Response of potatoes to impact loading

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Abstract
The experiments on the dynamic loading of tubers of 12 varieties of potatoes have been performed. Dynamic loading has been realized by the impact of a cylindrical bar on the tuber. The used method enables to obtain force – time record as well as the time history of the surface displacement. The main features of the force and displacement function have been described both in the time and frequency domain. Obtained results suggest that given method can be used for the detection of the potato tubers damage origin as well as for the differentiation among different varieties of the potatoes.

Key words: *Impact loading, potatoe, surface response, frequency analysis*

Introduction

Various methods, such as uniaxial compression (Thybo and van den Berg, 2002, Blahovec, 2001), tensile test (Verlinden *et al.*, 2000), penetration tests (Anzaldua-Morales *et al.*, 1992), puncture test (Ranganna *et al.*, 1998) and numerous variants of small deformation tests (Laza *et al.*, 2001) have been proposed for the evaluation of the mechanical/textural parameters of raw and treated potato tubers. For the evaluation of potatoes resistance against forces which originate during their harvesting,sorting and transportation mechanical test under impact loading are needed. One of such tests has been applied by Nedomova (2009). This technique is a fast, nondestructive measurement of firmness, where the potatoe tuber is excited by being struck with a probe and the frequency spectrum from the recorded response,i.e. surface velocity and/or surface displacement is obtained. Some impact response parameters such as maximum force, maximum deformation and duration of impact have shown to be closely related to firmness. This technique has been applied for testing of many fruits, eggshells,seeds etc. In the given paper this technique has been used for testing of tubers of 12 varieties of potatoes.

Experimental details

Twelve potato cultivars were examined :Barbora, Janet,Jitka, Karin, Katka,Kornelie, Magda,Monika,Radana, Redanna, Terka and Valfi. All tested tubers were obtained from Research Institute of Potatoes (Havlíčkův Brod, Czech Republic). The geometry of the used tubers is described in (Bubeníčková et al. 2010).
The experimental device for the impact testing is described e.g. in (Nedomová 2009). The tubers have been impacted on the equator. The height of the bar fall has been increased up to value at which the tuber damage has been observed. The displacement has been recorded on the equator of the tuber. The displacement has been measured in direction normal to the tuber surface.

Results and discussion.

In the Fig.1 an experimental records of the impact force – time are shown. The damage of the tuber occurs at the height h =690 mm . The impact velocity 3.68 m/s corresponds to this height of the bar fall.
The dependence of the force F on the time t curve can be characterized by three parameters:

- the maximum force during the impact (F_m),
- the duration of the F(t) pulse, (λ)
- the time spent until the maximum force is reached, (t_I)

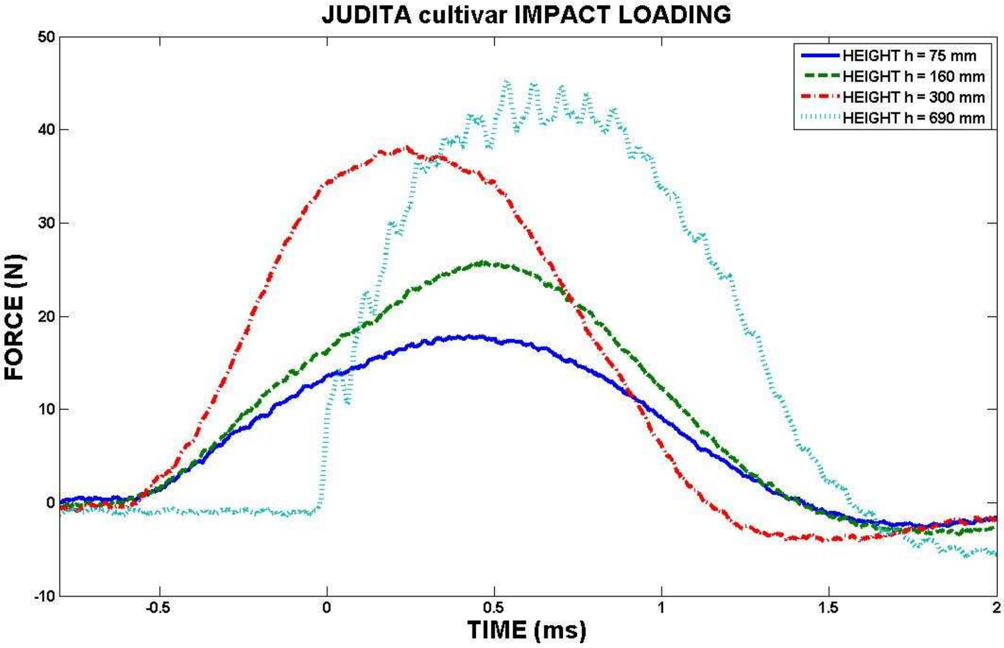

Figure 1 Experimental records of the impact force vs. Time.

The value of the force maximum increases with the height of the bar fall as expected. The value of this maximum depends on the potatoe variety as shown in the Fig.2.

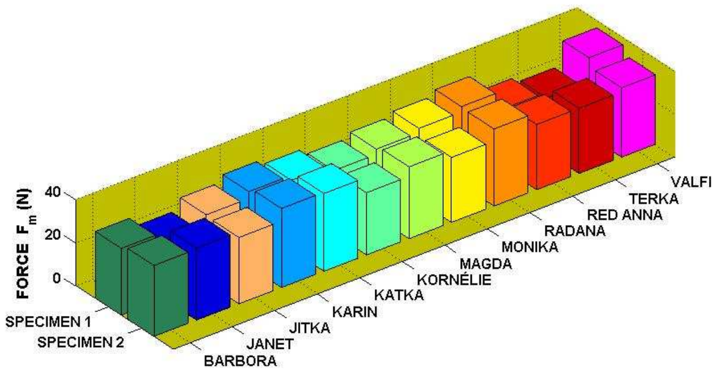

Figure 2 The maximum of the impact force. Height of the fall h = 160 mm.

The same conclusion is valid also for the two next force pulse parameters as shown in the Figs.3 and 4. The response functions are represented by the time histories of the tuber surface displacements. Example of these functions is shown in the Fig.5. The first part of this curve corresponds to the propagation of the pressure-stress pulse from the point of the bar impact. Its amplitude increases with the impact velocity of the bar. This part is followed by a release part (tensile pulse).

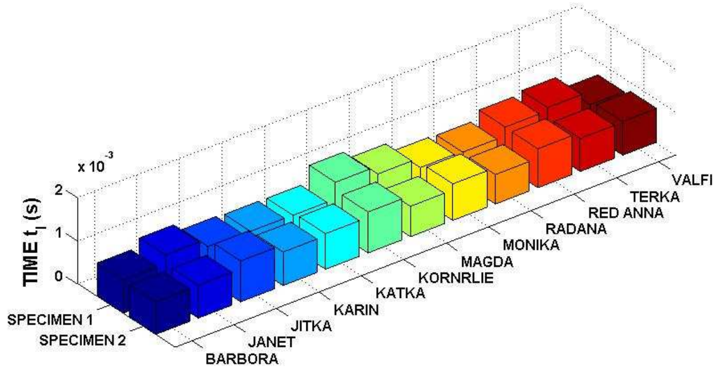

Figure 3 Time at which the force maximum is reached. Height of the fall h = 160 mm.

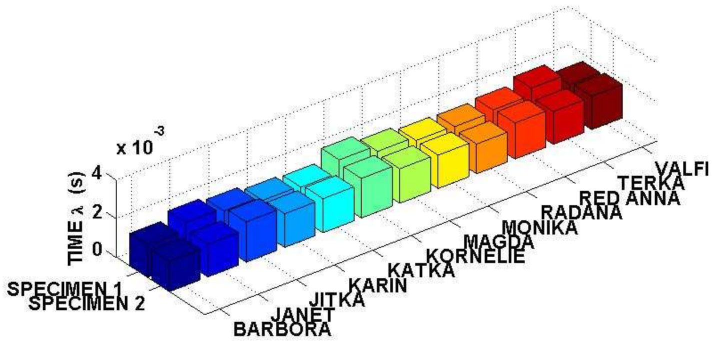

Figure 4 The time of the pulse F(t) duration. Height of the fall h = 160 mm.

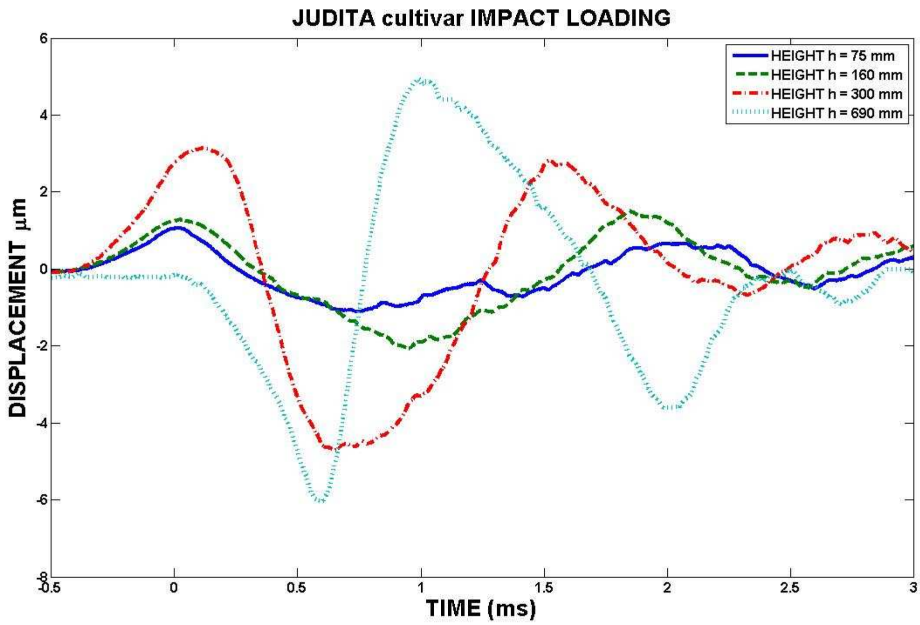

Figure 5 Surface displacements versus time curves for the different bar impact velocities.

The response of the potato tuber can be also described in the frequency domain. This procedure is based on the Fourier transform technique – see e.g.(Stein,2003) for a review.
For a continuous function of one variable f(t), the Fourier Transform F(ω) is be defined as:

$$F(\omega)=\int_{-\infty}^{+\infty} f(t)e^{-i\omega t}dt$$

And the inverse transform as

$$f(t)=\int_{-\infty}^{+\infty} F(\omega)e^{i\omega t}d\omega,$$

where F is the spectral function and ω is the angular frequency.
Example of the amplitude obtained for the displacement is displayed in the Fig.6.

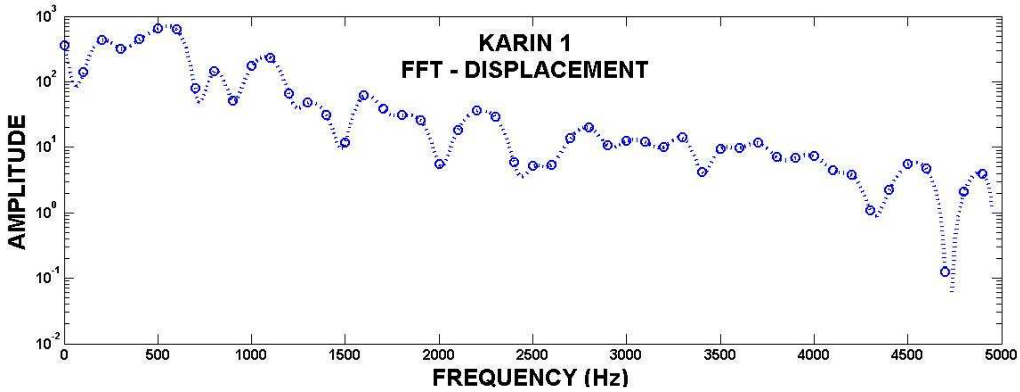

Figure 6 Amplitude of the spectral function (displacement) versus frequency.

The amplitude exhibits a maximum. The corresponding frequency is denoted as the dominant frequency. This frequency plays dominant role at the evaluation of the mechanical stiffness of many fruits and eggshell. Its value depends on the excitation intensity (i.e. on the height of the bar fall) and on the variety of potatoes. Values of these frequencies are plotted in the Fig.7.

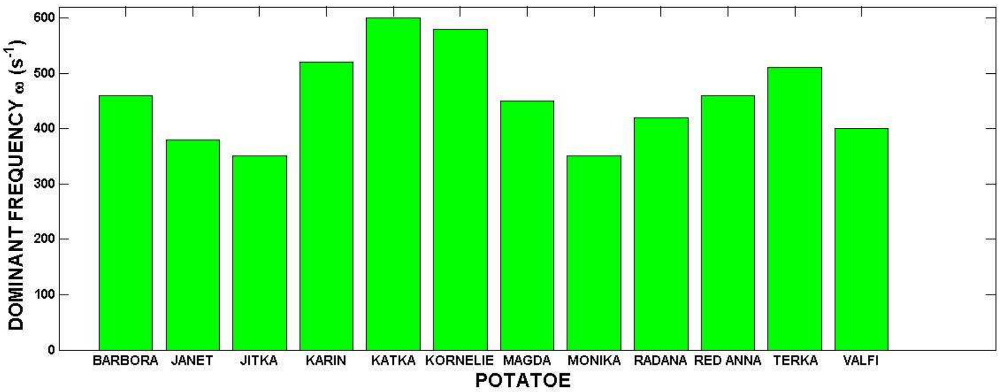

Figure 7 Dominant frequencies of the tested potatoes tubers.

Conclussions

In the given paper evaluation of potato tubers response to mechanical impact has been performed. Typical cultivar differentiation of the response of potato tubers was found. The differences have been observed both in the time and frequency domain. The suggested experimental method enables to study the mechanical resistance of the potato tubers against the impact loading. Response function, displacement versus time, exhibited main features corresponding to the surface wave propagation. The spectral function of the displacement exhibits a dominant frequency. It means there is a chance to use the obtained data for the evaluation of the mechanical properties of the potato tubers. The proposed method seems to be promising tool, how to distinguish between different varieties of the potatoes.

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References

Alzadua-Morales, A., Bourne, M.C., Shomer, I., 1992. Cultivar, specific gravity and location in tuber affect puncture force of raw potatoes. J. Food Sci. 57,1353–1356.

Blahovec J. and Esmir A.A.S., 2001**.** Precise study of cooked potato texture. J. Tex. Studies, 32, 165-184.

Bubeníčková, A. -- Simeonovová, J. -- Severa, L. Quantification of shape variation of potato tubers. In *9th International Conference on Food Physics.* 1. vyd. Nitra: Slovak University of Agriculture, 2010, s. 18--19. ISBN 978-80-552-0463-5

Laza M., Scanlon M.G., and Mazza G., 2001**. .** The effect of tuber pre-heating temperature and storage time on mechanical properties of potatoes. Food Res. Int., 34, 659-667.

Nedomová,Š. 2009. Response of the potato tubers to impact loading. Acta univ. agric. et silvic. Mendel. Brun., sv. 57, č. 4, s. 63--72. ISSN 1211-8516.

Ranganna B., Raghavan G.S.V., and Kushalappa A.C., 1998. Hot water dipping to enhance storability of potatoes. Postharvest Biol. Techn., 13, 215-223.

Stein, Elias; Shakarchi, Rami (2003), *Fourier Analysis: An introduction*, Princeton University Press, ISBN 0-691-11384-X

Thybo, A.K. and van den Berg, F., 2002. Full uniaxial compression curves for predicting sensory texture quality of cooked potatoes. J. Texture Stud. 32,119–134.

Verlinden B.E., Yuksel D., Baheri M., De Baerdemaker J., and van Dijk C., 2000. Low temperature blanching effect on the changes in mechanical properties during subsequent cooking of three potato cultivars. Int. J. Food Sci. Techn., 35, 331-340