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METHODS FOR IMPROVING COMPUTING METHODS FOR THE EVALUATION OF RHEOLOGICAL PROPERTIES OF FRUIT

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A b s t r a c t. There are problems with calculating the properties of the yield point when using electronic penetrometers. The authors suggest applying the method of calculating derivatives and searching for their extreme values.

K e y w o r d s: penetrometer, reology, stress derivative, yield stress

INTRODUCTION

There are two different methods to calculate the properties of the yield point for fruit and vegetables. First of all, we try to evaluate the yield stress and deformation on individual pieces. This article is to describe how to solve this problem. The other possibility is to calculate these properties on bulk materials [12].

TERMS AND DEFINITIONS

In computer programmes we calculate the next rheological properties along the acquired data:

σ compressive stress (y yield, r rupture)

ε compressive strain (y yield, r rupture)

l deformation or distance, mm

$\frac{\Delta\sigma}{\Delta l}$ stress-deformation derivative, MPa mm^{-1}

$\frac{\Delta\sigma}{\Delta t}$ stress derivative, MPa s^{-1}

$\frac{\Delta l}{\Delta t}$ deformation derivative, mm s^{-1}

$\frac{\Delta\sigma}{\Delta t}$ computed as a numerical derivative:

$$\left(\frac{\sigma_i - \sigma_{i-1}}{t_i - t_{i-1}}\right)_{i=2 \text{ to } n}$$

When calculating the derivatives at the *Texture Expert*: the moving average method is applied because of the great data acquisition rate (2 per s at *Fructométer*, 100 per s at SMS)

TESTED MATERIALS

Mainly apples were tested but there are also results from the measurement of cucumbers, apricots, melons, onions [1], tomatoes [2], mushrooms [11], etc. The apple varieties tested were Gloster, Golden Spur, Jonagold, Jonnee, Jonathan M41, Mutsu [4,5,7,10]. The cucumber varieties were Express ZKI, Levina RS, Inge RS, Minerva SG and Potomac ASG [3,6,8,9].

RESULTS AND DISCUSSION

There are two different types of texture testing machines used for evaluating rheological properties of food and agricultural materials. The old type is a Hungarian built *Fructométer* from the MEFI, Budapest. It is equipped with a fixed penetrometer tip for measuring the force and a flat touching tool for tracking the unhurt surface of the fruit. This is the displacement (deformation) caused by the force. So the measured speed depends on the stress or force.

Our newer instrument is a *Texture Expert* from the Stable Micro Systems, England. The measuring probe is mounted on the same fixture, so the evaluated speed is constant during the whole measuring process. When searching for the point of the yield stress (bioyield point) we had to elaborate different methods for the calculations.

Both testing machines are connected to a PC and all the measured data are written on a disk. At the *Fructométer* the data consists of stress, deformation and time for all the points of the graph. At the *Texture Expert* the data file consists of force and deformation (displacement) values because of the constant deformation speed. The force and stress can be computed from one another using the surface of the probe.

It is hard to evaluate the usual form of graphs (Figs 1 and 2). We cannot find the point of the yield stress on the graphs. Better selections are time derivatives (Figs 3 and 4). A well observable local maximum and a minimum can be found near the 4 mm deformation.

The best selection is the deformation derivative of the stress (Fig. 5). The first local minimum and maximum can be observed at 4.5 s. This method was proved the best for solving the problem of search for the yield point.

When using the up-to-date *Texture Expert* testing machine only one derivative is usable:

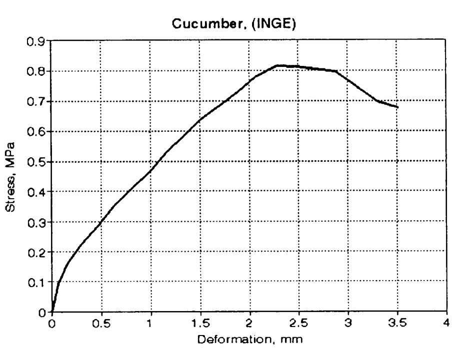

Fig. 1. Stress-deformation graph.

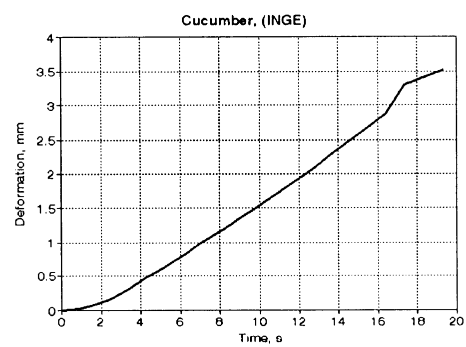

Fig. 2. Deformation-time graph.

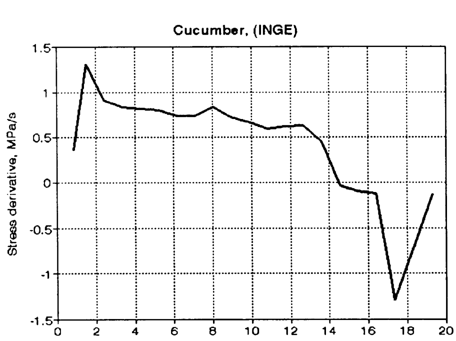

Fig. 3. Stress derivative.

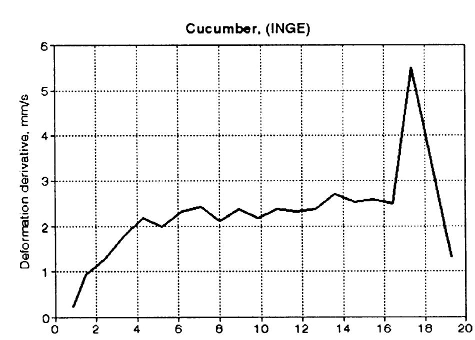

Fig. 4. Deformation derivative.

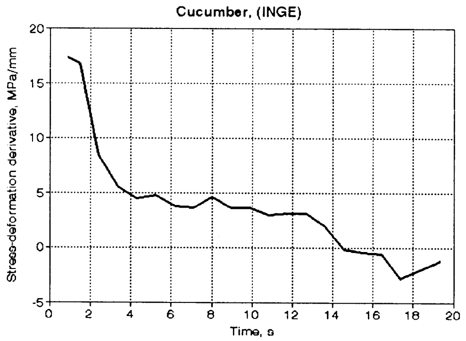

Fig. 5. Stress-deformation derivative.

the time derivative of the stress (N.B. the programme of the testing machine works on Force data instead of Stress). Although this poses a problem, we can use it because of the better data acquisition rate. Considering a great amount of data, we calculate this derivative for a special interval, so this procedure is similar to the moving average method and gives an acceptable calculating time.

CONCLUSION

The elaborated searching method proved useful in searching for the yield point of the graphs taken on fruits and vegetables at penetrometric tests.

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