The application of stepwise programmed stress in examination of rheological properties of meat and other solid foods*

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It is obvious that the good rheological method of texture examination of food products ought to be:

– versatilé what means that this method should be suitable for testing substances of different mechanical properties,

– analytical, what means that this method should be able to determine any rheological parameter uniequivocally as well as to detect any structural change occurring in the substance being under examination,

– and this method ought to be reproducible, simple and quick.

Such methods are available for substances of liquid character. These methods are based on testing the parameters of flows between two coaxial cylinders or through a tube of circular cross-section. There exists a number of practical realizations of these methods and they are used for testing Newtonian liquids as well as plastic and visco-elastic ones. Because these apparatus work in wide range of shears or gradients of velocity decrease, they make possible the examination of structural changes of tested bodies.

Unfortunately such a good method for examination of solid bodies does not exist. The existing methods are not quite analytic. Mostly only the determination of forces needed for sample destruction in predetermined cutting system is possible. If the analysis is recorded, the figure obtained may be investigated and give some analytical data. However, this type of figure is not very characteristic and it is difficult to be interpreted, mainly due to its stress – strain relations variability.

That was the reason why I intended to elaborate a method for analyzing the rheological properties and differentiating the characteristic structures of tested solid food products. I used a very simple apparatus, an ordinary penetrometer equipped with flat-ended pivot of circular cross-section. The pivot was directly loaded with weights. By this way different normal stress of predetermined value could be obtained. Movings of pivot were recorded or might have been observed on the scale. The most characteristic feature of his method is the way of stress changes programming. Such a program can be seen on figure 1. In the way of loading the pivot successively with weights of the same we obtain stepwise increase of stress value, which is then held constant for limited time, followed by unloading with coming back the stress value to the first level. Deformations caused by this type of stress changes and plotted against time are differentiated in a characteristic manner according to the rheological properties of sample.

* A III. Nemzetközi Élelmiszeranalitikai Módszertani Szimpóziumon elhangzott előadás. Szentendre 1975. okt. 8–11.

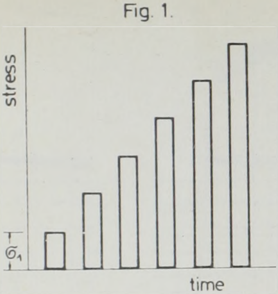

Fig. 1.

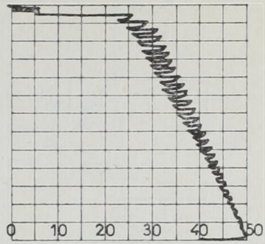

Fig. 2.

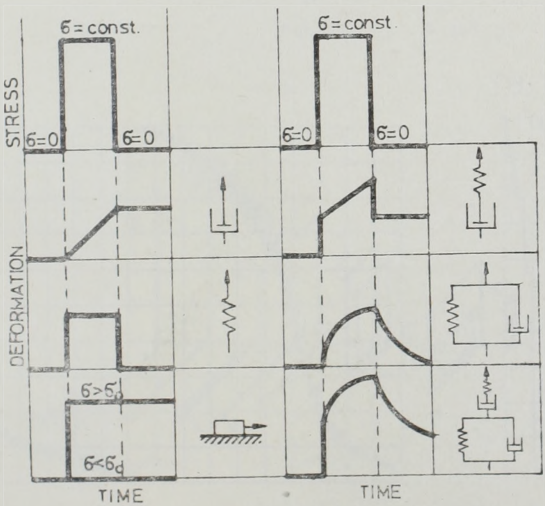

Fig. 3.

On figure 2 the curves typical for different fundamental rheological models can be seen. The sloping lines on diagrams manifest the existing viscous elements – "delaying factors" – and the vertical lines manifest the existing elastic elements. The vertical lines on deformations diagrams can also indicate the instant destruction, which is the characteristic feature of plastic body. According to the last statement, the most valid evidence for existing of body elasticity is the reconstitution of body shape after stress disappearing.

Asymptotic curves are typical for visco-elastic fluid of Kelvin – Voight.

On figure 3 the rheogram of canned ham can be seen. In this case one measure cycle of 30 sec. was divided into two periods:

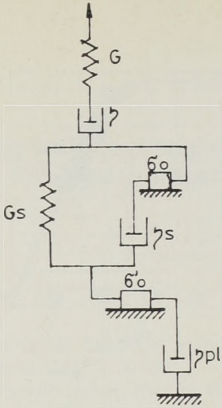

Fig. 4.

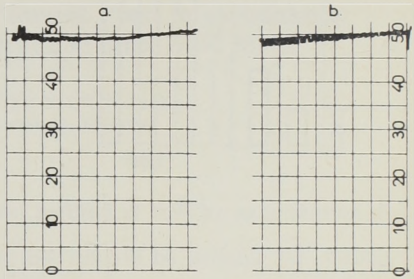

Fig. 5.

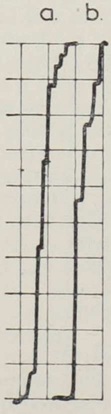

Fig. 6.

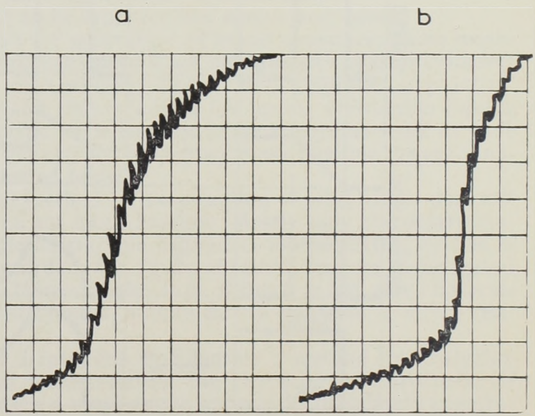

Fig. 7.

– first: 15 sec of loading (action of stress)

– and second: 15 sec of unloading.

The pivot diameter was 5 mm and load was carried out with 50 gram weights therefore the increase of normal stress was $7{,}85 \cdot 10^4$ N/m^2 each time.

The unit fragments of this rheogram show the composite structure of the product. Its model consists of plastic elements as well as of viscous ones, in series and parallel connections, as it is specific for model of Burgers' body. When the stress is relatively high, in that case the value was $243{,}35 \cdot 10^4$ N/m^2, structure of ham is damaged. Therefore the yield limit of tested ham was the same. So we can consider ham to be a plastic body and assuming some simplifications describe its characteristic with Bingham's equation.

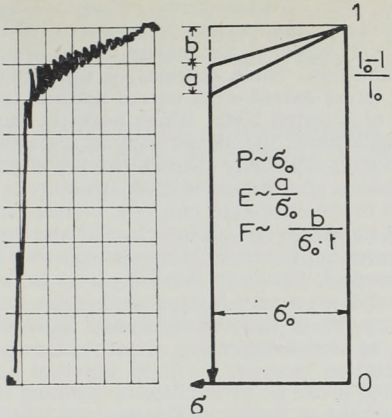

Fig. 8.

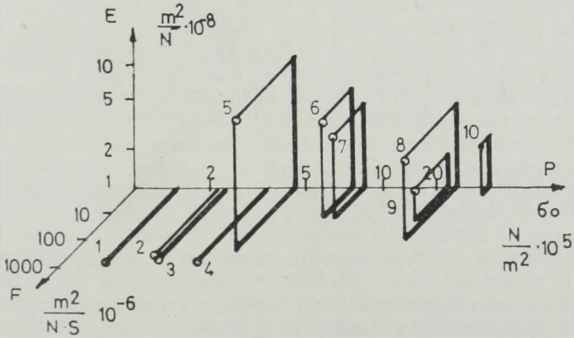

Fig. 9.

The method used can be applied for construction of rheological models of different bodies.

In figure 4 the rheological model can be seen of homogenous sausage called "serdelowa". This model consists of seven elements. Two of them are of plastic character and one is the constant value of apparatus and presents mechanical resistance of moving parts of penetrometer.

The model of ham is of the same character, except that the values of particular constants are different and the yield limit is higher.

Construction of rheological models and calculation of particular constant values can be done through all the range of stress but sometimes it is not purposeful.

From my point of view, more useful is selection of any synthetic parameters which could be able to characterize the mechanical properties of tested bodies in general. Such proposed unconventional parameters can be appointed on the base of rheograms outlines analysis. These outlines of rheograms are like magnetic hysteresis loops. The larger extension of curves limiting the rheogram outlines, the higher elasticity of a tested body. When both the curves are covered one with the other, we can assume the tested body as inelastic. Remembering that we are saying about a gum-type body characterized by high Young's modulus – in a contrary to the bodies of a firm crystalline structure or strongly dehydrated like lump sugar, sweet drops, chocolate, crackers, biscuits, radisch and so on.

The rheogram of radish we can see in figure 5^a and the rheogram of drops in figure 5^b. The intersecting elements of theser heograms are the leaps resulted from the unload of samples. The steep slope of curves is due to the elastic elements of structure and it means the body is susceptible to irreversible deformation. Two of the examples of such samples may be leaver-wurst and butter. Their rheograms can be seen in figure 6.

For the interpretation purpose the most univocal parameter is the yield limit. Using my method it can be determined by defining the stress range which is accompanied by the bend of rheogram. The shape of this bend characterizes the sample additionally. Sharp bends are typical for plastic bodies – we could see such a bend on the rheogram of ham – and soft and indistinct bends are typical for pseudoplastic bodies. Fermented cheese is one of good example of such a body. The rheogram of fermented cheese is presented in figure 7^a. From rheological point of view the coagulated caseinate is not a solid body but rather a very viscous overcooled liquid. Taking this rheogram as an example we can notice that there is a possibility of existing of two structures which are damaged in turn and therefore we can observed two yield limits. This phenomenon is typical for bodies of foamy or spongy structure containing gas bubbles, like fermented cheese or bread. The rheogram of bread sample we can see in figure 7^b.

The full comparability of the results in the discussed method can be obtained with the pivot of the same dimensions and when identical programs of stepwise stress changes are used. The duration time of measure cycles is also a very important factor, especially in the case of bodies containing viscous elements. In my detailed studies having in view the determination the values of different rheological parameters in the system containing parallely connected viscoás and elastic elements, I had to extend one measure cycle to twenty minutes. Therefore an empirical selection of the most suitable conditions of testing is necessary. Generally there is no matter which parameters characterizing the outlines of rheograms are chosen. As it concerns meat products I make an interpretation resulting from the fact that the rheogram is of triangle shape, what can be seen in figure 8. Three characteristic numbers are as follows:

plasticity $= \delta_0$.
elasticity $= a/\delta_0$
fluidity $= b/\delta_0 \cdot t$

On the basis of these parameters there is a possibility of setting up the systematic of rheological properties of solid food products.

In figure 9 we can see the three-dimensional diagram of P, E, F – coordinate system for different food products.

This diagram includes:
1- meat pie, 2- liver-wurst, 3- bread, 4- butter, 5- sausage, 6- luncheon meat, 7- radish, 8- ham, 9- drops.

It can be seen generally, that high elasticity is accompanied by low fluidity and vice versa. Bodies with high fluidity have a low yield limit.

More detailed observations would be made when specialists testing different food products would analyze more of them.

PROGRAMOZOTT FESZÜLTSÉG ALKALMAZÁSA A HÚS ÉS MÁS SZILÁRD ÉLELMISZEREK REOLÓGIAI VIZSGÁLATÁBAN

Tyszkiewicz, S.

A szokásos penetrométerek viszonylag egyszerű úton alakíthatók át lépcsőzetesen változó deformáló feszültségek lérrehozására. Az alkalmazott feszültség mértékének változtatása a mérési idő függvényében értékes információkat nyújthat a vizsgált élelmiszerek reológiai tulajdonságairól. A módszer alkalmazhatóságát szerző különböző húskészítményeken, kenyéren és vajon mutatja be elemezve a reológiai görbékből leolvasható adatokat.

ПРИМЕНЕНИЕ ПРОГРАММИРОВАННОГО НАПРЯЖЕНИЯ ПРИ РЕОЛОГИЧЕСКОМ ИСПЫТАНИИ МЯСА И ДРУГИХ ТВЕРДЫХ ПИЩЕВЫХ ПРОДУКТОВ

С. Тишкиевич

Обыкновенные пенотрометры относительно простым способом могут быть преобразованы для создания постепенно переменных деформирующих напряжений. Изменение степени применяемого напряжения в зависмости от времени измерения может предоставить ценные информации о реологических свойствах испытываемого продукта питания. Автор ознакомляет применимость метода на разнынх мясных изделиях, хлебах и сливочном масле, анализируя данные снятых с реологической кривой.

ANWENDUNG VON PROGRAMMIERTER SPANNUNG BEI DER RHEOLOGISCHEN UNTERSUCHUNG VON FLEISCH UND VON ANDEREN FESTEN LEBENSMITTELN

S. Tyszkiweicz

Die üblichen Penetrometer sind auf einem verhältnismässig einfachem Weg zur Erzeugung stufenweise verändernden Spannungen umsetzbar. Die Veränderung des Masses der angewandten Spannung als Funktion der Messperiode kann wertvolle Informationen geben über die rheologischen Eigenschaften der untersuchten Lebensmittel. Die Anwendbarkeit der Methode wird – nebst einer Analyse der von den rheologischen Kurven ablesbaren Angaben – auf verschiedenen Fleischerzeugnissen, Brot und Butter gezeigt.