Mechanics of Muscle Tissue Behavior During Massaging and Tumbling

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SUMMARY: In the process of research it was established that mechanical treatment significantly changes mechanical properties of meat raw material. These changes are stipulated by restruction of muscle tissue structural formations. Character of changes differs, depending on structure and content of connective tissue in meat. Experimental methods were suggested for mechanical treatment, based on methods of polymere mechanics and hystological analysis.

INTRODUCTION: Machines for massaging and tubmling are widely used in meat industry. The aim of mechanical treatment of meat is its tenderizing for better organoleptical characteristics of final product. Behaviour of meat raw material is influenced by a range of interdependent factors - technical characteristics of equipment, technological parameters, presence or absence of vacuum treatment, etc.(Addis P.B. et al.,1979; Mikel W.B. et al., 1988). For attainment of optimal tenderization level it is necessary to know dependence of mechanical characteristics of treated meat on parameters of technological process, and above all - duration of massaging and tumbling. Authors made an attempt to develop theoretical and experimental approaches to creation of physico-mathematical model of mechanical effect on meat raw material during different technological processes (massaging, tumbling, tenderization, etc.). The aim of the present study was to investigate influence of mechanical treatment time on mechanical properties and structure of beef muscle tissue.

MATERIALS AND METHODS: Beef muscle tissue (18 months old steers, I category of fatness, Black-and-White breed, from animal growing complex) taken 48 hours post mortem served as object of research.

Two types of muscles were studied: Longissimus dorsi (LD) and Triceps brachii (TB). pH measured at room temperature (t=18°C) 24 hours post mortem, was: for LD - 7.0 and for TB - 6.2

Modelling of mechanical processes was done on a special stand based on universal testing machine "TIRATEST-2200"(Germany). Loading of meat samples was done in automatic regime, according to cyclic programm of compression. Pieces of meat were compressed within 0.3-30N at the loading speed of 120mm/min. The testing programm consisted of 4 trials. At each trial 2 samples were tested - one from LD, the other from TB. Time of treatment for trial 1 was 100 cycles (20-25min.), for trial 2 - 200 cycles (40 min.), for trial 3 - 400 (80 min.) and trial 4 - 600 (120 min.). Sizes of samples were practically identical: 45 x 50 x 50mm.

To determine influence of cyclic loading on mechanical characteristics of muscle tissue, methods were applied, adopted in biopolymere mechanics. Mechanical testing was done for plotting of deformation diagrams: tension-deformation ($\sigma - \varepsilon$) under conditions of uniaxial

compression. After mechanical treatment from each piece of meat 7 samples of cylinder form were dissected(D=28mm, h= 15mm). Besides, control samples were used, obtained from pieces of untreated meat. In all cases samples were dissected perpendicularly to orientation of muscle fibers.

Trials were done on testing machine "TIRATEST-2200" at room temperature. Deformation rate was 100mm/min. According to experimental data dependencies load-deformation (P-E) were plotted, which were further grouped into family of curves for each experimental series. The obtained families of curves were subjected to statistical analysis, resulting in diagramms of deformation $\sigma-\varepsilon$ (Fig.1).

During structural analysis of muscle tissue methods of light-optic hystology were used. For microstructural study samples of muscle tissue were taken before and after mechanical treatment. Pieces of meat were dissected with the account of muscle fibers orientation. Experimental material was fixed in a 20% solution of formaldehyde, dehydrated and introduced into celloidin. Prepared cuts were coloured by hematoxylin-eosine and covered by polystyrene.

Besides quality analysis of microstructure method of scoring was applied to evaluate degree of structural changes in muscle tissue under influence of mechanical treatment. With the help of this method the following parameters were evaluated: state of nuclear formations in muscular and connective tissue cells, degree of muscle fibers loosening, degree of sinuousnus of muscle fibers, integrity of sarcolemma - degree of muscle fibers destruction.

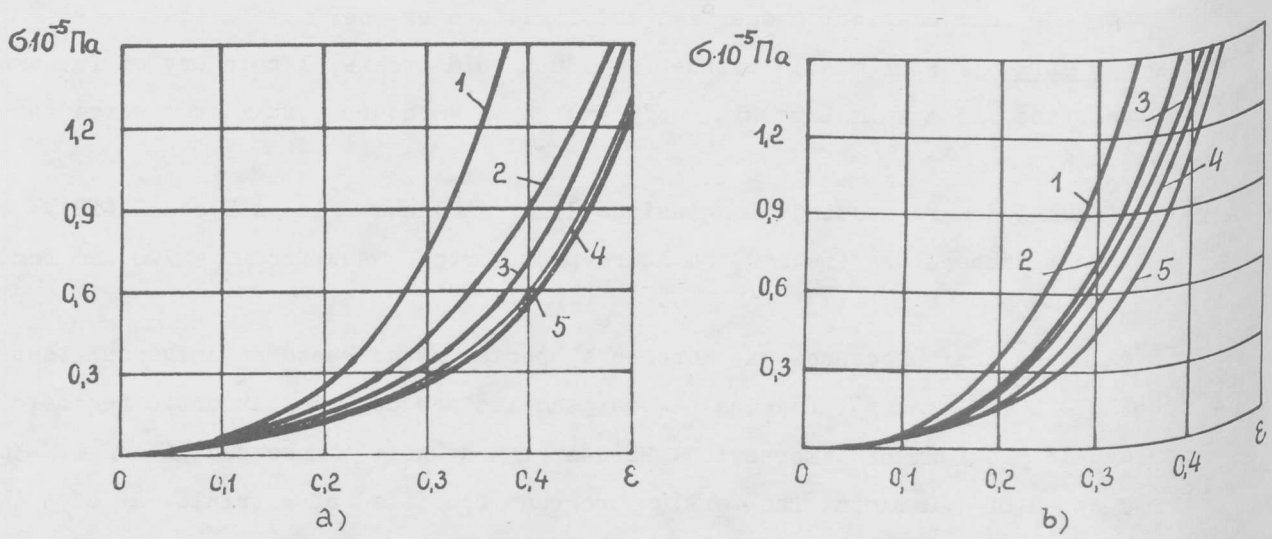
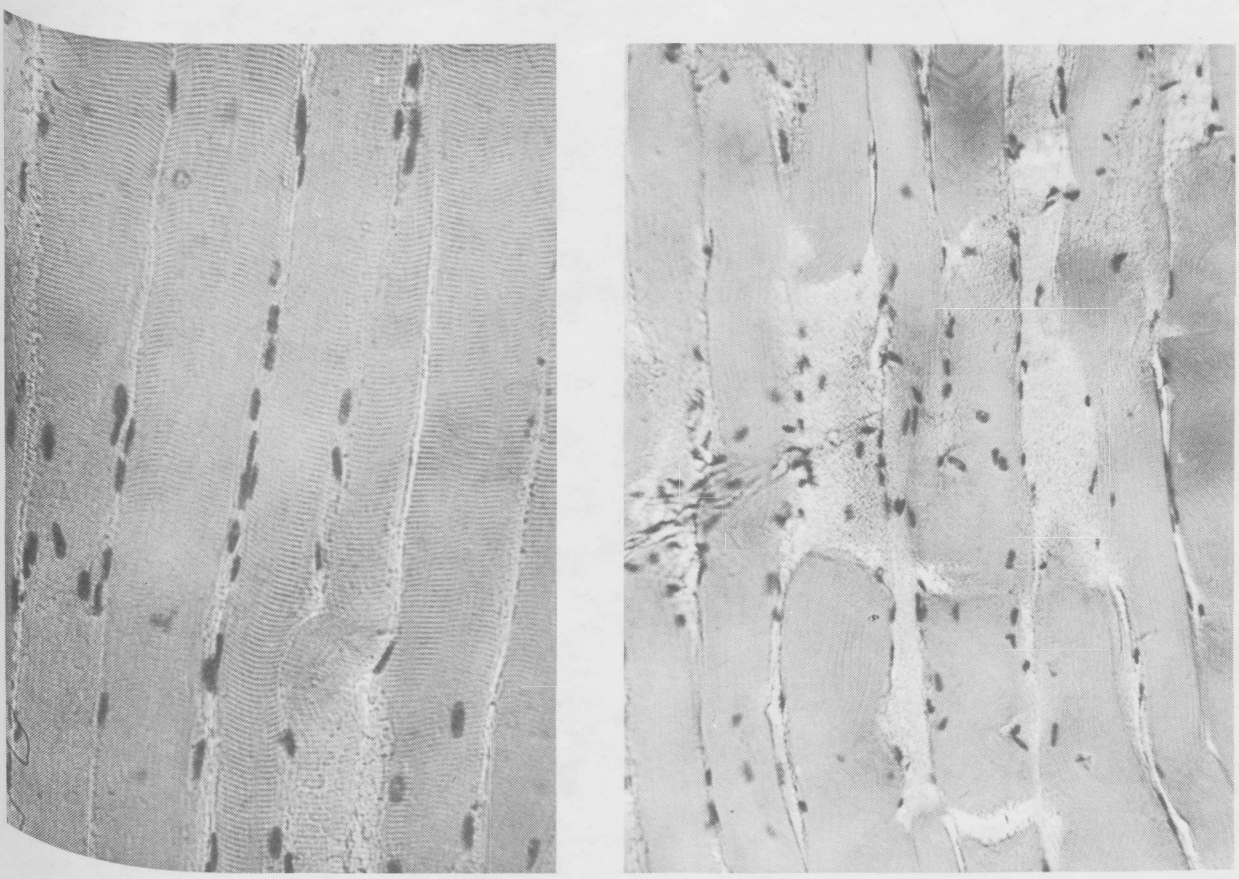


Fig.1. Deformation ($\sigma-\varepsilon$) diagrams of muscle tissue. a - LD muscle, b - TB muscle; 1 - control, 2 - 100 cycles, 3 - 200 cycles, 4 - 400 cycles, 5 - 600 cycles.

RESULTS AND DISCUSSION: Analysis of diagrams of deformation of LD and TB muscle tissue $\sigma-\varepsilon$, shown in Fig.1, enabled us to draw some conslusions. Firstly, irrespective of muscle type, character of mechanical treatment influence on deformation curves rests unchanged. Significant difference in rigidity of control and ezperimental samples is observed, that being in accordance with previous research data(Ivashov et al.,1985). Secondly, cer-

tain dependence of deformation curves on muscle type is evident. Diagrams $\sigma - \varepsilon$ of TB muscle are higher than for LD, this evidency about difference in their rigidity. It was shown that long treatment influences the studied quality microstructural characteristics of LD and TB muscle fibers. It was established that degree of destructive changes increase with increase of treatment time. Thus, in control samples of meat muscle fibers are dominating with expressed cross lines and limited number of zones with lengthwise lines (Fig.2a). Fibers preserve their integrity and show neither damage nor transversal splitting. After mechanical treatment with large number of cycles, numerous disruptures of fibers are observed, accompanied by transfer of sarcoplasmatic material to intercellular space and formation of granular mass. Cross lines are changed into lengthwise ones (Fig.2,b).

After scoring the following things were found out. Loosening of muscle fibers of LD gradually increases with prolongation of massaging. At the same time, during massaging of shoulder muscle, this loosening at first increase, then lowers a little and again increases in course of massaging. Degree of fibers sinuousness was different during experimental time, not showing any regularity for neither of the studied muscle. The state of nuclear formations in muscle fibers and connective tissue cells deteriorated slightly at maximal intensiveness of treatment. Damages of sarcolemma integrity accumulated in process of treatment, subjecting to strict regularity in LD and without any one in TB. Besides, changes took place earlier and were more intensive in surface layers of meat samples. In deeper zones these changes were observed after longer periods of treatment.



a) b)

Fig. 2. Microstructure of muscle tissue: a - control sample; b - sample after mechanical treatment (600 cycles)

CONCLUSIONS: It was established that time of mechanical treatment deeply changes mechanical characteristics of meat raw material. These changes are caused by destruction of structural formations in muscle tissue. Character of these changes differs showing dependence on meat structure and content of connective tissue in it. Correlation was established between microstructural changes and mechanics of muscle tissue behaviour during mechanical treatment of LD muscles. We failed to establish similar dependence for TB muscle.

Experimental methods were suggested for study of mechanical treatment processes, based on methods of polymere mechanics and hystological analysis.

Thus, it seems possible to create objective physical picture and mathematical model of tumbling and massaging processes, considering results of parallel research of mechanical properties and structure of muscle tissue, according to proposed methods.

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