DEVELOPMENT OF AN ULTRASONIC RESONATOR METHOD FOR DETERMINING THE CONTENT OF PROTEIN, FAT AND MOISTURE IN MEAT PRODUCTS

Sukhanova S.I., Pronina M.V. - The All-Union Meat Research and Designing Institute, Moscow, USSR

Sarvazyan A.P., Bukin V.A. - The Institute of Biological Physics, Pushtchino, USSR

The acoustic parameters of muscle tissue as effected with protein, fat and moisture levels were studied. Changes in the ultra-sound propagation rate and absorptivity were investigated relative to the level of protein, fat and moisture in muscle and fat homogenates and in minced meat. Muscle structure was found to influence little the acoustic parameters, which changes depended basically on the moisture in the former. Analytical and correlation relationships of the acoustic characteristics of muscle homogenates to their protein, fat and moisture contents are derived. Ultra-sound propagation rate in homogenates of different fatness degrees was measured as a function of temperature.

The data obtained allowed to develop a resonator method for determining protein, fat, moisture and mineral salts percentages in beef and pork homogenates. It may be useful for express-analysis of the quality of meat and meat products and for developing automated systems of monitoring technological production lines of least-cost products.

The acoustic parameters of meat as influenced with its basic components, viz., protein, fat and moisture levels, were studied. Changes in the ultra-sound propagation rate and absorptivity were investigated relative to the level of protein, fat and moisture in muscle and fat homogenates and in minced meat. Analytical and correlation relationships of the acoustic characteristics of muscle homogenates to their protein, fat and moisture contents are derived. Ultra-sound propagation rate in homogenates of different fatness was measured as a function of temperature. The data obtained allowed to develop a resonator method for determining protein, fat, moisture and mineral salts percentages in beef and pork homogenates. It may be useful for express-analyses of the quality of meat and meat products and for developing automated systems of monitoring technological production lines of least-cost products.

The application of ultra-sonic methods is based on the relation of the acoustic parameters of biological tissues to their composition, structure and condition. In studying ultra-sound propagation in biological objects, of interest are the rate, absorption, dissipation, reflection and refraction of resilient waves. Recently researchers concentrated on the use of ultra-sound to study the composition and properties of biological tissues, and there is certain progress in this field. In this respect, the establishment of a possible application of ultra-sound to determine meats composition is of scientific and practical importance.

The purpose of the reported experiments was to develop an express-method for determining protein, fat and moisture in the quality evaluation of meat and meat products; the method is based on the changes in ultra-sound propagation rate and absorptivity in meat homogenates.

The effect of the basic components of uncured raw meat (fat, protein, moisture) upon acoustic parameters was studied with a resonator method for measuring ultra-sound rate (U), it being based on measuring the frequency and width of the resonance peaks of an acoustic resonator. The latter is the space between two high-parallel pieso-tranducers filled with the medium under study.

Resonance peaks are determined with the appearance of a standing wave in the cell at the frequences, for which a whole number of semi-waves is covered by the length (1) between the pieso-transducers, i.e.

$$1 = n\frac{\lambda}{2} = \frac{U}{2f}$$

The frequency f_n of each n-th resonance is determined with the permanent distance between pieso-tranducers and with the ultra-sound rate

$$f_n = n\frac{U}{21}$$

i.e. f_n is a linear function of ultra-sound rate in the medium under study. The frequency difference between two adjacent resonances in a single-valued linear function of ultrasonic rate:

$$f_1 = f_{n+1} - f_n = \frac{1}{21}$$

The absolute value of ultrasonic rate in liquids can be derived from Eq. (3) starting from the measured frequency difference of two adjacent resonances.

It is convenient to estimate relative changes in ultrasonic rate ($\Delta U/U$) from the frequency of one of the chosen resonance peaks by the formula:

$$\frac{\Delta f_n}{f_n} = \frac{\Delta U}{U}$$

The resonance peak width δf_n is determined with the total power loss in the acoustic resonator due to ultra-sound absorption with a liquid, to partial reflection of an acoustic wave at the liquid-piesotransducer interface, etc. At low amplitudes of an acoustic wave this loss may be regarded as the additive one; then, the following expression is true:

$$\frac{\delta f_n}{f_n} = \frac{(\alpha\lambda)}{\Pi} + B$$

where α is sound absorptivity in a liquid, λ is wave length, B is a constant characterizing power losses in the acoustic cell, which are not due to sound absorption in a liquid; B is a function of frequency, depends on the design of a given resonator and can be found by measuring δf_n of the reference liquid having a known absorptivity value. Thus, ultra-sound propagation rate is proportional to the frequency δf_n, and absorptivity - to the width δf_n of the n-th resonance peak of an amplitude-frequency characteristics.

Eqs 3-5 allow to calculate ultra-sound absorptivity and rate in meat homogenates starting from the measured parameters of the resonance peaks of the cell. On this basis a model laboratory analyzer has been developed.

As test objects served uncured beef and pork. Samples were disintegrated in a meat grinder, a test portion m_{tp} was placed into the cup of a homogenizer and diluted with distilled water; the amount of added water was measured. The test portion was dispersed in an ultrasonic disintegrator for 4 min followed with comminution for 3 min since after dispersion there were some fibres left. Acoustic measurements of thus prepared homogenates were taken in the model laboratory analyzer in the frequency range from 2.5 to 3.0 MHz at 20 and 40°C.

A relation of acoustic characteristics to homogenate composition was found by measuring the acoustic parameters. Ultrasonic rate, absorption, temperature dependences of ultrasonic rate and absorption have different sensitivities to the level of meat components (fat, protein) in homogenates, and it enabled the determination of their composition by the measured values of the parameters.

In the simplest case, if one substance is dissolved in water and if the parameter to be measured (e.g., ultrasonic rate) is linearly related to the concentration "c" of the substance, e.g., of protein (c_{pr}), then, for a diluted solution

$$U = U_o + a_1 c_{pr} \quad (6)$$

where U_o is the value of a given property of pure water; a_1 is the coefficient of the relation between concentration c_{pr} and property U (to be determined experimentally). If U_o and a_1 are known, c_{pr} can be calculated from the measured U.

When there are several solutes in a mixture,

$$U = U_o + a_1 c_{pr} + a_2 c_{fat} + a_3 c_{water} \quad (7)$$

Then, to determine the concentration of c_{pr}, c_{fat} and c_{water}, it is necessary to measure several different physical properties (f, α, U, etc.), which would differ in their sensitivity to the concentration of meat components. The problem is then reduced to solving a system of linear equations:

$$U = U_o + a_1 c_{pr} + a_2 c_{fat} + a_3 c_{water}$$

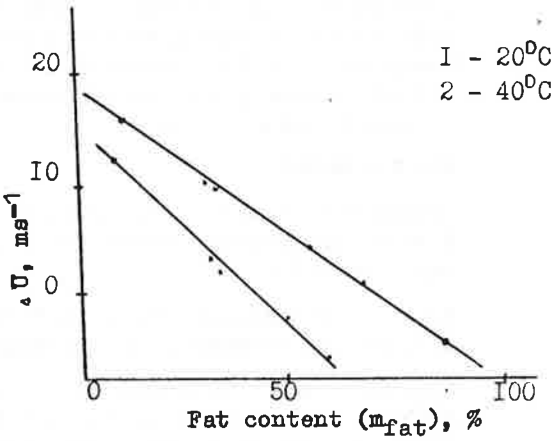
$$\alpha = \alpha_o + b_1 c_{pr} + b_2 c_{fat} + b_3 c_{water} \quad (8)$$

$$f = f_o + c_1 c_{pr} + c_2 c_{fat} + c_3 c_{water}$$

On the basis of the experimental results on the acoustic characteristics of raw meat homogenates, data are obtained on the independence of ultrasonic rate of the structure of raw meat (of meat integrity). This coincides with the earlier conclusion (Gorelov et al., 1984) that the acoustic rate in liquid and semi-liquid media is completely related to the molecular composition of a medium and does not practically depend on the type of the cellular and tissue structure.

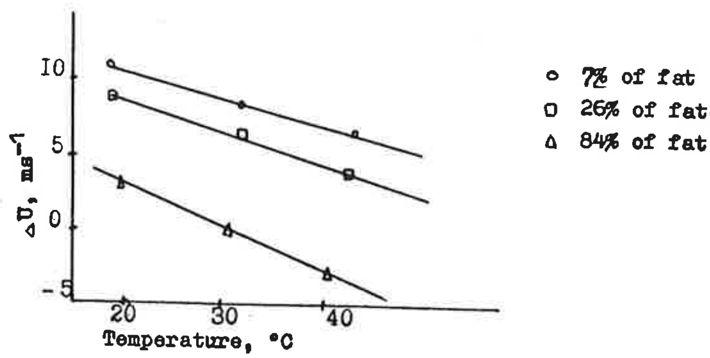
Muscle tissue contains, on the average, 76% of water, 1.9% of lipids, 21% of protein (Krylova & Lyaskovskaya, 1968). The main component, protein (without account for water) constitutes 86% of the dry solids of the tissue: consequently, changes in the acoustic parameters of muscle homogenates are primarily due to the content of protein. Fatty tissue contains, on the average, 7% of water, 91% of fat and 2% of protein; thus changes in the acoustic parameters of fatty tissue homogenates are basically due to the content of fat.

In the experiments on meat homogenates of different fat levels it was found that with a higher fat level ultra-sound absorption is linearly increasing and the acoustic rate is linearly decreasing (Fig. 1).



This agrees with the data available in literature on the relationship among these characteristics and lipid levels in biological tissues and liquids.

Fig. 2 shows ultra-sound rate in homogenates of different fatness as a function of temperature.



The rate of ultra-sound decreases practically linearly with a temperature rise, the decrease being steeper in case of higher fat contents in samples. If the values of the temperature dependence slope are extrapolated to the pure fat component and to the pure protein component, the slope for fat is one order higher than that for protein. Therefore, the slope of the temperature dependence is also a sensitive characteristic to determine fat-to-protein ratio. Contents of salts and organic low molecular components in the muscle tissue is about 3.5% (1% of salts and 2.5% of other compounds), i.e. 5 times as less as compared to protein content. Their total contribuition to the rate of ultra-sound is by 4 times lower than that of protein (it was established experimentally by means of dialysis separation of low-molecular compounds from muscle homogenates). On the basis of the above-said and earlier results (Lyrtchikov et al., 1986; Solntseva et al., 1986), one may state the lawfulness of the application of the additive scheme to calculate the acoustic parameters of meat homogenates. The data obtained allow to use the resonator method to estimate protein, fat and moisture percentages in raw muscles and minced meat.

REFERENCES

Gorelov, S.E., Zverkova, L.A., Sarvazyan, A.P. and Shvirst E. Mechanical properties of liver cells, Biophysics Knowledge, 1984, p. 102.

Krylova, N.N. and Lyaskovskaya, Yu. N. Meat Biochemistry (1968). M., Pishtchevaya Promyshlennost.

Lyrtchikov, A.G., Shestimirov, V.N., Solntseva, G.L., Sukhanova, S.I., Khlamova, R.I. and Afanasyeva, I.I. (1986). M., Agropromizdat, Myasnaya Industrija SSSR, No. 9, p. 432.

Solntseva, G.L., Sukhanova, S.I., Khlamova, R.I., Khrapunkova, O.V., Lyrtchikov, A.G. and Shestimirov, V.N. (1986). M., Agropromizdat, Myasnaya Industrija, No. 10, p. 34.