IMPROVEMENT OF METHODS OF DETERMINATION AND CALCULATION OF CONSISTENCY CHARACTERISTICS OF MEAT PRODUCTS WITH THE HELP OF UNIVERSAL TESTING MACHINE "INSTRON"

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SUMMARY

"Instron" universal testing machine of different modifications (1122, 1140, 1185, 4202, ets.) is proved to be a good device for studying the complex of structural and mechanical characteristics (SMC) of various kinds of the food raw material, half-finished and finished products, casing, and concomitant materials.

The Academy of Applied Biotechnology and the All-Russian Scientific Research Institute of Meat Industry had decade experience in investigating of food and meat products. It allowed to improve methods for determining SMC of raw material, half-finished and finished products including meat products using "Warner-Bratzler" and "Kramer Shear Press" (Fig. la and lb) measurement cells, "Magness-Taylor" (Fig. lc) cylindric indentors, and conical indentor (Fig. ld).

"Warner-Bratzler" measuring cell is the simplest device for determining strength characteristics of products with expressed anisotropy of properties. It is proved to be reliable by studying the influence of different technological process on SMC of whole-steak meat raw material with "Classic" parallel orientation of muscle fibres. To measure SMC, a cylindric sample (dia:12.7 x 10^{-3}m) of a portion of meat (native or processed) with fibres orientation parallel (version 1) or perpendicular (version 2) to the geometric axis of the cylinder is cut out by means of a cylindric punch. The testing sample is placed on the horizontal surface of the measurment cell under the cutting plane in such a way that the generating line appears to be perpendicular to the vertical cutting plane. In dependence on the version of sample preparation (1 or 2), it is possible to use three ways of measuring anisotropic SMC of a testing sample: across fibres I(1), along horizontal fibres = (2), and along vertical fibres II (3).

The shear stress is the quantitative characteristic of the sample strength estimated by the formula:

$$Q_{I,=,II} = \frac{F_{I,=,II}}{S} = 7.898 \times 10^3 F,\ Pa,$$

where F - shear stress, H;
S - cross-sectional area of cylindrical sample, m^2;
7.898 x 10^3 - coefficient of proportionality, m^{-2}.

"Warner-Bratzler" measurement cell may be also used for measuring strength characteristics of homogeneous solid food products.

By comparing resulted measurements of strength characteristics of anisotropic and homogeneous (isotropic) tested samples, it is recommended to carry out measurements under the following condition: rate of application of the breaking deformation (cutter move) - 50mm/min.(0.83 x 10^{-3} m/s) and rate of tape movement of the recording meter - 200 mm/min.(3.33 x 10^{-3} m/s).

"Kramer Shear Press" measurement cell shown in Fig. lb is a cubic chamber. Chamber cover and bottom have by ten through vertical parallel slots for free passage of ten cutter blades transfered by "Instron" traverse with the given line speed. Samples of tested product are cut by means of a hollow cylindrical punch (dia: 25.4 x 10^{-3}m) and cut up on round disks about 10^{-2} m high. The disks are placed on the bottom of the "Kramer Shear Press" cubic chamber one by other (usually four). As soon as tests were carried out and

maximum force was determined on the diagram tape, the shear stress was estimated according to the following formula (Lipatov et al., 1991):

$$Q = \frac{P_{max}\ \delta}{\pi R^2\ h_{mean}\ n} = 1.481 \frac{P_{max}}{h_{mean}},\ Pa$$

where
P_{max} - maximum force caught by tensosensor by cutting out the sample, H;
δ - width of vertical slot (δ = 0.003), mm;
R - radius of product sample, m;
h_{mean} - mean height of product sample, m;
n - number of samples placed into the chamber;
1.481 - coefficient of proportionality, m^{-1}.

As a matter of fact the practical determination of SMC index of tested products in accordance with above mentioned method has a number of important advantages over the method of shear stress determination by means of "Warner-Bratzler" one-blade measurement cell because one measurement of shear stress made by "Kramer Shear Stress" measurement cell is equivalent to the mean result of 16 measurements made by "Warner-Bratzler" measurement cell.

As experience of numerous tests showed, to cut up products with similar Q_{mean} values, it is necessary to apply different shear cut. To determine it the following formula is proposed (Lipatov et al., 1991):

$$A_{cut} = \frac{S\ V_{tv}\ \delta}{V_t\ \pi\ R^2\ h_{mean}\ n} = 0.370 \frac{S}{h_{mean}},\ J/m^2$$

where
V_{tv} is speed of traverse movement (50 mm/min.), m/s;
V_t is speed of diagram tape movement (200 mm/min.), m/s;
S is space under "force-deformation" curve limited by the vertical from the left, which defines the moment of the ten-blade cutter passage through slots of the chamber bottom to a definite distance (in our case this distance is 52 x 10^{-3} m from the point of intersection of the curve with P = 0 line of the diagram tape, Fig. 2), H · m; 0.370 is coefficient of proportionality, m^{-1}.

"Magness-Taylor" cylindrical indentor (Fig. ld) is proved to be well-designed for determining surface characteristics of food products. For this purpose a tested mass (system) is placed in the cylindrical basin (its diameter is two times higher than the diameter of the indentor bottom). Cylindrical basin is fastened on a rest. After that the indentor is lowered down till the contact with tested product surface. The pen of the recording meter is drawn aside to the right on the half of the full scale of the diagram tape (Fig. 3b, point A). Then the traverse (indentor) stroke down is switched on and it is moving with speed V_{tv} = 10 mm.min.(0.16 x 10^{-3} m/s); the tape is moving with speed of V_t = 50 mm/min.(0.83 x 10^{-3} m/s).

As soon as the indentor begins exerting pressure on the product with force of 2H (point B), the traverse stops and is kept in this position for 60 s (BC curve). Then the traverse stroke up is switched on and it is moving with the same speed.

The force created by the plunger at the moment when it loosens touch the product P_o is registered on the diagram tape. The following indices are estimated: adhesive-cohesive strength (R) and specific adhesive-cohesive work ($A_{sp.}$):

$$R = \frac{P_o}{F} = 3.921 \times 10^2 P_o,\ Pa$$

$$A_{sp.} = \frac{S\ V_{tv}}{V_t\ F} = 0.784 \times 10^2 S,\ J/m^2$$

where
P_o is force created by the plunger when it loosens touch the product;
F is contact space, m^2;
S is space under DEK curve (Fig. 3b) expressed in H m; 3.921 x 10^2 and 0.784 x 10^2

are coefficients of proportionality, m^{-2}.

For studying penetration characteristics of paste-like, gel-like and solid food products the authors used a conic indentor (Fig. 1d) with 60^0 angle at the cone apex.

Taking into account specific characteristics of various types of "Instron" testing devices, we analyse parameters of penetrating properties of tested products paying attention to the force required to penetrate up to the given depth but not to the very depth of its penetration. The authors carried out a number of experimental investigations of various minced meat products which demonstrated that well-reproduced results concerning the interaction between the constant depth of penetration and the force required for this purpose may be obtained when the indentor penetrates through tested products not less than on 25 mm. It is the reason why the very depth of penetration is chosen as "standard depth".

To obtain comparable results of tests concerning the indentor penetration through tested products and taking into account specific characteristics of "Instron" device the rate of penetration equal to 50 mm/min.(0.83×10^{-3} m/s) is considered to be acceptable.

A tested product is placed into the cylinder on a special support just under the indentor. It is necessary to remember that indentor diameter must be 4-5 times less than the cylinder diameter in order to avoid the influence of "the end effect".

As soon as the conical indentor reaches the depth of penetration equal to 25 mm, the traverse stops and the indentor is held within the product for 30 s, that is the period of time necessary for stress relaxation.

The following parameters characterized penetration properties of elastico-plastico-viscous products are adopted: stress of standard penetration (Θ_{st}) and stress relaxation period of the standard penetration (τ_p). These parameters are calculated on basis of experimental curve parameters (Fig. 3a) registered by the recording meter.

Standard penetration stress is calculated by known Rebinder-Agranat equation (Gorbatov et al., 1983):

$$\Theta_{st} = C \frac{P_{st}}{h^2} = 3.42 \times 10^2 P_{st}, \text{ Pa}$$

where P_{st} is force of standard penetration, H;
Θ_{st} is stress of standard penetration, Pa;
h is depth of cone penetration, m;
C is cone constant (angle at the cone apex is 60°, C = 0.214);
3.42×10^2 is coefficient of proportionality, m^{-2}.

Period of stress relaxation of the standard penetration is calculated by the following equation:

$$\tau_p = \frac{30}{\ln \frac{P_{st}}{P_{30}}}, \text{ s}$$

where 30 is time of relaxation, s;
P_{30} is force corresponded to the 30-second holding period of the indentor within the tested product, H.

<u>Reference</u>

1. Gorbatov A.V. et al.(1983) Structural and mechanical characteristics of food products: - M. "Light and Food Industry", p. 294.
2. Lipatov N.N., Sizykh E.V., Scherbinin A.A. (1991) Study of structural and mechanical properties of raw material, finished products and supplementary materials in the meat and dairy industry using "Instron-1122" universal test device. Methodic text-book for researches, engineers, post-graduates and students. - M., p. 26.

Fig. 1 Changeable appliances for "Instron" universal testing device:

a - "Warner-Bratzler" measurement cell;

b - "Kramer Shear Press" measurement cell;

c - "Magness-Taylor" appliance;

d - conic indentor.

Fig. 2. Geometric interpretation of the shear cut.

Fig. 3. Characteristics curves by determining:

a - stress of standard penetration;

b - adhesion-cohesion strength and specific adhesion- cohesion work.