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THE INFLUENCE OF COLLIDING SURFACE PROFILE IN FRUITS AND VEGETABLES IMPACT RESPONSE

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Abstract: *This paper presents an analysis of impact forces response when fruits and vegetables hit surfaces having different geometrical forms. The impact forces are obtained using a digital device called "digital potato" which can simulate the behavior of a real fruit and vegetable in the conditioning chain.*

Key words: *impact, forces, potato, surface.*

1. Introduction

Economic losses due to fruit and vegetable bruising are significant. Most of the costs of bruising are passed back on the grower in the form of lower prices, reduced demand and increase storage losses. The effects of bruising are felt by every handler and consumer of potatoes and are a major economic drain on the industry. The preponderance of tuber bruising typically results from impacts sustained by the tubers during harvesting and handling. The impacts occur primarily when the tubers strike hard surfaces or each other while being conveyed, or in dropping from one conveyor to another.

Impact sensitivity (bruise susceptibility) in potatoes varies considerably, but a reliable method for assessing, predicting and managing that sensitivity has not been available. It therefore becomes important, above all, to measure the intensity of the impacts to the produce during harvest and post-harvest and subsequently to correlate this with the probability of damage to the produce itself.

For this purpose the researchers in potato mechanical damage field, use impact sensors for assessing mechanical impacts. These sensors are part of a potato shaped element named digital *potato*.

2. Working Method and Materials Involved

At its simplest, the digital potato acts as a food dummy which quickly locates many damage-causing parts in all types of potato handling machinery (including washers). At its most sophisticated, the digital potato can focus on very specific levels of damage-causing problems; record and download to a PC, information about problems in different machines or the same machines at different times; and change its sensitivity to suit different potato varieties or even other fruits and vegetables. The

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'potato' element contains tri-axial shock sensors, a radio transmitter and a battery. When the potato receives a shock of sufficient strength to register an electronic signal, this signal is transmitted to the 'Receiver'. The signal is heard in the headphones plugged into the receiver, it registers on the receiver's display as it occurs and it is logged in the receiver's memory (Figure 1).

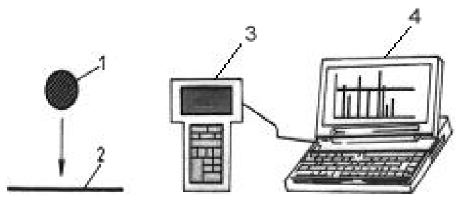


Fig.1. *Impact recording:*
1 - *digital potato;* 2 - *impact surface*;
3 - *receiver*; 4 - *computer*

A lot of bruises occur in harvesting operations when fruits and vegetables are dropped from greater heights on different surfaces from harvesting chain. The digital potato is used to assess the impact loadings which generate mechanical damages in potatoes. For this purpose the digital potato 4 is dropped from a dropping device presented in Figure 2, on specific surfaces presented in Table 1 [2].

The device allows the potato to fall from measured heights. The gliding element 2 allows the digital potato 4 to be fixed at measured heights from the impact surface 5. When the desired height between the digital potato and the impact surface is achieved, the digital potato is released by a pneumatic device 3 and hits the impact surface. The electronic potato can be damaged if it drops from greater heights on hard surfaces. This kind of situations has to be avoided. For soft surfaces the heights can be increased. For each situation 30 measurements are carried out. Every 30 measurements are taken in a run. After every run the results are downloaded in a portable computer and treated in Excel files.

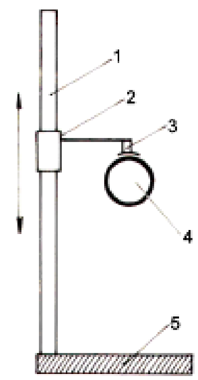


Fig. 2. *The dropping device:*
1 - *fixed stand;* 2 - *gliding element;*
3 - *pneumatic device;* 4 - *digital potato;*
5 - *impact surfaces*

3. Procedure for Impacts Analysis

When the potato hits the surfaces, a condenser placed inside the potato absorbs the energy of impact. Due to constructive defects, the entire energy is not always discharged at once. So there are different delays between several shocks. In the dynamic situation, when the delay between two peaks is less than 0.4 s shocks are added.

The impact surfaces Table 1

Material	**Characteristics of the materials**		
	Thickness [mm]	**Length × width [mm]**	**Components**
Steel plate	4	500x500	Carbon steel
Rubber	4,5	500x500	Rubber A 9506
C profile band	23	8730x350	Rubber, steel hearth (platband)
Sieve band N 40	18	3560x800	Rubber, steel hearth (platband)

When the delay between two peaks is more than 0.4 s the shocks are considered to be different. After impacts, data are downloaded from the receiver in the computer and are exported by the PTR200 program as text files. The text files are converted into Excel files. The impact forces values are calculated by Excel with formula (1):

$$F = \mathrm{e}^{\frac{\ln(x)+7.8877}{2.048}}, \quad (1)$$

where F is the impact force and x the maximum impact value showed by receiver.

4. Statistical Interpretation using the t-Test

The number of calculated forces is different from run to run. This is the reason for choosing the t-test in the interpretation of the data. This procedure compares two series of calculated forces [2]. If the *t-value* is higher than t_α (provided by the table of t-distribution), the differences between the series are considered to be significant. The t-value was computed by formulas (2) and (3):

$$t = \frac{|x_A - x_B|}{\sqrt{\frac{s^2}{n_A} + \frac{s^2}{n_B}}}, \quad (2)$$

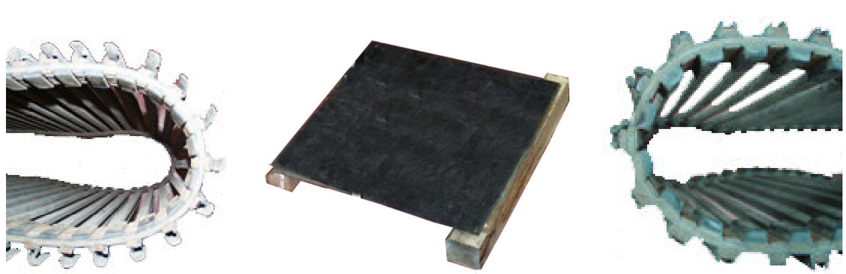
$$s^2 = \frac{(n_A - 1)\cdot s^2{}_A + (n_B - 1)\cdot s^2{}_B}{n_A + n_B - 2}, \quad (3)$$

where: n_A - number of forces for the first series; n_B - number of forces for the second series; s_A - standard deviation for the first series; s_B - standard deviation for the second series; t - distribution; s^2 - population variances.

5. Obtained Results

In the Table 2 and graphic from Figure 4 are presented the results obtained when the digital potato is dropped on several materials revealed in Table 2 and Figure 3. The chosen dropping height for these measurements was 20 cm. This height normally is described in literature to be non-harmful especially for potato tubers and was chosen for more accurate measurements considering the purpose of this paper.

The comparison between the mean forces when the potato is dropped on steel covered with rubber and mean forces when the potato is dropped on rubber covered with steel plate reveals the differences between the impacts forces involved in these two situations. The graphic results confirm that the mean of impact forces have high values when the digital potato is dropped on hard surfaces (steel over rubber) and smaller values when the digital potato is dropped on less hard surfaces [1].



a) b) c)

Fig. 3. *The impact surfaces form*:
a) C profile band; b) rubber over steel; c) sieve band

6. Conclusions

When the rubber surfaces cover the steel plate, the cushioning makes the impact smaller absorbing the impact energy. The form of the surface is very important in the impact response. Due to its form (letter C) the C profile is more elastic and band elements absorb the impact energy very well. Because of its form and cushioning, the sieve band absorbs the impact better that the steel over rubber or rubber over steel but less than the C profile. The impact values are presented in graph 4.

The impact results Table 2

Material	mean	st. dev.	n[i]	n	alfa	s^2	t	t_alfa
comparison for C profile - rubber / steel								
C	99,46807	35,30743	11	39	0,05	5849,467	**7,882718**	2,002
r/s	311,973	86,23606	30					
comparison for C profile - sieve								
C	99,46807	35,30743	11	39	0,05	3560,134	**3,206706**	2,002
sieve	166,9096	66,01439	30					
comparison for C profile - steel / rubber								
C	99,46807	35,30743	11	39	0,05	4545,515	**9,292988**	2,002
s/r	320,3102	75,38612	30					
comparison for rubber on steel-- sieve								
r/s	311,973	86,23606	30	58	0,05	5897,278	**7,31607**	2,002
sieve	166,9096	66,01439	30					
comparison for rubber on steel-steel over rubber								
r/s	311,973	86,23606	30	58	0,05	6559,862	0,398672	2,002
s/r	320,3102	75,38612	30					
comparison for sieve -- steel over rubber								
sieve	166,9096	66,01439	30	58	0,05	5020,483	**8,38494**	2,002
s/r	320,3102	75,38612	30					

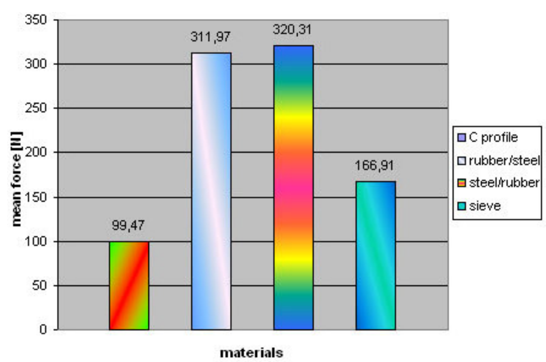


Fig. 4. *Means of impact forces on several materials*

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