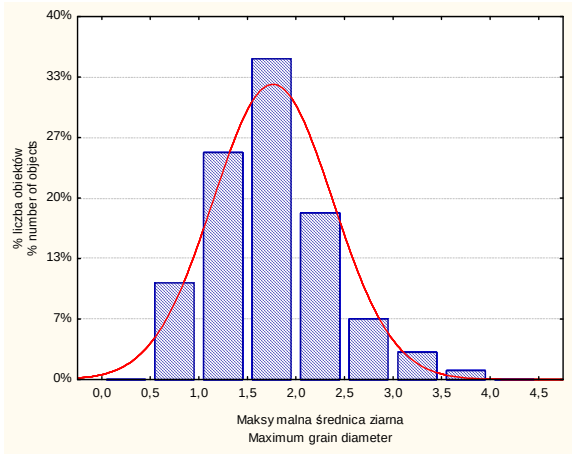
The images obtained during the analysis were measured and the maximum grain diameter was assessed.

After performing the measurements of geometric dimensions of fertilizer particles, a statistical analysis of the obtained measurement results was carried out with the use of Statistica software. Using the Shapiro-Wilk compatibility test, which consists in fitting the normal distribution to the obtained data, at a significance level of $p<0.050$ for fertilizer A and B, the distribution of maximum particle diameter sizes was determined in Statistica 9 software.

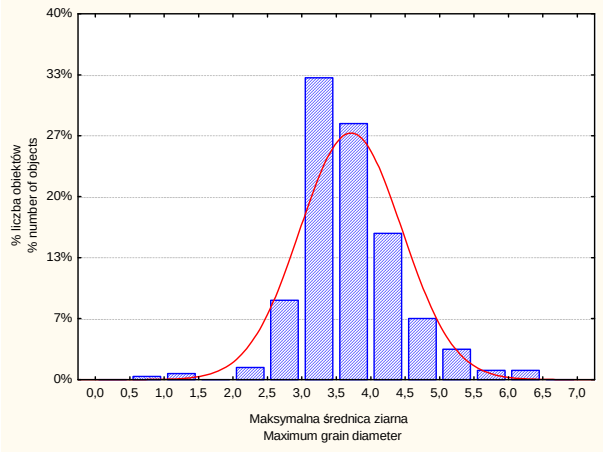
4. Test results

The granulometric compositions of the tested fertilizers A and B are shown in fig. 4, in the form of histograms.

a)



b)



Source: own work / Źródło: opracowanie własne

Fig. 4. Granulometric distribution: a) fertilizer A, b) fertilizer B
Rys. 4. Rozkład granulometryczny: a) nawozu A, b) nawozu B

A comparative analysis of the maximum diameter of the tested fertilizers was performed by means of a box plot (fig. 5).

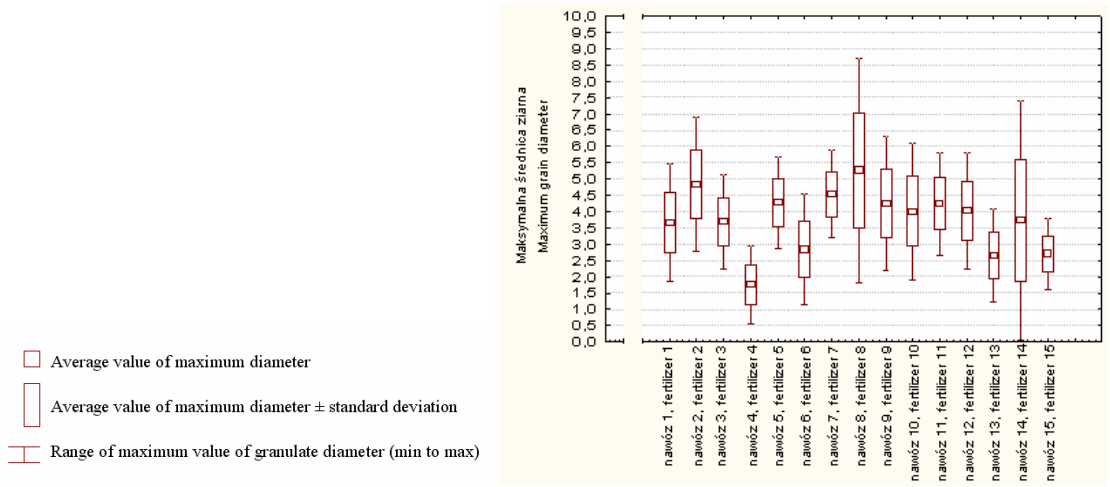
The average value of maximum particle diameter measured by means of computer analysis was 1.753 mm for fertilizer A and 3.693 mm for fertilizer B.

The small value of standard deviation during measurements of diameter size of fertilizer particles in computer image analysis shows that the measurement results are centred around the average value and may differ from their average value by 0.613 mm for fertilizer A and 0.740 mm for fertilizer B.

The performed Shapiro-Wilk compatibility test at a significance level of $p<0.050$ showed the normal distribution of maximum particle diameter for both fertilizer A and B.

The scattering of the obtained results is quite significant, i.e. 3.393 mm for fertilizer A and 5.412 mm for fertilizer B. In both these cases the measurement was performed for 300 objects.

It was also noticed that the values of variance are lower for coated fertilizers (4 out of 5) than for pelleted fertilizers (from 0.308 to 0.547). The obtained results (for coated fertilizers) are largely concentrated around the average value of the measured parameter. This may be indicated by the fact that these fertilizers are produced using a different technology compared to pelleted fertilizers.



Source: own work / Źródło: opracowanie własne

Fig. 5. Comparative analysis of maximum diameter of fertilizers by means of a box plot
Rys. 5. Analiza porównawcza maksymalnej średnicy nawozów za pomocą wykresu pudełkowego

On the basis of the obtained plot, the average values of maximum diameter for all fertilizers and their standard deviations were compared graphically. An analysis of the plot allowed to determine a range of values for 50% of the results and to read the highest and the lowest values for the measured parameter.

5. Conclusions

1. Computer image analysis enables quick determination of the values of geometric parameters of large numbers of objects.
2. On the basis of the obtained results and the performed Shapiro-Wilk compatibility test at a significance level of $p<0.050$, the normal distribution of maximum particle diameter for both fertilizer A and B was obtained.
3. The average value of maximum diameter was 1.753 mm and 3.693 mm for fertilizers A and B, respectively.
4. The values of variance of measurement results for coated fertilizers are lower than for pelleted fertilizers (from 0.308 to 0.547). The obtained results (for coated fertilizers) are largely concentrated around the average value of the measured parameter, which may indicate that these fertilizers were produced with the use of a different technology than pelleted fertilizers.
5. The method makes it possible to work with computer applications, which facilitates inference and makes it easier to perform quick analyses.
6. Computer image analysis is a method that may find its use as a tool for the assessment of the granulometric content of agricultural and horticultural fertilizers.

6. References

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