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Texture changes of vegetable cultivars measured by non-destructive methods

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Summary: According to our experiments the tested group of non-destructive methods offers a useful tool not only to follow the texture changes of vegetables during storage but to characterize the firmness and vision parameters during the growing period as well. Advantages of these methods are: they are mobile, easy to set up, easy to use and quick. The suitable maturity state – and so the optimum harvest date also - can be determined by these methods. In addition, these methods can be built into sorting lines making possible to sort and classify great amounts of produces. These methods help the producer to offer homogenous products of controlled quality. They can be used for measuring different effects on vegetable's quality parameters (fertilization by different microelements, different irrigation effects on the product) as well.

Key words: non-destructive methods, firmness, acoustic, impact, PC vision, quality

Introduction

Customers' demand is continuously increasing for buying high quality vegetables. The quality of vegetables must fulfill the prescriptions of the Codex Alimentarius Hungaricus and the EU regulations. So product quality must be checked from the grower to the costumer in order to determine and follow quality, to establish optimal harvest date, to fulfill the demand for the sample homogeneity and to classify the vegetable into different quality groups. Objective, rapid and suitable measuring methods are needed to be able to measure great amount of samples. The maturity state is an important characteristic feature of post harvest products for classification and treatment. The overall quality of horticultural products could rapidly decrease after harvest and during post-harvest storage. (*Zsom,* 2003) In order to have good quality products in the market, vegetables must be harvested in the initial maturity state. Packing and processing must be started as soon as possible after harvest. In the case of overripe products, quality degradation could be unacceptable during packing, processing, transporting and storage. Maturity state can be characterized by investigation of external features, such as size, surface color and stiffness. There are commercially available equipments, which classify by the above mentioned first two external features. During the reception, processing and storage of raw materials one of the most important quality features is the stiffness. Based on stiffness, the maturity state and texture of the product can be assumed. For determining stiffness, we can apply the well-known and broadly used precision penetrometer, and firmness tester applied in most cases in research and in practice. Because of their destructive nature, those methods were not able to follow the textural changes of the same sample.

Nowadays the development of non-destructive methods is in the focus of interest. Our aim was the investigation of non-destructive, rapid physical methods capable for the determination of product parameters, and to give a general impression about the possible methods of non-destructive texture analysis, based upon some examples from the practice.

Material and method

For stiffness determination, generally sensory methods ("the growers' experience") or destructive methods are used. The sensory assessment is subjective and the disadvantages of destructive methods are:

- the destructively measured samples are not consumable,
- after the measurement the sample is not suitable for storage any further, it enables only one measurement,
- we arenot able to follow the textural changes during storage, because of the destructive way of measurement.

These are the main reasons why the interests toward non-destructive measuring methods is continuously increasing. The advantages of the non-destructive methods are:

- with the test we do not interfere in the life of the sample, so we can store it further after the measurement
- we can follow the changes exactly during storage, because we can measure the same sample every day
- the product does not suffer any serious harm, so after the test it can be sold or processed so these methods are more advantageous concerning economy.

Methods

Acoustic stiffness method The non-destructive acoustic test method (based on mechanical excitation of the sample and frequency-domain analysis of the acoustic response of the sample) is applied usually to spherical, mainly homogeneous and solid samples (onion, tomato). The acoustic method gives relevant information about the overall stiffness of the sample. According to new research this method can be applied for measuring the stiffness changes of elongated vegetables (carrot, cucumber, iceberg radish) as well in the case of mainly homogenous samples.

The sample was tapped lightly with a wooden stick and a microphone located under the cushioning sample holder sensed the sample's acoustic response. *(Figure 1)* The microphone's output was recorded by a sound card built in a computer. The Custom Fast Fourier Transform software was used to analyze the recorded acoustic response. There is a significant connection between the peak (characteristic) frequency of the acoustic signal and the sample's firmness (*Felföldi*, 1996). The characteristic frequency and the sample weight were used to calculate the firmness coefficient:

$$S = f^2 * m \ [N/mm],$$

where S = acoustic firmness coefficient
f = characteristic frequency of the sample
m = sample mass

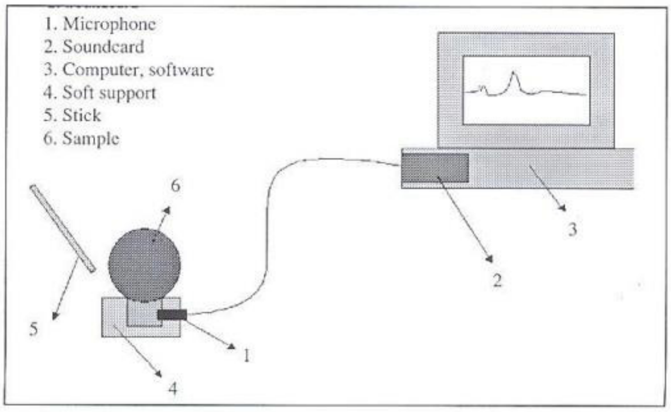

Figure 1 Arragement of the acoustic stiffness method

This method is suitable for following the changes in stiffness (softening) sensitively, reproducibly and objectively. The sound response of the product hardly depends on position of the sample and the tapping location; it is independent on the person who taps the product and the hitting stick. The acoustic stiffness method can be used successfully for following the textural changes during storage.

- **Dynamic impact method**

The impact method characterizes the firmness of the sample surface. This method is based on the observation that the impact hammer's deceleration depends on the sample's firmness and modulus of elasticity. The measuring system consists of an impact hammer with a changeable weight, an electronic signal converter and a dynamic signal analyzer. (*Figure 2*) A piezoelectric accelerometer is built into the hammer. The voltage signal of the accelerometer is recorded and displayed by the dynamic signal analyzer. This curve is analyzed by a special program developed for this purpose. The time and voltage differences between the initial and the maximum point of the curve are determined by the program. The impact stiffness coefficient is used for characterizing the sample's firmness (Felföldi, 1999):

$$D_d = 1/\Delta T^2 \ [ms^{-2}]$$

where: D_d = impact stiffness coefficient
ΔT = time difference between the initial and the maximum point of the curve in milliseconds

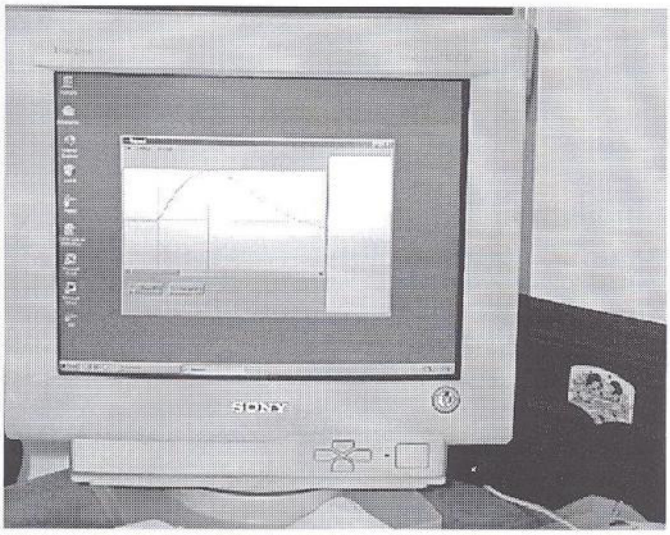

Figure 2 Arrangement of the impact method

Several trials were carried out in order to determine the surface stiffness of the horticultural samples by impact method. The main advantages of the method are: it can be automated, it can be easily built into the sorting or classifying and qualifying lines, so it can be used in the practice.

- **PC vision system**

A digital photo was taken from the sample and it was transferred to the PC. This method provides information about the shape and color of the sample. It is suitable for creating archives too.

Shape analysis: The central point of the samples is determined by the software, and the shape is characterized by the length and the angle of the vectors pointing from the center to the circumference points. Based on these, objective data classification according to the size, or recognition of the cultivar is possible.

Color analysis: the correct analysis needs acceptable conditions. The illumination is important because reflection causes data loss. For correct automatic separation of the sample and the background, selection of the appropriate color of the background is necessary. Color analysis was used to determine the maturity state and the diseases.

Archive: Because pictures were taken from the same sample in a given position regularly after given time periods, the visual changes of the sample can be followed.

During our experiments which were performed at the Corvinus University of Budapest, Faculty of Food Science and Faculty of Horticulture the most important vegetable cultivars were measured with the above mentioned methods:

- beet
- carrot
- garlic
- mushroom
- onion
- paprika
- potato
- tomato

Results

We found that vision system was perfectly suitable for all vegetable tested. Beets, carrots, onions, paprika, potatoes, and tomatoes were perfectly measurable with both dynamic non-destructive methods for texture and firmness parameters. The results of our experiments follow the textural changes of the samples during storage. According to the new research the acoustic stiffness method could be used for measuring the textural changes of carrot as well. Garlic has a complex structure, therefore the acoustic method is not suitable for this crop, while the impact method is suitable for measuring the stiffness of garlic. The mushroom can be measured by dynamic impact method but the stiffness changes of the surface are observed later than the visual changes, detected by PC vision. The texture of the

Table 1 Applicable non-destructive methods for texture measurement of different vegetable cultivars (2002–2004)

Vegetable cultivars	Impact method	Acoustic stiffness method	PC vision
Beet	+	+	+
Carrot	*	+	+
Garlic	+	–	+
Mushroom	**	-	+
Onion	+	+	+
Paprika	+	+	+
Potato	+	+	+
Tomato	+	+	+

\+ The cultivar can be measured successfully by this method.

– This cultivar is not measurable by this method.

* It can be measured by the impact method, but the acoustic stiffness gives better overall results.

** It is possible to be measured by the impact method, but it is less sensitive than by PC vision.

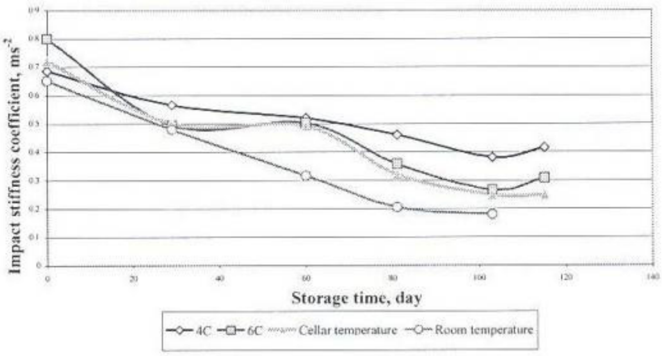

Figure 3 Texture changes of garlic measured by the impact method (2002)

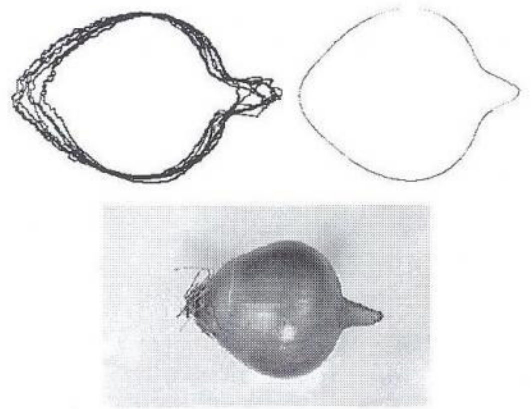

Figure 4 Average characteristic shape (quantitative feature of this variety) of onion, measured with the vision system (2002)

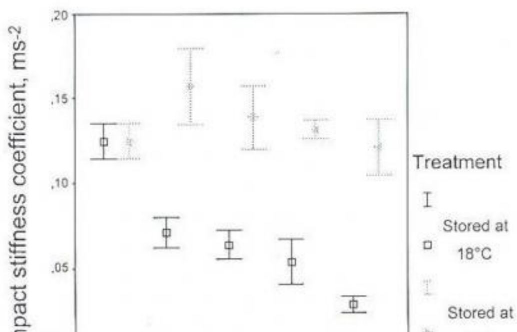

Figure 5 Texture changes of potato measured by the impact method (2004)

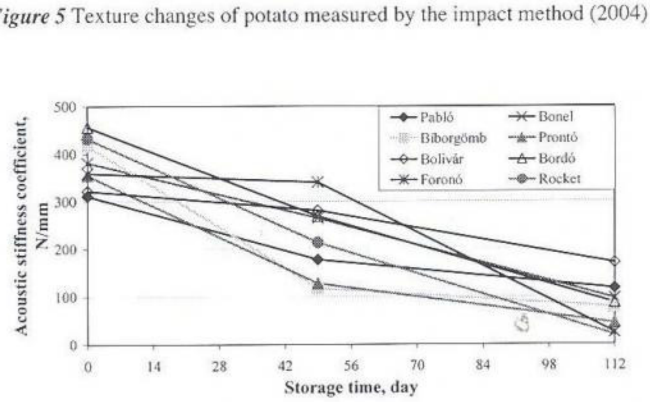

Figure 6 Stiffness changes in beet varieties measured by the acoustic method (2003)

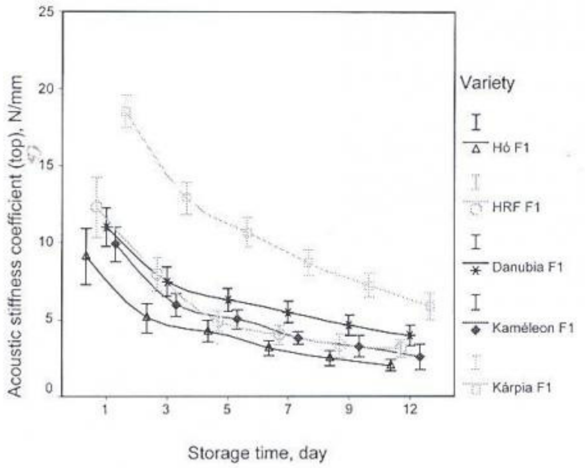

Figure 7 Changes in the acoustic stiffness coefficient at the top of the paprika varieties versus storage time (2003)

paprika was suitable for measurement by impact method. According to new experimental results the acoustic method can be used for measuring paprika firmness and firmness changes during storage very well.

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