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DETERMINATION OF THE STORAGE INFLUENCE FOR POTATO TUBERS BASED ON THE IMPACT RESTITUTION COEFFICIENT

Daniel Mihai DĂNILĂ[1]

Abstract: *The paper aim is to determine the impact coefficient for three potato varieties cultivated in Romania: Roclas, Diana and Nicoleta. Mechanical impact is generated by a computer-controlled pendulum. Subsequently the samples are stored for a specific time to determine the influence of the storage period on the potatoes of the three varieties on the basis of the impact restitution coefficient In conclusion, it is possible to establish on the basis of the impact restitution coefficient that the storage period influences the elasticity of the tubers.*

Keywords: *potato, coefficient, impact, storage, pendulum*

1. Introduction

In order to produce machinery, equipment and equipment for harvesting, transporting and handling tubers with minimal mechanical damage to the tubers, it is necessary to know in qualitative and quantitative terms the process of damaging tubers under the influence of mechanical impacts. The notion of resistance to mechanical damage to potato tubers is a complex character resulting from a complex of distinct features. Like all strengths, resistance to mechanical injuries is the result of the combined action of various, often independent, physiological, anatomic and morphological biochemical manifestations and processes. The properties that characterize the resistance to mechanical damage to tubers are influenced by many factors, so the study of tuber resistance to mechanical stresses is very difficult to achieve because the factors affecting this property are not known precisely. Among the anatomical properties that influence the resistance to mechanical damage must be mentioned the thickness and elasticity of potato, the core density and the shape of the tuber. Physiological and biochemical properties include crush resistance, specific tissue resistance, cell wall resilience and elasticity [1]. Peel resistance and harms caused by harvesting are important for reducing storage losses, especially for seed potatoes. Researches on tuber peel strength have revealed a

[1] Department for Engineering and Management in Food and Tourism, *Transilvania* University of Brasov, 148 Castelului street, Brașov, 500014, Romania;
Correspondence: Daniel Danila; email: d.danila@unitbv.ro.

significant concordance of tuber resistance according to variety. Shear resistance and mechanical damage caused by harvesting are important for reducing losses during storage, especially for seed potatoes and for consumption.

In his studies on the resistance of the peel, Ulrich demonstrated the influence of the position of the tubers in the soil [1]. Analyzing the data it is found that the strength of the peel, expressed in scale portions, is higher in the superficial position of the tuber. The author asserts that although differences in the resistance of the peel of the surface tubers and those placed deeper cannot be considered in all cases observed, however, there is a tendency towards greater peel strength for the tubers at surface.

Hands, tracked the influence of tuber size on the strength of the skin by concluding that it does not always influence it. Along with the resistance of the peel, it was concluded that some tested varieties differ significantly in core strength [1]. It has been found that the potato core is usually more resistant to the extremities than in the middle.

Research has also highlighted the influence of chemical composition on potato tuber behaviour at impact loads. Thus, Kuciumov shows that high starch content would impart to varieties greater resistance to mechanical injuries [2]. Hoff points out that the tuber membrane cell wall is a determining factor for tuber processes. It seems that the pectin substances that form the cell membranes and the lamellae have a strengthening role. The predominance of pectin substances denotes that cells do not suffer from the aging phenomenon of massive cellulosic mass storage. These give solidity to the cell membranes, so it is believed that the resistance to mechanical damage should be correlated with the chemical composition of the tubers. Meini and Effmart considered that the different strength of the core would be decisive for the dry substance content. As for the elasticity of the tubers, an important parameter that can be determined on the basis of the impact resistance coefficient, Gall and Lamprecht tested a variety of varieties in terms of elasticity with the help of pendulums, concluding that there are differences between varieties of this character. Fuchs tests the resistance to mechanical damage with the pendulum considering the elasticity given by the value of the first rebound and concludes that the variety influences this index [1].

2. The Pendulum Method

Testing the potato tubers with the pendulum device starts from the assumption that there is no physical difference between the situation where a table potato with mass m_1 falls freely from the height h_1 on a plane body with a rigid mass, and the situation where the same tuber is hit by a pendulum with mass m_2 as presented in Figure 1. For equivalence, the effective impact mass m_2 is equal to the mass of the tuber m_1, and the height h_2 which the pendulum falls is equal to the height h_1 the tuber falls. For the situations presented in Figure 1 the potential energy Ep as well as the v-velocity, have the same values given by the relations:

$$E = m_1 g h_1 = m_2 g h_2 \qquad (1)$$

$$V = \sqrt{2gh} \qquad (2)$$

Other parameters presented in the relations (1) and (2) are: *h*, the height of fall of the two masses.

The impact force of the pendulum is determined by the initial angle of the arm, the mass of the pendulum arm and the mass of the impact, and the air resistance. The small resistance of the air it can be neglected.

Figure 2 shows the time variation graphs of pendulum velocity during impact with Dacia tubers for the energies: E = 0.072 J. The graph shown that in the impact process the speed drops from an initial value to a value equal to 0,after which it changes its mark and starts to rise to a maximum negative value.

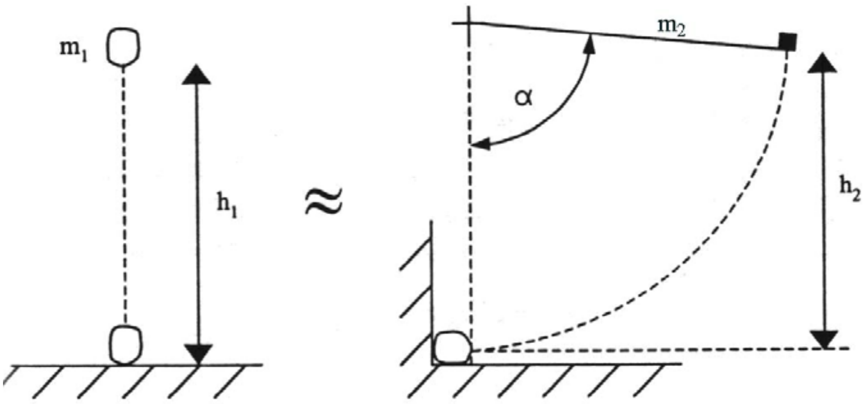

Fig. 1. *Testing the potato tubers with pendulum device* [3]

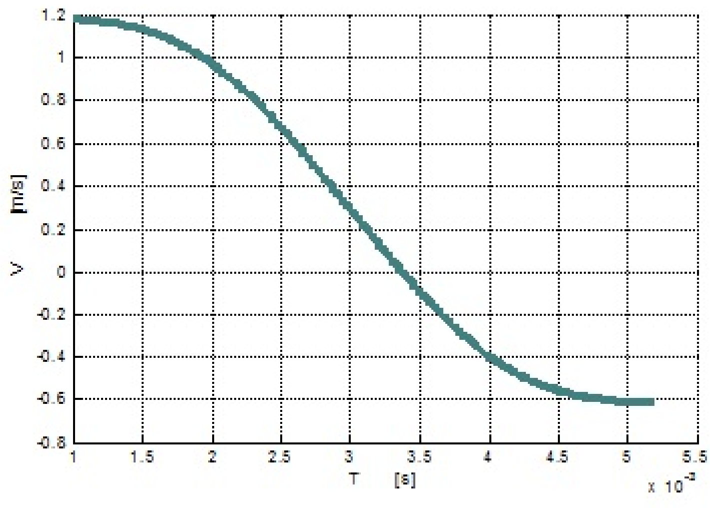

Fig.2. *The impact velocity evolution in time*

The explanation for this phenomenon is that at the moment of the impact the tuber suffers a sudden compression followed by a relaxation. At the beginning of the impact, the pendulum impact body compresses the tuber and the pendulum velocity begins to decrease until it reaches 0. In this moment the most of the impact energy is transferred to the tuber. The immediately following phase corresponds to the decomposition of the sample when the pendulum arm changes its direction of motion so that the speed changes its mark.

3. Results and Discussion

The restitution coefficient for the one-dimensional impact of two bodies in motion of pure translation is defined as the ratio of the relative speeds (with a changed sign) between the two bodies at the end and the beginning of the collision. This is a measure of the impact energy lost due to internal sources: elastic, plastic deformations and friction in the contact area. Considering of the case of the transversal impact (without friction), perfectly resilient, the return coefficient *K* will be in this case the thermal energy dissipated in the contact area. For a limited initial impact *Vi* range, the restitution coefficient can be written as [3]:

$$K = 1 - \alpha V_i \quad (3)$$

in which: α *is* a coefficient of material which for steel, bronze and ivory is between 0.08-0.32 s / m. Linear equation 3 cannot be applied over certain limits of the impact velocity *Vi,* which depend on the material and the geometry of the contact surfaces. Determination of the impact restitution coefficient is important because it is a measure of the value of the energy absorbed by the viscous-elastic body. The absorbed energy is correlated with the mechanical injuries suffered by the tubers.

Knowing the variation of the impact body velocity in the potato impact process is important because the ratio between the speed of the impact body at the end of the impact with the tuber and the speed at the onset of impact, determines the value of the impact restitution coefficient.

A first step in determining the restitution coefficient is to determine pre- and post-crash speeds. For low to moderate impact velocities, the crash between the bodies is elastic and plastic, causing rigid permanent imperfections on the contact surface. The force-penetration relationship is irreversible. The mechanical work of the contact force is partially consumed during compression by the elastic waves, plastic deformations in the contact area and friction. These modes of initial kinetic energy dispersion during collision depend on the relative velocity between the bodies at the point of impact, the properties of the material and the inertial properties (which depend on the impact configuration and the deformable sample bearing conditions).

For experimental research, it was calculated as a sign-to-shift ratio between impact velocity at the end of collision (V2) and impact body velocity at the beginning of collision (V1). The impact force of the collision end is determined from the speed-time variation curve of each sample for the first impact.

As mentioned in the experimental research methodology, the tubers were stored for a specific time, after which they were tested with the pendulum. In these experiments, a single initial impact energy of 0.072 J was used, corresponding to a pendulum arm angle of 28^0, the speed at impact being V1 = 1.17 m/s. The mean values of the impact parameters for the tested tubers of the three varieties are shown in Table 1. The meaning of the table sizes is as follows: a_{max} is the maximum impact acceleration at the time of the first shock; *Fmax* - the maximum force with which the impact body interacts with the sample at the moment of shock; *V2* - the impact velocity of the impact body after the first shock; *d* - maximum sample deflection (arrow) during impact; *K* - the impact-return coefficient expressed as a ratio between the V2 (negative) rebound speed and the initial V1 positive initial velocity; t - duration of impact, representing the impact time.

After another storage period, the potato tubers belonging to the three varieties were retested with three initial impact energies. This way can be determined the influence of the initial impact energy of 0.072J and to compare the energy values of the energy values absorbed by tubers: E1 = 0,072 J - at the pendulum arm angle of 28^0 and the initial impact velocity V1 = 1.17 m / s; E2 = 0,325 J - at the angle of the pendulum arm 620 and the initial impact velocity V1 = 2,49 m / s; E3 = 0.516 J - at the angle of the pendulum arm 81^0 and the initial impact velocity V1 = 3.15 m /s.

Table 1

Parameters determined when testing the tubers at the initial energy impact ratio Ei = 0.072 J for a predetermined interval of time

Soi	a_{max} [m/s²]	F_{max} [N]	V_2 [m/s]	*d* [mm]	*K*	*t* [ms]
Nicoleta	798	79	0,64	1,83	0, 54	5,2
Dacia	825	82,5	0,63	1,95	0,531	5,23
Roclas	793	79,3	0,68	1,68	0,581	5,37

Initial impact velocities and initial impact energies for different angles of the pendulum arm were presented in Table 2. The mean values of the impact parameters obtained in testing the tubers of the three varieties for the initial impact energy of 0.072 J are presented in Table 1.

Table 2

Parameters determined when testing the tubers at the initial energy Impact Ei = 0.072J after a new storage period

Soi	a_{max} [m/s²]	F_{max} [N]	V_2 [m/s]	*d* [mm]	*K*	*t* [ms]
Roclas	795	79,5	0,69	1,73	0,589	5,3
Dacia	830	83	0,63	1,94	0,536	5,1
Nicoleta	810	81	0,65	1,84	0,55	5,2

In Figure 3 is presented the comparative graph of the variation of the impact restitution coefficient for the three tested potato varieties and three initial impact energies. From the graph we can see that at the impact from the initial the highest restitution coefficients for impact were obtained for the samples of the Roclas variety followed by the samples of the Nicoleta and Dacia varieties. When the impact originated from the initial energy of 0.325 J, the impact resistors with the highest values were obtained for the Nicoleta variety samples followed by Dacia and Roclas. The impact coefficient with the highest value was obtained for the initial energy of 0.516 J for the Dacia variety followed by Nicoleta and Roclas.

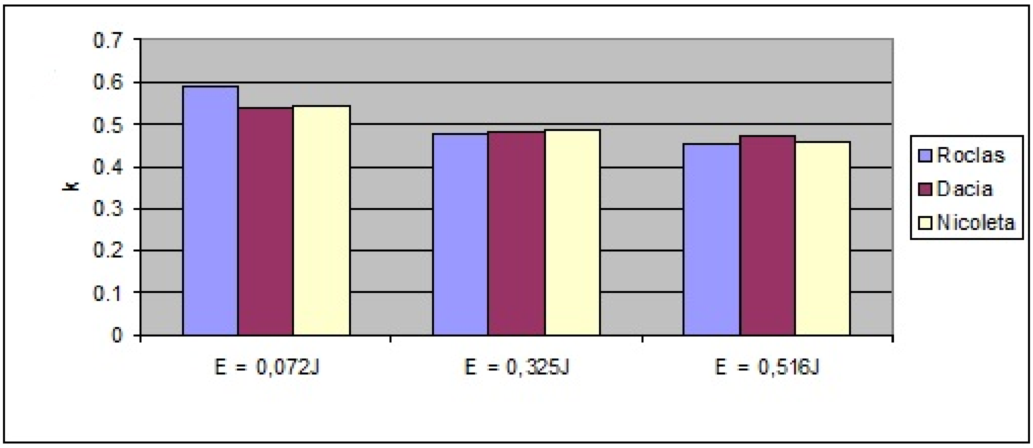

Fig. 3. *The comparative graph of restitution coefficient variation for three impact energies*

4. Conclusions

From the tables presented, it can be noticed that by increasing the storage period there has been an increase in the elasticity of the tubers for the samples of all varieties, manifested by the increase in the impact coefficient *K*.

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