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A STUDY INTO THE INTERRELATION OF MOISTURE CONTENT AND ACOUSTICAL CHARACTERISTICS OF THE MUSCLE TISSUE

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SUMMARY

Acoustical parametres as effected with moisture as the basic component of muscle have been studied. Ultra-sound propagation rate and absorption coefficients as related to moisture level in the muscle tissue, minced meat and homogenates were measured with a device developed at the IBP. Muscle structure (integrity) was found to effect the acoustical parametres slightly, their changes being mainly dependent on the level of moisture. Analytical equations describing these relations have been derived.

INTRODUCTION

Determination of meat acoustical characteristics relation to other parametres of its state, composition and quality is a necessary stage of the development of acoustical methods for meats express-analyses.
Ultrasonic methods use for control in the meat industry is limited because biological tissues acoustical characteristics in relation to their composition and structure are not sufficiently studied yet. There are publications on acoustical values for biological objects (1,2). The parametres have a wide range: rate - from 1,540 to 1,630 m/s, attenuation - from 0.1 to 1.2 per sq.cm.
There are data testifying that water content is very important (3,4); however, there is no concrete answer as for the strength of the relation between acoustical characteristics and such factors as tissue structure.
The object of the work is to determine the influence of one of the main molecular components of the muscle tissue, water, upon acoustical parametres. Other components, such as lipids, proteins, minerals, change with water. Acoustical parametres relations were determined for the same samples, in which, while changing moisture, other tissue components were maintainedat certain propertions. The influence of tissue structure upon its acoustical parametres was determined; a quantitative relation of ultra-sound and attenuation rate to moisture content in the sample was investigated. For this, the rate of ultra-sound distribution rate and attenuation coefficient, moisture content both in integral muscle tissue, minced meat and homogenates were measured.

MATERIALS AND METHODS

As the test object served beef l. dorsi. Measurements were done 4-6 hrs after slaughter. From the plane, non-damaged surface free of membranes 1.0 x 1.0 x 0.6 cm tissue samples were taken. The remaining tissue was ground and served test ground meat. Before sampling the ground meat was mixed. All the results to be reported were obtained using beef muscle tissue from eight different animals. A test portion of the ground meat was mixed with distilled water and homogenized evenly in an ultrasonic disintegrator, the test tube with the sample to be homogenized being placed into a glass filled with cold water and ice to prevent protein denaturation. Acoustical parametres were measured using the RUZI-6 apparatus developed by Sarvazyan and Shestimirov at the IBP (5-7).
The ultrasonic rate was determined by the resonance peak frequency, the attenuation coefficient - by the width of the phase-frequency characteristics. The relative error of the measurements of the ultrasonic rate in diluted homogenates with the concentration of up to 80 mg/g was $5\cdot10^{-4}$%, in tissues and thick homogenates $5\cdot10^{-2}$%. The relative error of of the measurements of the attenuation coefficient was 1%. All the measurements were talen at 25°C within 7.0-7.5 MHz. Moisture content in tissues, ground meat and homogenates was found by dehydration at 103±2°C to the constant weight. The relative error was 0.5%.

RESULTS AND CONCLUSIONS

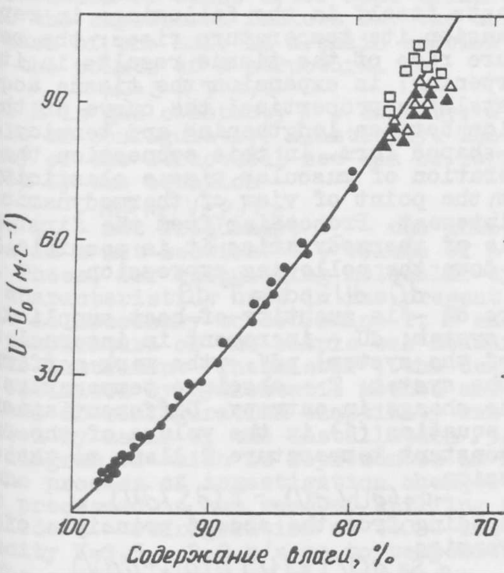
The results of measuring ultrasonic rate and attenuation coefficients of homogenates, ground meat and intact tissues as related to their moisture content are given in Figs. 1 and 2. The ultrasonic propagation rate and attenuation coefficients were measured parallelly and perpendicularly to muscle fibers. The relation of ultra-sound rate to solution concentration is a complex non-linear one. Taking into account that a solution consists of a solute and a solvent and that they constitute 100% titally, the relation is expressed as a function of the ultrasonic rate to the mass fraction (%)of the solvent (water in our case):

$$\Delta U = a_1\,(100 - C_0) + a_2(100 - C_0)^2,$$

where $\Delta U = U - U_0$ is the ultrasonic rate in the solution U and the solvent U_0; a_1 and a_2 are coefficients constant for any given object; C_0 is solution concentration.
The solid line in Fig. 1 represents the curve with the coefficients $a_1 = 2.85$ m/s/% and $a_2 = 0.04$ m/s/%, these values most optimally describing the results obtained. This indicates that, irrespective of the sample (intact muscle, ground meat, parallelly or perpendicularly to muscle fibers), the ultrasonic rate in beef muscle is mainly determined with the moisture level in the test sample.
Sound attenuation in muscle tissue, homogenates is stipulated by energy absorption and dissipation on medium non-uniformities (8,9). In biological tissue, having a structure, along with sound absorption by macromolecules, sound dissipation is also observed due to tissue non-uniformity.
With homogenate concentrating, aggregates number and size are increased and dissipation contribution to the value of the attenuation coefficient correspondingly; this shall lead to the non-linear relation of ultrasound attenuation to solute concentration. The results in Fig. 2 demonstrate that at higher concentrations of homogenates and with a closer approach to the concentration of non-diluted ground meat, a non-linear relation α to C_0 appears which can be described as follows:

$$\Delta\alpha = b_1\,(100 - C_0) + b_2\,(100 - C_0)^2,$$

where $\Delta\alpha = \alpha - \alpha_0$; α and α_0 are attenuation coefficients of the test medium and



Moisture content,%

Fig.1. Ultra-sound rate as related to moisture content in the muscle tissue
Δ - parallel to muscle fibers;
▲ - perpendicular to muscle fibers;
□ - ground meat;
• - homogenate.

of the solvent, respectively; ℓ_1 and ℓ_2 are coefficients constant for any given object.

The solid line in Fig.2 represents the curve with the coefficients ℓ_1 = 1.5 cm^{-2}/% and ℓ_2 = 0.05 cm^{-1}/%, these values most optimally describing the results obtained.

As the result of the investigation carried out, the following conclusions can be drawn:
- the values of ultra-sound propagation and attenuation rates are only slightly connected with the structure (integrity) of the muscle tissue and are mainly determined with its moisture content;
- the relations of ultra-sound rate and attenuation coefficients to the moisture content of the muscle tissue are non-linear; the analytical expressions describing these relations are derived.

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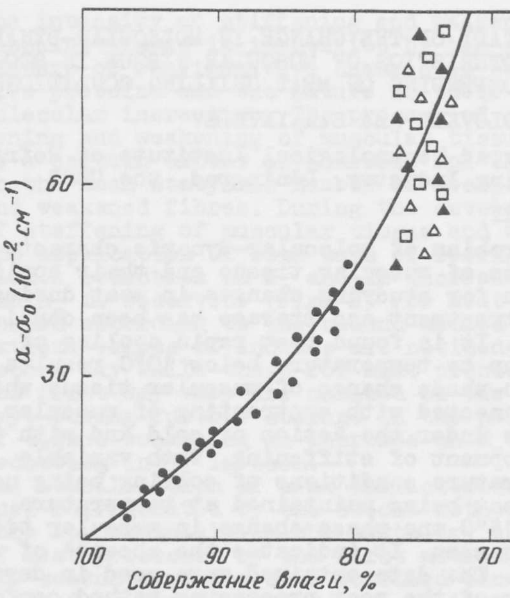

Moisture content,%

Fig.2. Attenuation coefficient as related to moisture content of the muscle tissue
Δ - parallel to muscle fibers;
▲ - perpendicular to muscle fibers;
□ - ground meat;
• - homogenate.

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