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FAILURE AND ACOUSTIC EMISSION OF POTATO TUBER TISSUE OF SELECTED VARIETIES IN COMPRESSION TESTS AT VARIOUS STRAIN RATES

Artur Zdunek, Krystyna Konstankiewicz, Marek Gancarz
Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland

ABSTRACT

Results of compression tests of various strain rates with measurements of the total counts sum of the acoustic emission for the samples of six selected potato varieties with various appropriations have been presented. It was shown that an increase in the strain rate cause a decrease in failure strain and an exponential increase in the total counts sum. No influence of the strain rate on the failure stress was observed. It was found that the total counts

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sums were higher in the case of edible medium-late varieties as compared to the medium-early starch varieties within the range of the strain rates studied. No such relation was found for the failure stress and failure strain.

Key words: potato, failure, cracking, acoustic emission

INTRODUCTION

Due to high competition in food production and the increase in consumer demand, modern agriculture needs products of better and better quality. Losses both in yield and during storage, as well as the maintenance of the high quality of products during processing are also an important problem in vegetables and fruit including potato tubers [3, 8, 10, 13].

One of the important factors which lowers the quality of potato tubers is mechanical damage [12]. This type of damage is relatively easy to identify during preliminary sorting, on the surface. Internal damage which is not visible on the tuber surface is a far more serious problem. The result of damage is most often the so-called black-spot phenomenon [1, 9, 12]. It is manifested as a change in tissue colour visible only after the tuber has been peeled or cut by the customer. The problem of mechanical damage and black-spots is also relevant in the case of both potatoes for direct consumption (boiled or steamed potatoes) and food processing (dried potatoes, fried potatoes, frozen and preserved potatoes). Instructions to manufacturers and breeders suggest that they “achieve the lowest possible susceptibility” of potato tubers to black-spots [2, 12, 13].

One of the methods that allows investigation the cracking processes of deformed materials is the method of acoustic emission [7]. Acoustic emission (AE) is a phenomenon of the generation and propagation of elastic waves caused by the release of energy stored at a certain point of the object studied. The source of the signal can then be micro- and macro-cracks of the compressed material. The elastic waves generated as a result of the structure cracking, called a signal of acoustic emission, propagate in the material and can be recorded at its edges by special sensors. The frequency of the acoustic emission signal depends on the character of the source and can range from a few Hz to 1 MHz [7].

Konstankiewicz and Zdunek showed that the source of the acoustic emission signal in the plant tissue are cracks in the cell membranes [5, 11]. The value of stress and strain in the beginning of the process of cell membranes cracking decreases with an increase of the tissue turgor and strain rate [4, 6]. In the solution proposed by Konstankiewicz and Zdunek, the signal of acoustic emission “monitors” the deformation process [5]. In the above case, a certain information on tissue cracking is received at each point of the stress-strain curve. The variable that gives information on the course of the cracking process is the total count sum Nc_{zl}. It is obtained by summing up all counts of the AE signal recorded at the beginning of cracking up until the failure of the sample.

The present study gives the results of failure measurements (failure stress, failure strain) and acoustic emission (total count sum) obtained in the compression test at various strain rates for the samples of parenchyma tissue of six potato varieties with various appropriations (edible and starch) and various harvest dates (medium-early and medium-late).

MATERIALS AND METHODS

The experiment was carried out for the samples of parenchyma tissue of six potato varieties:

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– with various appropriations:

- edible: Agria, Danusia, Mila and Triada,
- starch: Kuba and Saturna;

– with various vegetation periods:

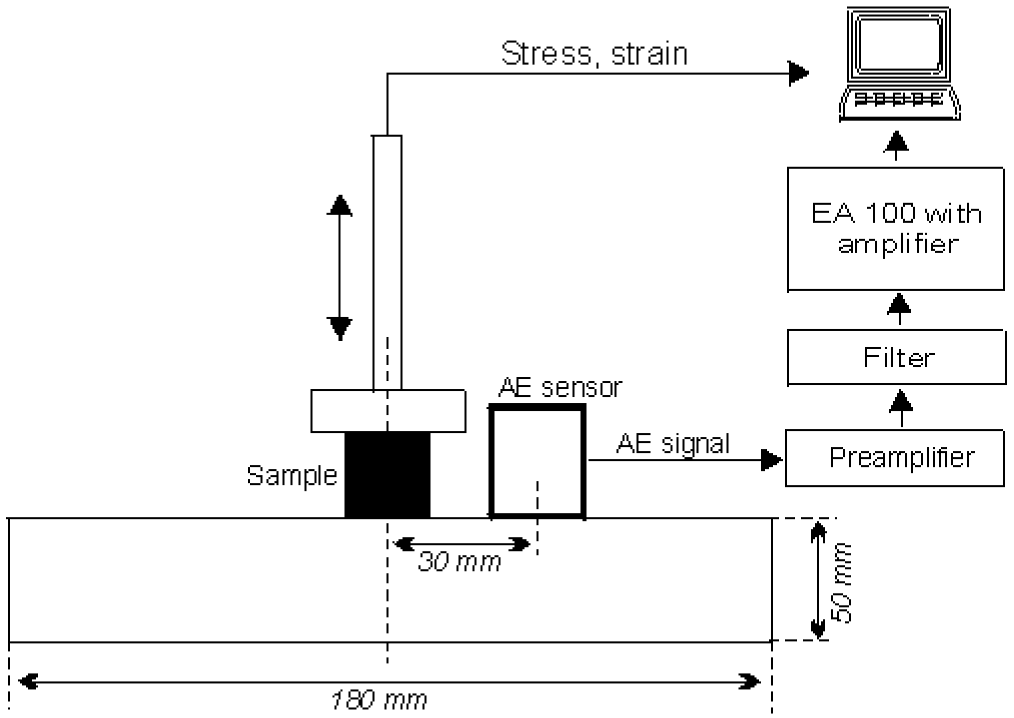
- medium-early: Kuba, Mila and Triada,
- medium-late: Agria, Danusia and Saturna.

The study material originated from the Institute of Plant Breeding and Acclimatisation in Jadwisin, from the harvest of 2000. The studies were carried out on tubers after 5 months of storage in controlled conditions (temperature of 6°C, relative air humidity of 95%).

Compression tests were carried out on the samples with cylindrical shapes, diameter of 5 mm and a high of 5 mm taken from the parenchyma of potato tubers. Uni-axial compression was carried out for the selected five quasi-static strain rates up to the moment of sample failure described by R - failure stress and e_m - failure strain. The measurements were taken for each variety and each rate in 50 repetitions. Signals of acoustic emission (AE) were recorded together with the stress-strain dependence.

The tests carried out, showed that the testing machine Lloyd LRX did not cause any disturbances in the AE signal recorded. For the recording of the acoustic emission signal, a wide-band piezoelectric sensor, type WD was used. The sensor is characterised by high sensitivity in the frequency range from 25 kHz to 1 MHz.

Figure 1. Lay-out of the measuring apparatus used in the present experiment



Due to the small size of the samples used in the experiment, it was not possible to fix the AE sensor directly on the sample. This problem was solved by fixing the AE sensor to the jaw of

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the testing machine (Figure 1). The AE signal passes the material with lower density and enters into the material with higher density at the border between the sample and the jaw (potato tissue – steel), signal suppression and deformation is then only small. In order to eliminate any friction, silicon grease was applied.

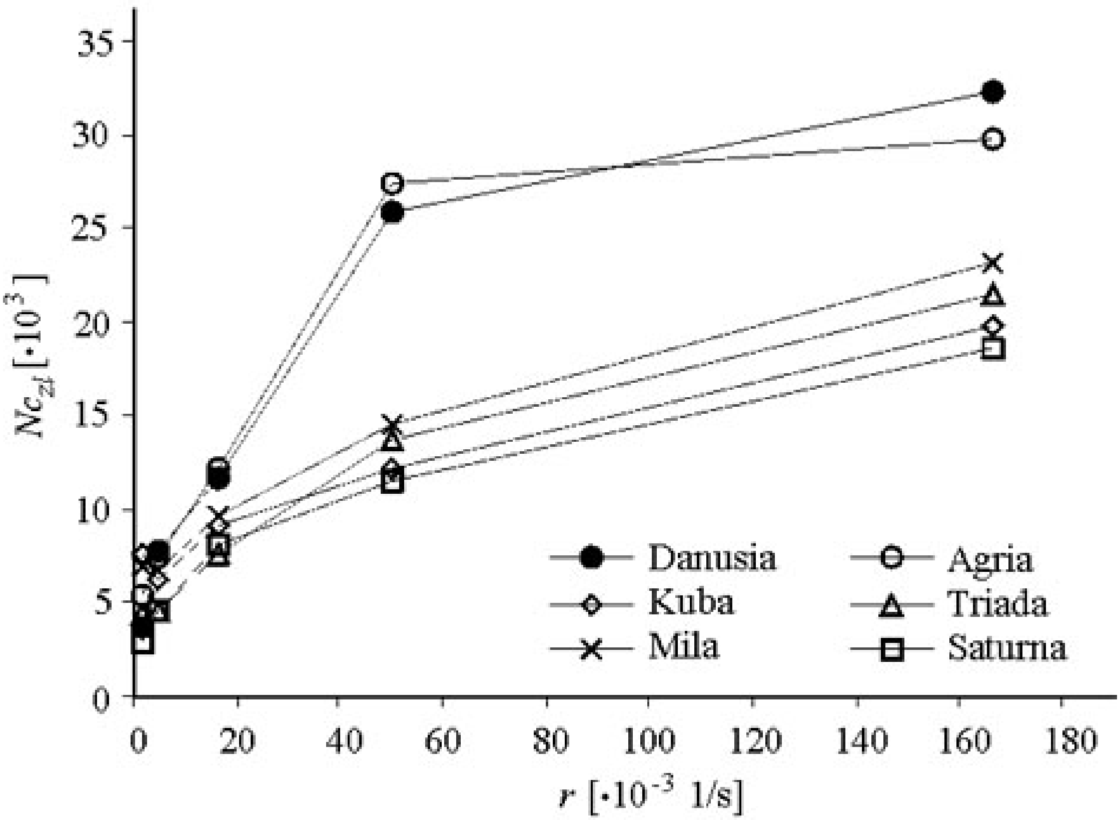
In the solution presented in Figure 1, a surface wave of the AE signal is recorded. The AE sensor is fixed to the same jaw surface of the testing machine on which the samples tested is placed.

Due to the small amplitude of the AE signal, the sensor of acoustic emission was connected to a pre-amplifier with about 30 cm long cable. In order to eliminate noises in the proper signal by sounds from the environment, an high-pass filter with a threshold frequency of 25 kHz was applied. Then, the AE signal was amplified and electronically transformed into the rate of counts. The rate of counts is obtained by the determination of a number of peaks of the AE signal with an amplitude higher than the assumed one (discrimination level) in the selected time range [5]. The count sum recorded in the test up to the sample failure was called the total count sum Nc_{zl} [5, 7].

RESULTS

As a result of the experiment for all the potato tubers studied, a relation between the total count sum Nc_{zl} and strain rate r, was obtained. The above relations are presented in figure 2. Each point in the plot is a mean of 50 repetitions in a given series. An analysis of the results was carried out by means of a t-test for the dependent samples at a significance level of 0.05.

Figure 2. The relation between the total count sum Nc_{zl} and strain rate r for the potato tubers of the six varieties studied



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The results analyse shows that the strain rate *r* has a significant influence on the total count sum Nc_{zl}. For all the potato varieties studied, the above dependency is of an exponential character:

$$Nc_{zl} = a \cdot r^{b} \quad (1)$$

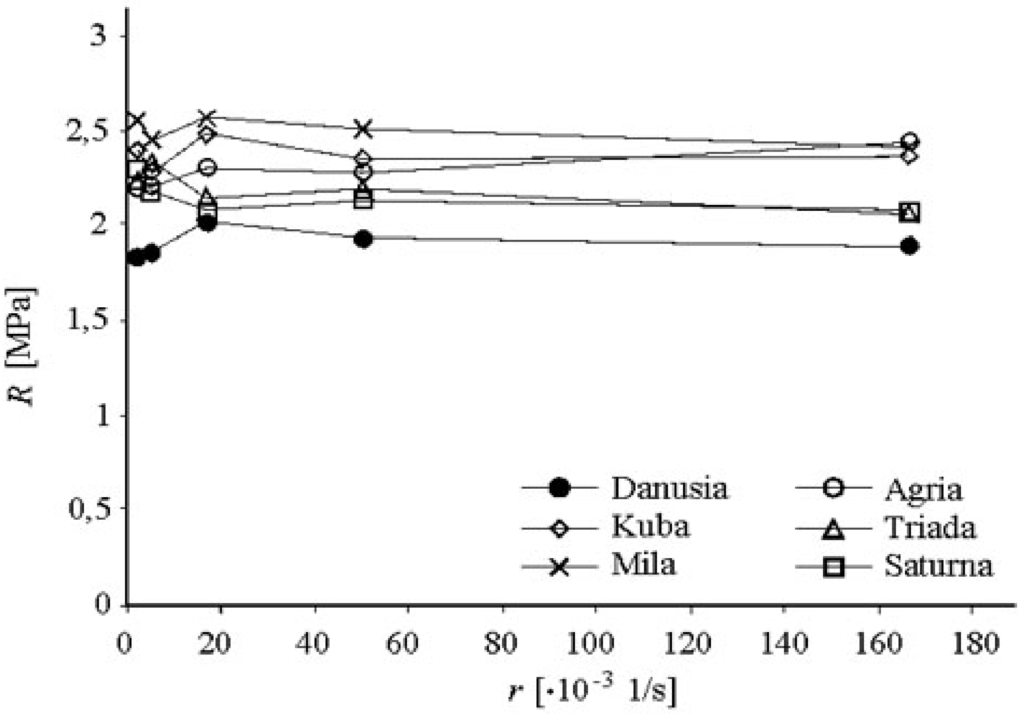
where: *a* and *b* – numerical coefficients shown in Table 1.

Figure 2 clearly shows a difference in the course of curves for the varieties Agria and Danusia as compared to the remaining varieties. In the case of the above varieties, the mean Nc_{zl} values stronger depend on the strain rate *r*. Test-t showed that the results obtained fell into two groups: group I – Kuba, Mila, Saturna and Triada, group II – Agria and Danusia, in which the results for individual varieties are not significantly different. The above groups refer to the product of *a* and *b* coefficients of the curve fitting shown in table 1. Taking characteristics of varieties into account, it can be said the group I consists of medium-early starch varieties, whereas group II consists of medium-late, edible varieties. At the same time the *b* coefficient of the curve fitting, equation (1), for the medium-late variety is higher than for the medium-early variety (Table 1).

Table 1. Coefficients *a* and *b* for the curve of the equation (1)

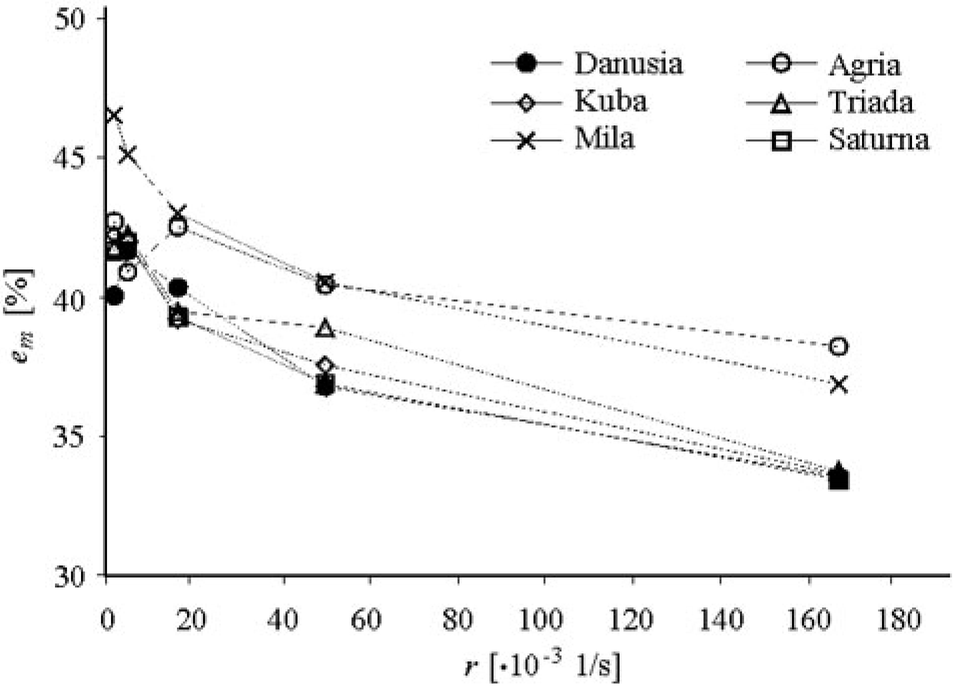
	Variety	*a*	*b*	*a b*
Group I	Kuba	7023	0.22	1545
	Mila	6995	0.27	1888
	Saturna	3872	0.41	1587
	Triada	4704	0.37	1740
Group II	Agria	6905	0.41	2831
	Danusia	5737	0.48	2753

Figure 3. The relation between the values of the failure stress *R* and strain rate *r* for the tubers of six potato varieties



Figures 3 and 4, respectively, show relations between the failure stress *R* and failure strain e_m as a function of strain rate *r*. Test-t showed that the failure stress *R* does not depend on the strain rate *r* – the course in Figure 3 is flat. Another dependency is observed for the failure strain e_m which shows a clearly decreasing tendency with an increasing values of the strain rate *r,* especially in the range of higher *r* values (Figure 4).

Figure 4. Relations between the values of the failure strain e_m and strain rate *r* for the tubers of six potato varieties



Figures 3 and 4 show that the values of the failure stress *R* and failure strain e_m are different for different varieties. However, it was not possible to observe any clear influence of the variety, appropriation for consumption or vegetation period on the results obtained.

CONCLUSIONS

The experiments carried out, showed that the basic parameters describing tissue failure (failure stress and failure strain) do not correlate with such varietal properties of potato tubers as edibility and vegetation period. The above correlation was observed for one of the descriptors of the acoustic emission signal – total count sum. Hence, the AE method gives additional information on the characteristics of the potato varieties, enables their grouping with respect to their appropriation and vegetation period. The studies on the failure and acoustic emission in the compression test with various strain rates on the parenchyma tuber tissue of six potato varieties allowed the following conclusions to be drawn:

1. The total count sum Nc_{zl} increases exponentially with an increase of the strain rate *r*.
2. The coefficients (*a* i *b*) of fitting of curves describing the relations total count sum Nc_{zl} – strain rate *r*, allow the two groups of the varieties studied to be separated: I – starch and medium-early varieties (Kuba, Mila, Saturna and Triada), II – edible and medium-late varieties (Agria and Danusia).

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3. Strain rate *r* does not influence the values of the failure stress *R*, but the failure strain e_m decreases with its increase.

Presented work deals with cracking of plant tissue subjected to external loading. This problem is not solved yet, both the experimentally and theoretically. Therefore, explanation of the presented results cannot be complete now. Full interpretation of obtained relationships requires taking into account discrete, stochastic and highly metamorphic structure of the potato tuber tissue resulting from its anatomic variability.

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Submited:

Artur Zdunek, Krystyna Konstankiewicz, Marek Gancarz
Institute of Agrophysics, Polish Academy of Sciences
4 Doświadczalna Street, P.O. Box 201, 20-290 Lublin 27, Poland
tel. (+48 81) 74 450 61
e-mail: azdunek@demeter.ipan.lublin.pl