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The Method of Determining Seed Moisture Based on the Signal Generated by the Piezoelectric Plate

***Abstract**. The paper presents research on determining the moisture content of various species of seeds based on the shape of the signal generated by the piezoelectric plate when hitting the seeds against it. For this purpose, a measuring stand was made on which the tests were carried out. The studies used different seed species with a near-spherical shape to eliminate the influence of the grain's impact on the plate. Based on the obtained signal waveforms, an algorithm was proposed with which the voltage rise coefficient on the piezoelectric transducer was calculated.*

***Streszczenie.** W pracy przedstawiono badania dotyczące określania wilgotności różnych gatunków nasion w oparciu o kształt sygnału napięciowego generowanego przez płytę piezoelektryczną przy uderzeniu nasion. W tym celu wykonano stanowisko pomiarowe, na którym zostały przeprowadzone testy. W badaniach wykorzystano różne gatunki nasion o kształcie zbliżonym do sferycznego, aby wyeliminować wpływ kształtu nasion na wyniki pomiarów. Na podstawie uzyskanych krzywych sygnału zaproponowano algorytm, w którym obliczono współczynnik wzrostu napięcia na przetworniku piezoelektrycznym. (**Określanie wilgotności różnych gatunków nasion w oparciu o kształt sygnału napięciowego generowanego przez płytę piezoelektryczną**)*

Keywords: seeds, moisture, piezoelectric plate,
Słowa kluczowe: nasiono, wilgotność, przetwornik piezoelektryczny,

Introduction

Vegetable products are commodities of strategic importance. They or their derivatives are the basis of the food industry, also serving as animal feed. The demand for vegetable products will increase steadily due to the increasing number of people on earth [1]. In order to meet these requirements, the focus should be on increasing production efficiency, as expanding the area of cultivation is not always possible. That is why numerous studies are conducted to boost production efficiency. This research is conducted at many levels, including in laboratories where work is being carried out on new varieties or in crop agrotechnology itself [2].

The second important issue, apart from increasing plant production, is obtaining the highest quality of the harvested material. The quality of the material depends on its further usefulness for further production.

The quality of the material should be taken care of throughout the entire production cycle, from the selection of the right seed to the final product. When it comes to plant material, the main factor influencing the quality is its moisture content.

This parameter is a determinant throughout the production cycle. Starting from the harvest, where the moisture of the seeds determines the optimal harvesting time, on to the storage of crops, where this factor has a decisive impact on the storage capacity of the material, up to the processing stage where it affects the quality of the final product.

Several methods of seed moisture measurement are known and described in the literature. These methods can be divided into laboratory and industrial ones. Laboratory methods, as opposed to industrial procedures, are characterised by high accuracy. These methods, unlike industrial ones, take a long time to get the correct results.

One laboratory method is the weight method. It consists in weighing a sample of a given mass before the measurement and then drying it in strictly defined conditions and duration. The sample is then weighed again and the water content is determined based on the weight difference. For example, in the Polish Standard PN-R-65950 the drying time of the sample can be up to several hours.

In industrial conditions the most often used methods are electrical ones. They use the electrical properties of the measured material, such as capacitance or resistance, and on their basis the moisture content of seeds is indirectly calculated [6]. These methods are characterised by measurement inaccuracies, but they are commonly used due to the immediate reading of the value and the low cost of the measurement system.

Another example of seed moisture measurement described in [3] is placing the seeds in a sealed sample and measuring their relative humidity at a given temperature. This parameter is uniquely correlated with the moisture of the seed data. Relative humidity was measured on the indicator paper, which changes colour depending on the relative humidity. A similar method of measurement, i.e. using relative humidity, is presented in paper [4], in which the authors developed a probe for measuring grain moisture. An alternative way of measuring humidity involves radio frequencies (RF), in which the correlation between dielectric properties of RF radio waves and moisture content are used [7].

The methods described above focus on the measurement of a seed sample with a weight of several grams. This limitation is important in the case of seeds of small size, e.g. rape or mustard seeds, especially when one wants to measure the moisture of seeds before harvesting. The purpose of the present work is to develop a method for estimating seed moisture for individual grains. This method is to be characterised by an immediate reading of the value.

Preparation of the experiment

The seeds used in the research were collected in the harvest of 2017 and included:

- white mustard (*Sinapis alba L.*),
- hemp (*Cannabis sativa L.*),
- millet (*Panicum miliaceum L.*)
- mung bean (*Phaseolus mungo L.*)
- coriander (*Coriandrum L.*)
- rapeseed (*Brassica napus L.*)

The seeds were then stored in warehouses. A sample of 1 kg was collected from the seeds, then the moisture content of a given sample was measured by the gravimetric method in accordance with PN-R-65950, with part of the seeds being ground before the measurement according to the standard. Humidity values are recorded in Table 1.

To determine the humidity of seeds, a test stand was used as in Figure 1. The main element of the stand is the measurement system using the Murata 7D-25-18000 piezoelectric plate shown in Figure 2. This plate converts the impact force into an electrical signal. The operating principle of the stand was as follows:

Yable 1. Humidity of the seeds

Name	Humidity (%)
mustard	6.5
hemp seed	7.3
millet	5.4
mung beans	6.9
coriander	5.7
rape	7.4

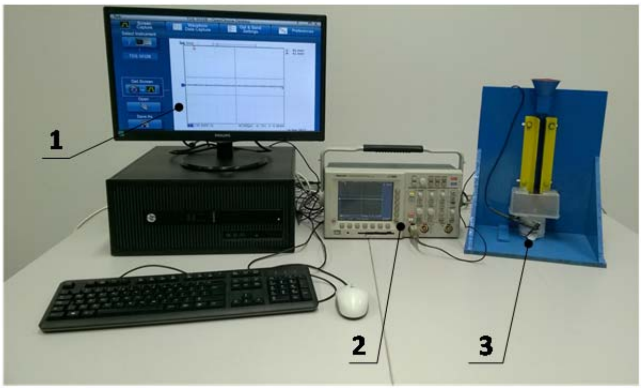

Fig. 1. Test stand: 1 – computer processing the signal, 2 – oscilloscope; 3 – measuring system

The seeds were dropped from a fixed height onto a piezoelectric plate, which generates a signal dependent on the force of the impact. This signal is then recorded by the Tektronix TDS 3032B oscilloscope, which is then stored in computer memory.

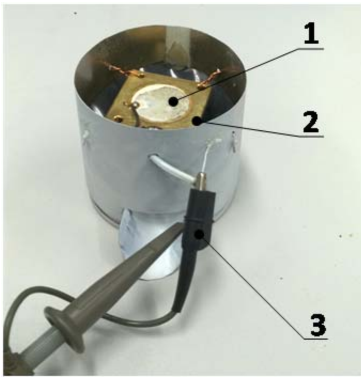

Fig. 2. The measuring system: 1 – piezoelectric plate, 2 – plate suspension, 3 – cable leads to the oscilloscope

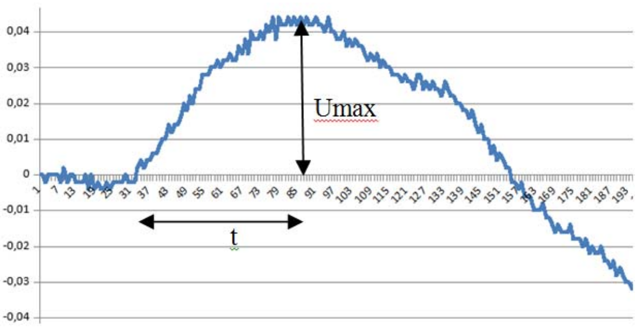

Fig. 3. The method of determining parameter *k* [5]

Then the signal is analysed in accordance with the algorithm proposed by the authors in study [5] and calculated on the basis of the following formula:

(1) $k=(A/t)*w$)

where : A – U max [V], t – time [ms], w – coefficient depending on oscilloscope parameters.

Parameters *A* and *t* are determined from the graph as in Figure 3. The methodology of measurements has been modified in relation to work [5] in such a way that only the signals in which the average of three successive amplitudes is smaller than the previous one were used to determine the coefficient k. On the other hand, measurements with a course other than in Figure 4 were rejected.

Results and Discussion

The obtained results of the research on the dependence of the voltage rise coefficient as a function of humidity show that the seeds used behave very differently. Their impact force during the collision with the transducer depends on the humidity, but for each variant it has a different course.

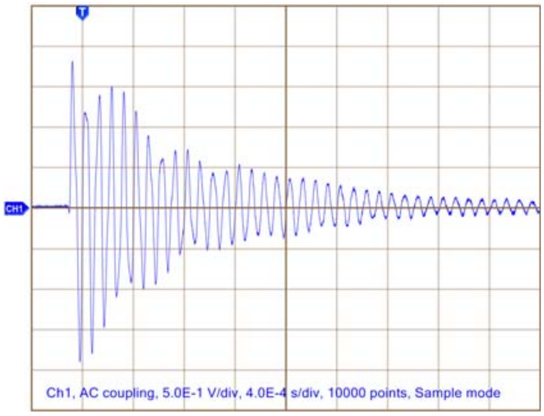

Fig. 4. Waveform of the signal generated by the piezoelectric plate

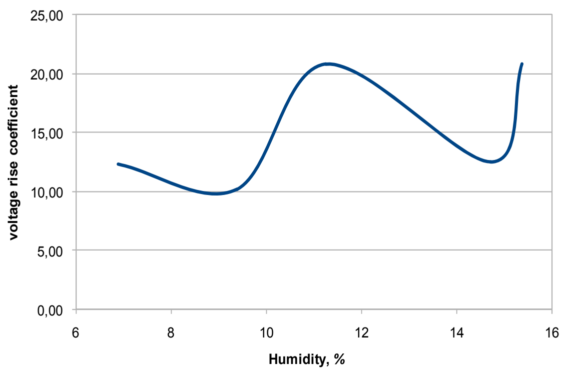

Fig. 5. The value of the voltage rise coefficient on the piezoelectric transducer for Mung beans

Research on Mung bean seeds showed a significant increase in the rate of voltage rise on the transducer at a relative humidity of about 11%. Increasing the coefficient can be an indication that treatment of seeds at this humidity will cause the greatest forces that can lead to damage to the seed. The relationship between the voltage rise and the moisture coefficient for Mung bean seeds is shown in Figure 5. The rate of voltage rise for coriander seeds shows a certain downward trend at a relative humidity of about 13%. It is the value of moisture which shows the greatest ability of seeds to absorb energy during an impact. This can be important for storing seeds as well as their post-harvest treatment (Fig. 6).

For hemp seeds (Fig. 7), the obtained graph of the coefficient of the voltage rise rate shows a certain increase in moisture content from 12% to 16%.

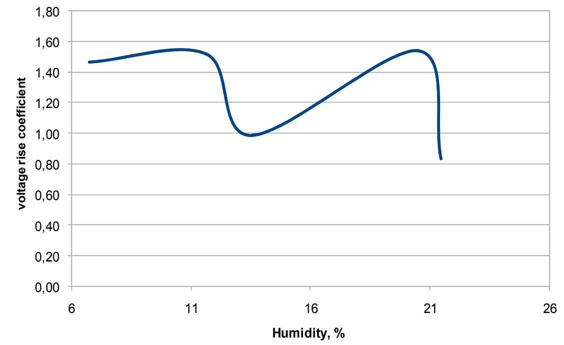

Fig. 6. The value of the voltage rise coefficient on piezoelectric transducer for coriander seeds

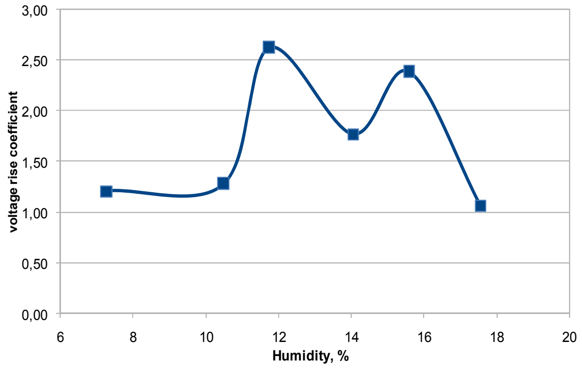

Fig. 7. The value of the voltage rise coefficient on the piezoelectric transducer for hemp seeds

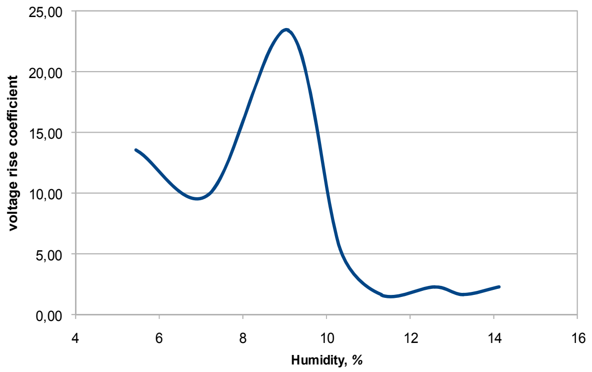

Fig. 8. The value of the voltage rise coefficient on the piezoelectric transducer for millet seeds

The millet seeds subjected to the research showed a significant increase in the coefficient for relative humidity of about 9% (Fig. 8).

Research on mustard seeds showed that the rate of voltage rise on the transducer is significantly dependent on humidity and decreases with its increase (Fig.9). In this case, the use of the method of measuring the rate of voltage rise on the piezoelectric transducer seems justified. There is a possibility to develop a quick method for determining seed moisture using the percussion method.

From the research of rape seeds (Fig.10) it can be noticed that the value of the coefficient decreases with the increase of humidity.

The tests allow to conclusively state that the value of the coefficient for different humidity depends on the seed species. For seeds that have the shape of a sphere the dependences are more closely correlated with each other. Based on this correlation, it can be concluded that it is possible to develop a method for measuring seed moisture using the measurement of the seed's impact force during the impact.

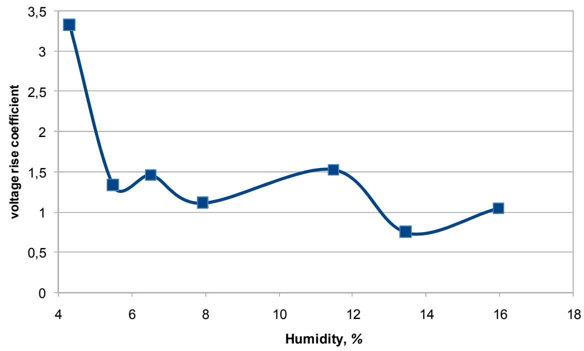

Fig. 9. The value of the voltage rise coefficient on the piezoelectric transducer for for mustard

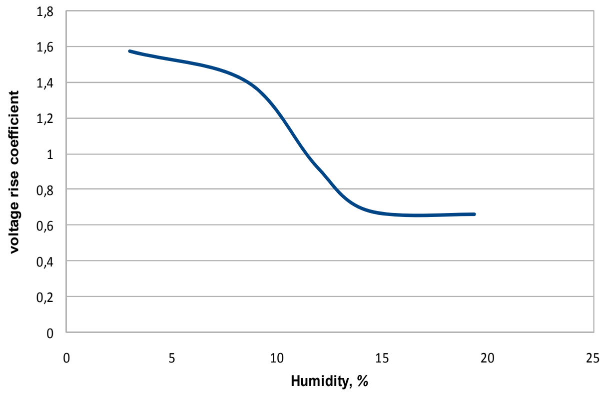

Fig. 10. The value of the voltage rise coefficient on the piezoelectric transducer for rape

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