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DEFINITION OF THE GENERAL TEXTURAL PROFILE OF FRUITS

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The term of the texture of foodstuffs is applied to the structural elements of foodstuffs and to the way in which these elements are registered by the physiological senses at their consumption. Thus Szcześniak specified the notion of the texture of foodstuffs generally in the year 1963 [1]. The notion of the texture of foodstuffs was used intuitively already earlier at the commissional testing of the quality of foodstuffs. In the mentioned work [1] Szcześniak not only defines the notion of texture, but she also suggested a system of textural parameters, which, if they are determined, form the general textural profile of the pertinent foodstuff. Here we shall deal only with the mech anical parameters. Their list and key words of the scale are compiled in Table 1.

In the last ten years the expert circles have paid increased attention to an objective determination of the textural parameters on the basis of different tests, in which these parameters are being measured. This interest is shown by the subject of monothematic collections of papers [2, 3] and also of a majority of works published in the special periodical — Journal of Texture Studies. One of the first suggestions as to how to determine the mechanical parameters of the textural profile by means of an apparatus was the application of the texturometer of General Foods Co. [4]. This texturometer simulates, by means of a periodical impressing of various devices, the activity of teeth at the mastication, and after an evaluation of the recordings of the applied force and time it is possible to evaluate [4] a set of textural parameters mentioned in Table 1. The method of determination of the textural parameters was chosen particularly with regard to the properties of pulpy and semiliquid materials. This method of determining the textural profile was used by Bourne [5] for fruits. In this case use was made of the universal deformation apparatus Instron instead of the texturometer. In the same way also the mechanical parameters of the textural profile were determined in cucumbers [6].

It is the purpose of this work to provide information on how, at our school, the textural profile, its mechanical parameters, and the method of the determination of these parameters obtained in a deformation test have been changed. The motives for these changes will perhaps become obvious from our further explanation. However, substantially they were based on the andeavour to give the parameters a good physical substantiation and to link them to the rheological and mechanical properties of fruits and vegetables.

MECHANICAL PARAMETERS OF THE TEXTURAL PROFILE

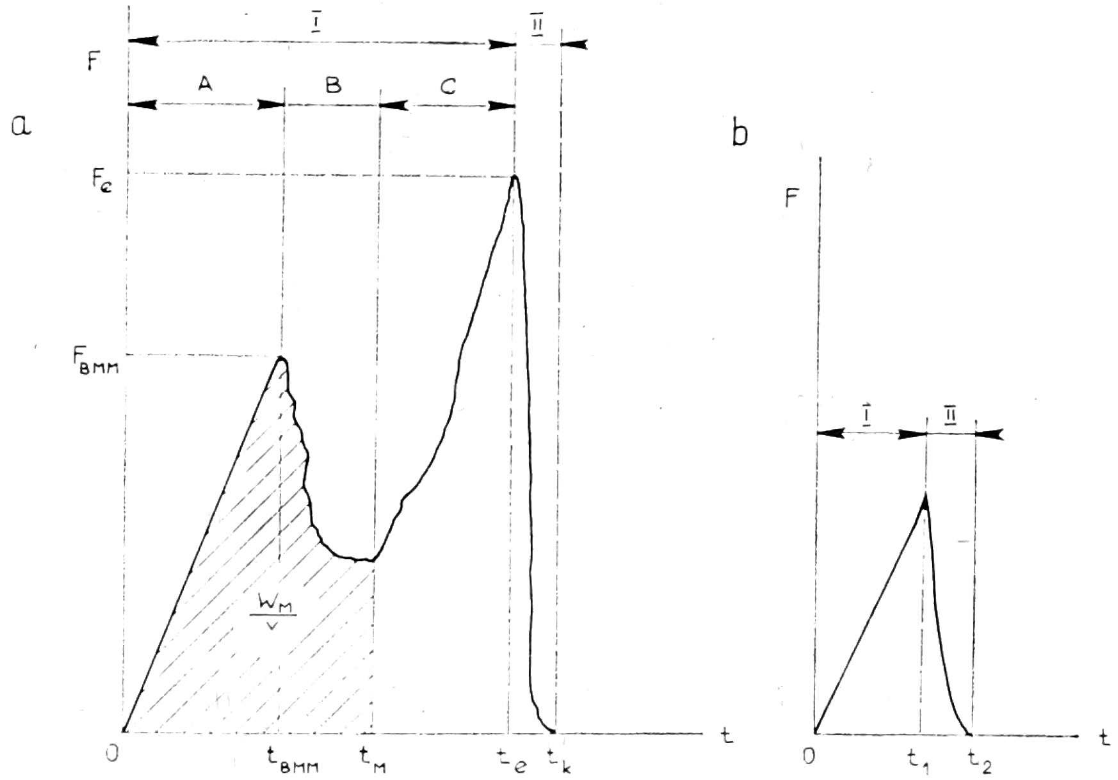
The basic mechanical parameters remain the same as for solid substances in Table: *I* — hardness, *II* — cohesiveness and *III* — elasticity. In the following explanation there will be a more accurate definition especially of the complex of parameters called cohesiveness. In our case the basic test for the determination of the mechanical parameters is the pressure test: a compressing of the sample of the cross section A perpendicularly to the acting pressure force *F* and to the height h between two plates.

Table

Mechanical parameters of the general textural profile (according to [1])

Primary parameters	Secondory parameters	Scale
Hardness		soft-firm-hard
Cohesiveness	brittleness	crumbly-crunchy-brittle
	chewiness	tender-chewy-tough
	guminess	short-mealy-pasty-gummy
Viscosity		thin-viscous
Elasticity		plastic-elastic
Adhesiveness		sticky-tacky-gooey

Actually Fig. 1 shows two tests performed with two different samples. In both cases the tests consist of loading (*I*) and unloading (*II*). In the first case the sample is deformed up to crushing (Fig. 1*a*), and in the second case the biological limit of macrodeformation is not exceeded (see Fig. 1*b*). The rate v of the deformation in the case of loading is constant and is, as regards size, the same as is the rate of the decreasing of the deformation — v at the unloading and equals the rate of the squeezer of the deformation apparatus. In the course of the testing the recording paper moves at a constant speed. Thus the recording shows the dependence of the pressure force *F* acting on the sample in the time *t*. Fig. 1*a* is typical for the great deformation of pressure samples produced from the tissue of fruits and vegetables. In the region *A* there occurs a viscoelastic, non-destructive deformation of the sample. After an exceeding of the biological limit of macrodeformation (*BMM* — $v.t_{BMM}$; F_{BMM}) the tissue cracks in consequence of the shearing stress and gradually splits. This process takes place in the whole region *B* and is practically terminated in a minimum of dependence *F* — *t*. In the region *C* there occurs a compacting of the tissue and its sideward creeping. The test shown in Fig. 1*b* serves practically only for the determination of the elasticity of the undisturbed tissue.



1. The dependences of force on time obtained from deformation tests: *a*) large deformation, *b*) small deformation, I — loading, II — unloading

We shall now examine the different mechanical parameters of the textural profile one after the other and we shall state always their physical definition *PD* and the definition obtained in the pressure test — the operationalistic definition *OD* together with a concise explanation.

I. Hardness *H*.

PD: the resistance of the material against great (plastic) deformation expressed by the secant modulus.

$$OD: \quad H = \frac{F_e h}{A D_e}, \qquad (1)$$

$$[H] = Pa,$$

where D_e is the maximum compression:

$$D_e = t_e \cdot v \tag{1a}$$

and v is the velocity of the shifting of the cross bar of the deformation machine.

In this case of importance is the choice of the size of the maximum compression of the sample D_e with regard to its height. With regard to the fact that in samples of fruits and vegetables the minimum dependence $F - t$ appears in the case of deformations corresponding to a value of $(0.3—0.5) \cdot h$ and the value F_e should not be affected markedly by the processes of the crushing of tissue taking place in the sphere B, Fig. 1*a*, then the choice of $D_e = 0.75$ h mentioned by Bourne [5] is suitable.

II. Cohesiveness

— is not defined by a simple parameter, but it forms a complex of four partial parameters.

IIa. Strength S.

PD: the resistance of the material against the disturbance of the stability of the deformed sample expressed by the stress at the strength limit of the material.

OD:

$$S = \frac{F_{BMM}}{A}, \tag{2}$$

$$S = Pa.$$

The biological limit of macrodeformation is connected with ruptures and cracking of samples as typical properties of the deformation of fruit and vegetable tissues. In the case of deformation by means of pressure it is not possible to observe other ways of loss of stability than is a brittle fracture (for example necking). For material that is not disturbed by fraction or cracking and in which the biological limit of macrodeformation does not appear at the deformation by pressure, it is not possible to determine strength by means of the above mentioned method.

IIb. Brittleness B,

PD: the inclination of material towards a loss of stability in the case of a small plastic deformation or without it.

OD:

$$B = \frac{1}{2} \frac{F_{BMM} \cdot t_{BMM} \cdot v}{W_M}, \tag{3}$$

Brittleness defined by the relation (3) expresses actually the proportion of the deformative energy accumulated in the sample in the course of the viscoelastic deformation to the deformative energy required for the grinding of the sample. If, however, the deformation curve shows no BMM, then the definition (3) fails and zero can be considered to be the value B. B can acquire values from the interval (0,1).

IIc. Stretching capacity — gumminess (G).

PD: the ability of the material to deform itself without any disturbance by means of a partially reversible method.

OD:

$$G = \frac{t_{BMM} \cdot v}{h} E_1, \tag{4}$$

where E_1 is the initial elasticity defined by the relation (6a).

The stretching capacity defined by the expression (4) is a non-dimensional quantity, which can, theoretically, acquire values from the interval (0,1). In the case of more brittle substances, as are fruit and vegetable tissues, at the deformation of which there appears in the deformation curve a biological limit of macrodeformation, the definition (4) shows the stretching capacity limited by fracture. A limiting of the stretching capacity by means of other mechanisms (necking ct.) cannot be revealed principally by means of a pressure test. For materials in which these mechanisms are typical, no *BMM* appears in the deformation curve and it will not at all be possible to define the stretching capacity, or it will be possible to use directly the initial elasticity E_1 instead.

IId. Toughness T.

PD: The proportion of consumed energy for the crushing of the sample and of the volume of this sample.

OD:

$$T = \frac{W_M}{A \cdot h}, \tag{5}$$

$$[T] = Jm^{-3}.$$

The parameter of toughness takes place of the parameter of chewiness of Table 1, as it more suitably illustrates the gradiation of the key words for this term (see Table 1). For materials with BMM the definition (5) is clear with regard to FD. It somewhat differs from the toughness defined by Finney [7], which is defined from the deformation energy related to BMM. Definition (5) includes in the toughness also the deformation energy of the whole course of the crushing. In the case that no BMM should occur in the deformation curve of the material, the following relation can be applied for toughness

$$T = \frac{W_{40\%}}{A \cdot h} \cdot \frac{1}{(1 - E_2)}, \tag{5a}$$

in which $W_{40\%}$ is the deformation energy at a relative deformation equalling 40% (this deformation corresponds approximately to a minimum in the deformation curves of fruit and vegetable tissues) and E_2 is the final elasticity (see relation (6b). Then physically the relation (5a) contains a deformation energy at 40% of plastic deformation.

III. Elasticity (*E*).

PD: the ratio of the reversible deformation to the total deformation is also called the degree of elasticity.

OD:

$$E_1 = \frac{t_2 - t_1}{t_1}, \tag{6a}$$

$$E_2 = \frac{t_k - t_e}{t_e}, \tag{6b}$$

The initial elasticity E_1 has been defined for deformation as being smaller than is that corresponding to *BMM*. Its determination is shown by the test in Fig. 1*b*. The final elasticity E_2 corresponds to the constant deformation (time t_e in Fig. 1*b*) under conditions when brittle tissue is crushed.

EVALUATION OF THE SUGGESTED SYSTEM OF TEXTURAL PARAMETERS AND CONCLUSION

The suggested system of textural parameters is added to the number of various systems mentioned by various authors (see, e.g. [8]). The system suggested by us is based on some of the older systems ([1, 2]), but it consistently uses physically substantiated quantities. In this way at least some of the operationalistic arbitrary decisions are removed as well as errors and inaccuracies resulting from them. Another advantage of the suggested system is the comparatively simple test on the basis of which the textural parameters are determined; a sample of simple shape is compressed by means of pure compression. More difficult, however, is the numerical expressing of textural parameters, which cannot be done without any planimetry of the deformation curve W_M, or without any integrator in connection with the measuring device of the deformation apparatus.

The greatest disadvantage of the suggested system is the fact that it is suitable only for the evaluation of brittle materials. For plastic materials it is possible, according to the suggested method, to determine only a limited number of textural parameters: elasticity, hardness and toughness. However, the suggested system of textural parameters is suitable for the description of the texture of root vegetables, kernel fruits, and of other mellow vegetables and fruits.

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OKREŚLENIE OGÓLNEGO PROFILU STRUKTURALNEGO OWOCÓW

Streszczenie

Pomiary własności strukturalnych owoców i warzyw przeprowadzono na podstawie zmienionej i uzupełnionej metody Bourne'a.

Modyfikacja tej metody pomiarowej miała na celu powiązanie wyników badań z właściwościami reologicznymi tych materiałów nadających, fizyczną treść właściwościom strukturalnym badanych owoców i warzyw.

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ОПРЕДЕЛЕНИЕ ОБЩЕГО СТРУКТУРНОГО ПРОФИЛЯ ФРУКТОВ

Резюме

Метод Бурна измерения текстурных свойств фруктов и овощей был изменен и уточнен таким образом, чтобы он был прямо связан с реологическими свойствами этих материалов и с физическим содержанием отдельных определений текстурного профиля.

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