Muscle protein structure and WHC of pre-rigor beef prior to and after electrical stimulation

ORESHKIN E.F., BORISOVA M.A., TASHPULATOV M.M. and BOLSHAKOV A.S.*

The All-Union Meat Research Institute, Moscow, USSR
*The Moscow Technological Institute of Meat & Dairy Industries, Moscow, USSR

At present meat manufacturers apply electric current to accelerate meat ageing (electrostimulation) /1,2/. Besides, there are reports on its feasible application to intensify curing process (electromassaging) /3,4/. The latter, however, has not become common, a reason of the insufficient use of electric current in the production of cured meats being our limited knowledge of the structural changes in muscle proteins and in protein/water binds which are consequences of electric effect and, to a greater extent, predetermine finished meats quality.

The purpose of the paper was to study the effect of electrostimulation (ES) upon pre-rigor protein structure and its water condition. To get information on protein structural changes, meat samples were studied with the protein intrinsic fluorescence method /5/. As test objects served longissimus dorsi muscles dissected from beef carcasses, grade II, 35 minutes after slaughter. The muscles were halved: one half was stimulated, the other was not stimulated (control). ES had the following parametres: stimulation time - $4.8 \cdot 10^2$s, voltage - 220 V, impulse duration - 0.6 s, impulse intervals - 0.4 s.

Fluorescent analysis of control and test (ES) samples were performed 2 hours after slaughter, the temperature of the samples being 32 ± 1.5°C. Fluorescence spectra were taken within the 20-90°C temperature range according to the procedure reported by Oreshkin E.F. et al. /6/.

The pattern of structural changes in the proteins was judged by the basic fluorescence parametres, i.e. the spectrum maximum position (λ), radiation quantum yield (S) and the contribution of the four classes of tryptophanyls (S, I, II and III) to the total fluorescence spectrum.

Our previous work demonstrated that beef meat fluorescence was entirely determined with that of actomyosin proteins /8/, therefore, below we shall discuss only these proteins.

Heat denaturation of meat is known to be accompanied with a number of structural transitions being changed as related to the condition of meat /6,7/. Thus, heat denaturation of non-stimulated pre-rigor meat is accompanied with six structural transitions in its proteins within the following temperature ranges: I - at 35-42°, II - at 42-52°C, III - at 52-62°C, IV - at 62-75°C, V - at 75-85°C, VI - at above 85°C (Fig. 1 a). Transitions I, IV,VI are of the coagulation type, i.e. twisting of modified meat protein chains, this being confirmed with a shift of the fluorescence maximum towards shorter wavelengths and with the predominating contributions of the tryptophanyls S and II to the total fluorescence spectrum. Transitions II, III, V are characterized with the development of the intrinsic denaturation process, i.e. loosening of the protein structure, this being reflected in a shift of the fluorescence maximum towards longer wavelengths and in the predominating contributions of tryptophanyls I and III(Fig. 1b).

The fluorescent pattern of the heat denaturation of ES pre-rigor meat is greatly different (Fig. 1a). There are here five structural transitions within the following temperature ranges: I - at 32-40°C, II - at 40-50°C, III - at 50-60°C, IV - at 60-72°C, V - at above 72°C. As fluorescence parametres indicate, however, in contrast to non-ES pre-rigor meat, transition IV is of the intrinsic denaturation, rather than of the coagulation type; at above 72°C, high-temperature coagulation is initiated which proceeds up to 90°C, i.e. a high-temperature coagulation zone, which starts only at above 85°C in case of non-ES pre-rigor meat (viz., at 72°C). Protein coagulation is known to precede denaturational changes in the course of which the links, stabilizing the native protein structure, are destroyed, the protein chains are untwisted, an additional number of charged groups appear on the surface, this predetermining interactions of their modified forms, i.e. coagulation. Fluorescent studies make it possible to find that ES induces this process at much lower temperatures and that it is localized mainly in the proteins of the actomyosin complex. Thus, we can assume that ES results in the "weakening", loosening the structural arrangement of pre-rigor meat proteins. In the present work, the pattern of changes in the state of ES pre-rigor meat water was followed by the dynamics of juice separation during heating from 20 up to 90°C of non-ES and ES beef meat. Juice separation was studied thermogravimetrically with a Q-derivatograph (MOM, Hungary), modified by Oreshkin and Borisova /9/. The analysis of the thermogravimetrical curves (TG) for beef weight losses indicated that juice separation occured as evaporated moisture and free-falling droplets (Fig.2).

A comparison of the TG-curves derived for non-ES pre-rigor beef (Sample 1) and ES beef (sample 2) makes it clear that intensive droplet-losses (DL) start in both cases, practically, at the same temperature, i.e. at about 65°C, though later quantitative characteristics of DL become different. The DL-curve of the non-ES pre-rigor beef can be conditionally divided into four zones, viz., 65-76°C, 76-83°C, 83-87°C and above 87°C, each being characterized with different DL-rates (0.7, 0.6, 1.9 and 0.3% / min., respectively).

The DL-curve for Sample 2 can be also divided into certain temperature zones but, in contrast to the DL-curve for Sample 1, there are only two such zones, viz., 65-81°C and above 81°C. The DL-rates within these temperature zones constitute 2.0 and 0.3% / min., respectively. Thus, within the temperature region up to 81-83°C the DL-rate for the ES-meat is nearly three times as high as compared to the non-ES-meat. It should be noted that within the whole range of meat heating from 20 up to 90°C both the DL-rate and the total weight losses for the ES-meat are much higher than for the non-ES-sample, though this difference

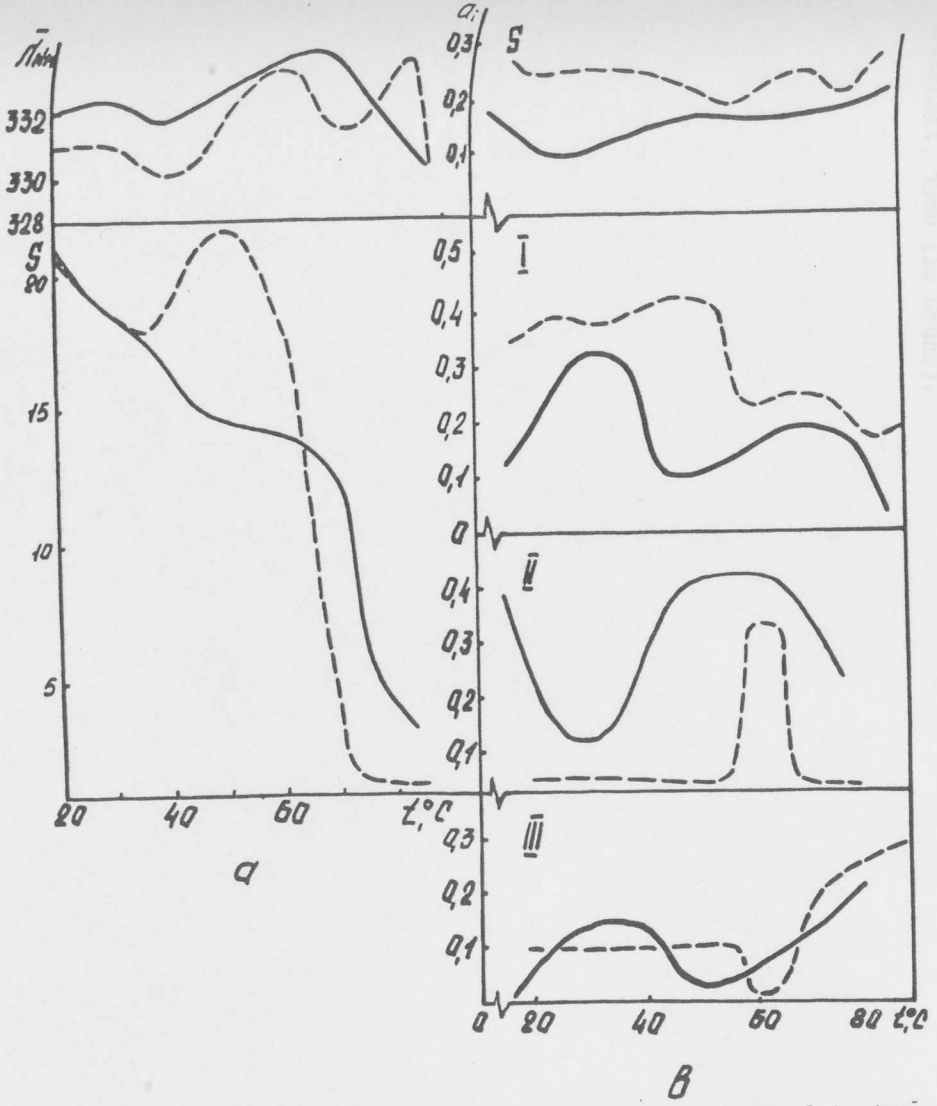

Fig. 1. The basic parametres of fluorescence as related to temperature: maximum position ( ), radiation emission (S), a contribution of the four forms of tryptophanyls (S,I,II,III) of pre-rugor meat to the total fluorescence spectrum prior to (- - - - -) and after(————) stimulation

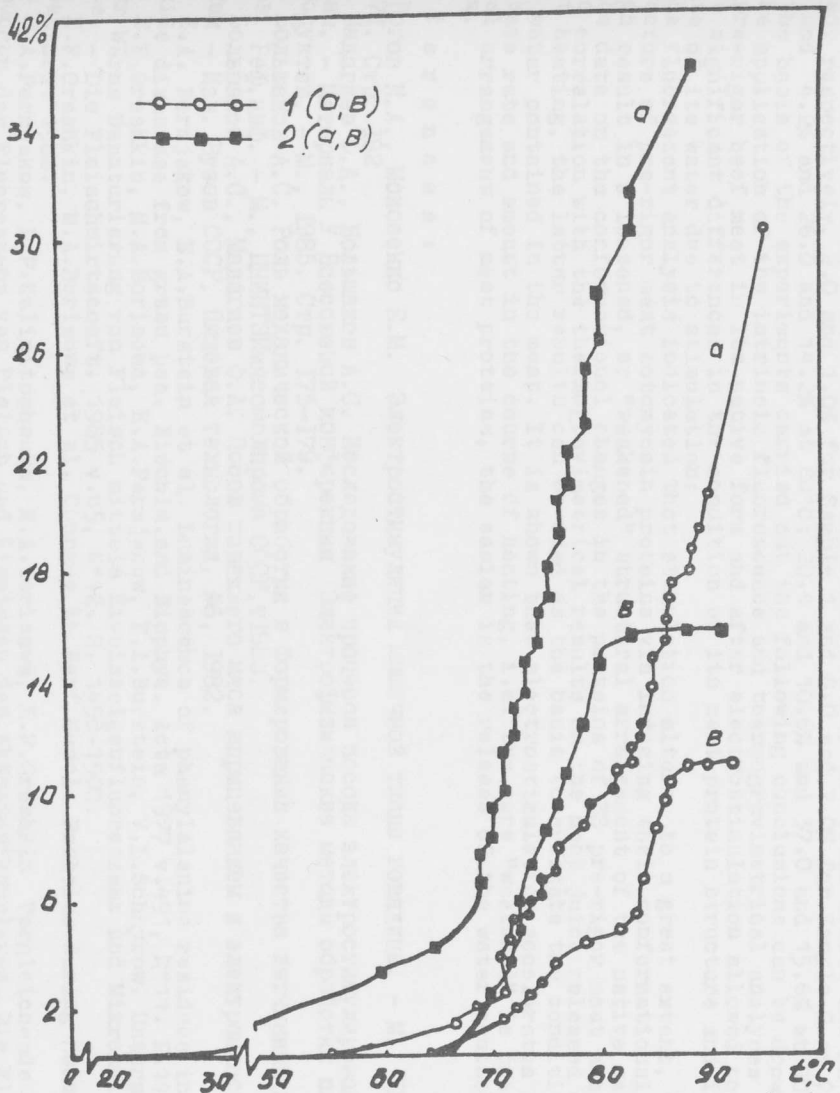

Fig. 2. Thermogravimetric curves of meat juice losses during heating pre-rigor beef prior to (0) and after ( ) stimulation:
a - total losses;
b - droplet losses.

becomes smaller with a higher heating temperature. Thus, the total losses and DL constituted, respectively, 2.0 and 1.0% for Sample 1 and 8.0 and 2.0% for Sample 2 at 70°C; 9.4 and 4.2% and 26.0 and 14.2% at 80°C; 20.4 and 10.6% and 37.0 and 15.6% at 90°C.

On the basis of the experiments carried out the following conclusions can be drawn:

- the application of the intrinsic fluorescence and thermogravimetrical analyses to study pre-rigor beef meat in its native form and after electrostimulation allowed to determine significant differences in the condition of its meat protein structure and in the state of its water due to stimulation;
- the fluorescent analysis indicated that stimulation alters, to a great extent, the structure of pre-rigor meat actomyosin proteins via inducing their conformational changes which result in a loosened, or "weakened" structural arrangement of the native meat;
- the data on the conformational changes in the proteins of ES pre-rigor meat are in a good correlation with the thermogravimetrical results on the meat juice released during meat heating, the latter results can be used as the basis to evaluate the condition of the water contained in the meat. It is shown that electrostimulation accelerates juice release rate and amount in the course of heating, i.e. the more "weakened" is the structural arrangement of meat proteins, the easier is the release of the water contacting them.

R e f e r e n c e s :

1. Рогов И.А., Моисеенко Е.М. Электростимуляция мышечной ткани говядины. - М., "Наука", 1971. Стр. 192
2. Мадагаев Ф.А., Большаков А.С. Исследование процесса посола электростимулированной свинины. - Материалы У Всесоюзной конференции Электрофизические методы обработки пищевых продуктов. - М., 1985. Стр. 175-179.
3. Большаков А.С. Роль механической обработки в формировании качества ветчинных консервов. Реф.инф. - М., ЦНИИТЭИмясомолпрома СССР, т1983.
4. Большаков А.С., Мадагаев Ф.А. Посол говяжьего мяса шприцеванием и электромассированием - Изв. Вузов СССР, Пищевая технология, №6, 1982.
5. E.A. Permjakow, E.A.Burstein et al. Luminescence of phenylalanine residues in superoxide dismutase from green pea. Biochim.and Biophys. Acta 1977 v.491, N°11. P.149-154.
6. E.F.Oreshkin, M.A.Borisowa, E.A.Permjakow, E.A.Burstein, V.L.Schnyrow. Untersuchungen zur Wärme Denaturierung von Fleisch mittels Eiweisseigenfluoreszenz und Mikrokalorimetrie. - Die Fleischwirtschaft. 1985 v.65, N°12. S. 1498-1500.
7. E.F.Oreshkin, M.A.Borisowa et al. Changes in Beef Muscle Proteins during Heating. - Meat Sci. 1986.
8. E.A.Permjakow, L.P.Kalinitschenko, M.A.Borisowa, E.F.Oreshkin Vergleichende Untersuchungen der Fluoreszenz von Fleisch und Eiweissen des Aktomyosikomplexes. Die Fleischwirtschaft, 1986 (im Druck).