Microstructural changes during the mechanical and heat treatment of pork in the accelerated production of ham

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Introduction

The substitution of traditional methods by modern technologies affects the quality of foods (Schingnitz and Hildebrandt, 1985). The physical treatment of meat applied widely in the manufacture of heat processed hams contributes to the more uniform distribution and penetration of injected brines among muscle fibres and myofibrils, the extraction of greater quantities of myofibrillar proteins and the formation of a protein-salt extract playing a substantial part in the binding of the individual meat pieces and the formation of a quality product. The methods used demonstrate a vast variety: massaging and tumbling (Theno et al., 1978a,b,c; Krause et al., 1978), vacuum treatment and sound vibration (Zayas, 1981), vibromassaging (Strupin, 1981), electromassaging (Bolshakov et al., 1983).
Zeuthen (1984), in a review of some current trends in the technology of meat products, pointed out that mechanical treatment in ham manufacture had been extended to include a tenderizing treatment. The principle consists in that raw materials are passed through a machine equipped with rollers or movable stable needles.
Moticka and Bechtel (1983) tenderized mechanically brine-injected meat by its passing through two horizontal parallel rollers, on each of which 65 blades were mounted at a 5 mm distance. Scheid (1985) applied pressing of the meat pieces before or after brine injection between ribbed rollers in combination with tumbling.
The tenderization of meat chunks in Langen type B 120/13/N/J and B 120/4/N/J tumblers is effected in the course of tumbling by their falling on to a system of needles.
The diversity of the pieces of equipment used and the parameters of the mechanical treatment of meat on the different meat processing premises requires the development of objective methods of controlling and determining optimum operation regimes. Belousov et al. (1980) found that, among the physico-chemical, organoleptic and microstructural changes occurring upon the mechanical treatment of meat, a definite interrelation existed, allowing the objective assessment of tenderization, by microstructural indices.
With the present investigations, we aimed to study the effects of massaging and tumbling on the micro- and ultrastructure of pork and to use the microstructural changes that set in, for the objective assessment of the extent of the mechanical treatment applied.

Experimental

Materials and Methods

The experiments were conducted under industrial conditions. Chilled pork was injected with brine using a multi-needle injector and subjected to mechanical treatment as follows: (1) massaging for 14 hours with an active massaging time of 210 min in rectangular vats without vacuum; (2) tumbling for 4 hours with an active tumbling time of 120 min in cylindrical Laska type vats under cvacuum; (3) brine injection and tumbling for 14 hours with an active tumbling time of 150 min in a complex Langen type line.
Light microscopy studies were made using samples taken before and after curing and tumbling and after heat treatment. Blocks of dimensions of 0,5 x 0,5 x 0,5 cm were frozen in isopentane pre-chilled in liquid nitrogen, and cut using a Minotome cryostat, made in USA. Sections of a thickness of 10 microns stained with hematoxylin-eosin and with picroponso S, were observed using a Docuval - Carl Zeiss microscope, made in the GDR.
Electron-microscopic studies were made on blocks sized 1 x 1 x 2 mm, which, after conventional treatment, were embedded in durcupan. Ultrathin sections made using an LKB-III ultramicrotome and stained (contrasted) after Reynolds (1963) were observed using a Tesla BS 613 electron microscope at 80 kV.

Results and Discussion

The histological pattern of cooled meat before curing and mechanical treatment (Fig. 1) shows that muscle fibres are of a polygonal form and are surrounded by bright spaces dividing them from one another. Wider bright bands form the boundaries of individual muscle bundles. In the electron micrograph (Fig. 2) it can be seen that myofibrils are located rectilinearly, parallel to each other, and are divided by different width spaces of brightened sarcoplasm. I- and A-sectors, H-zones, M and Z-lines are well distinguishable and of a preserved integrity. In mitochondria, some swelling and destruction changes have occurred in the mitochondrial membranes and cristae.
In the process of mechanical treatment, injected brines have penetrated deep into the muscle pieces and, under their action, substantial microstructural changes have occurred. Muscle fibres have swollen and acquired a more or less pronounced rounded shape and bright spaces among them are reduced to a different extent (Fig. 3). In some places, they are closely adhering to one another and their boundaries are outlined, to a definite extent, by their nuclei (Fig. 4). Among muscle fibres and in the perimysium, a fine granular mass can be observed, made of coagulated protein-salt exudate (Fig. 5).
Injected salt solutions and the mechanical treatment of the meat pieces have also induced strongly pronounced ultrastructural changes. Myofibrils are swollen to such an extent that they are closely sticking to one another and bright sarcoplasmatic spaces have completely disappeared. M-lines are not outlined and H-zones are represented by wide optically dense bands. Z-lines are fragmentary and aside of them, parallel thin optically dense dark bands have formed. The canals of transversal tubules are expanded. In the middle of some A-sectors, myosin

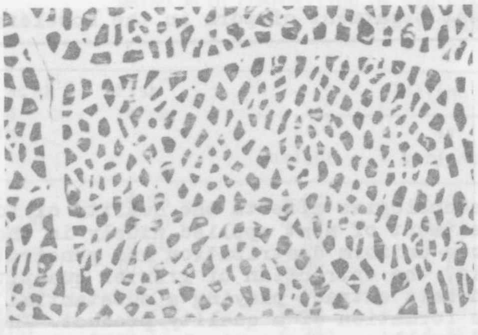

Fig. 1. Cross section of chilled pork prior to brine injection. (x 20)

Fig. 2. Longitudinal section through part of a muscle fibre from chilled pork before brine injection. (x 4750)

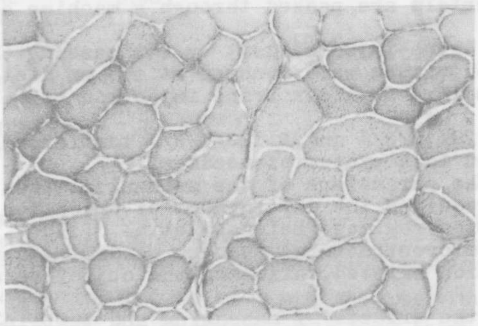

Fig. 3. Cross section of muscle from finished ham. Coagulated protein exudate among muscle fibres. (x 50)

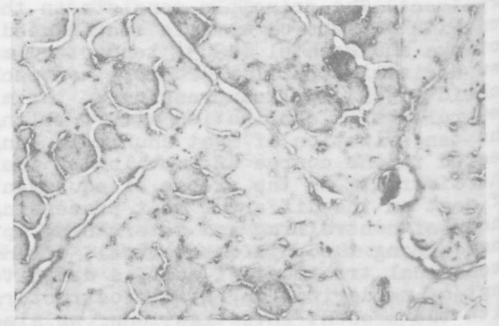

Fig. 4. Cross section of muscle after tumbling. Pronounced swelling of muscle fibres and obliteration of boundaries among them. (x 50)

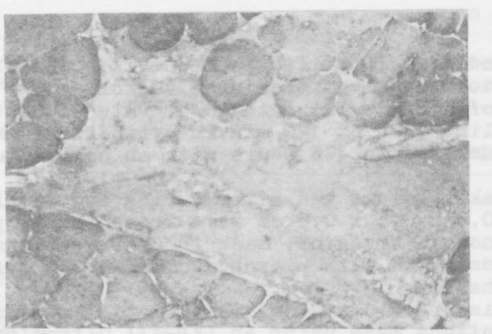

Fig. 5. Cross section of muscle from finished ham. Fine granular mass of coagulated protein in the perimysium. (x 80)

Fig. 6. Longitudinal section through part of a muscle fibre after tumbling. Destructive changes in some A- and I-disks. (x 10000)

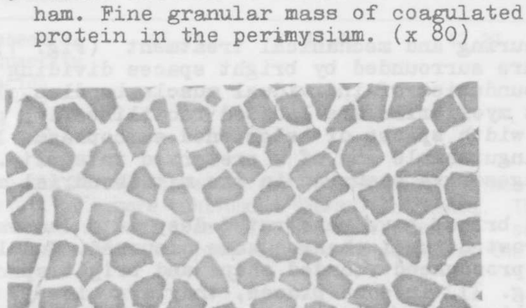

Fig. 7. Cross section of muscle from finished ham. Preservation of the polygonal form of muscle fibres and bright spaces among them. (x 50)

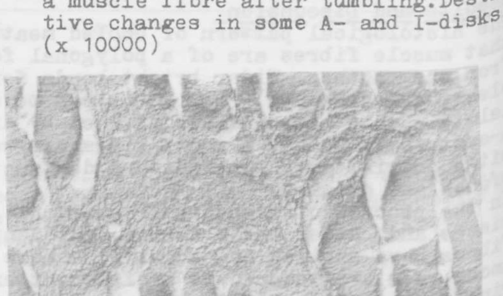

Fig. 8. Longitudinal section of muscle from finished ham. Destructive changes in muscle fibres following injected brine. (x 50)

protofibrils are severely torn and, to a certain degree, salt-extracted and those places appear as wide bright spaces. We believe that these changes are the result of the comparatively better penetration of brine, which has exerted an extraction effect on myosin protofibrils. Undoubtedly, mechanical treatment itself has also played a positive part (Fig.6).
The microstructural and ultrastructural changes described are due unquestionably to both the effects of salt and polyphosphate, and the mechanical treatment. The mechanism of salt and polyphosphate action on meat structure has been thoroughly treated of by Offer and Trinick (1983) and Voyle et al. (1984).
The mechanical treatment of meat pieces in the presence of sodium chloride and polyphosphate results in the formation of a sticky exudate on their surface (Theno et al., 1978 a,b,c; Schmidt and Trout, 1982). That exudate contains myofibrillar proteins, mostly myosin. These proteins coagulate upon heat treatment and bind the individual meat pieces. For that reason, the conditions under which these proteins are extracted, are of substantial importance (Voyle et al., 1984).
Given a good knowledge of the microstructural and ultrastructural changes occurring upon the mechanical treatment of meat pieces in the presence of salt solutions containing sodium chloride and polyphosphates, it is possible to form criteria for objective assessment. We feel that these criteria can be summarized into three degrees: insufficient, optimum, and overoptimum mechanical treatment.
Insufficient mechanical treatment of the raw material. It is characterized by the following peculiarities in the microstructure of muscle fibres: deep into the muscle pieces, muscle fibres have preserved, to a considerable degree, their polygonal form and are divided from one another by bright bands; their swelling is insufficient and there is hardly any protein-salt extract among them (Fig. 7); an uneven distribution of salt solution is found, with severe destruction changes under its action and a preservation, in some places, of the cross striation of muscle fibres (Fig. 8); on the ultrastructural level, an insufficient swelling of myofibrils is found owing to a weak penetration of salt solution into muscle fibres (Fig. 9); tenderness and the water-holding capacity of the meat product are improved insignificantly at this degree of mechanical treatment.
Optimum mechanical treatment. It is characterized by the following: a significant swelling of muscle fibres, loss of their polygonal form, a considerable amount of protein-salt extract found among them and in the perimysium (Fig. 5); in individual fibres, in some places myofibril destruction is observed and a formation of a finely-granular protein mass, located both inside and among the muscle fibres. Using electron microscopy, a pronounced swelling and close sticking of myofibrils is observed, a fragmentation of protofibrils and extraction of parts of them (Fig. 6). The fragmentation of protofibrils contributes to the increase in the number of free bonds which can hold additional amounts of water.
Overoptimum mechanical treatment of the raw material. It is characterized by considerable de-

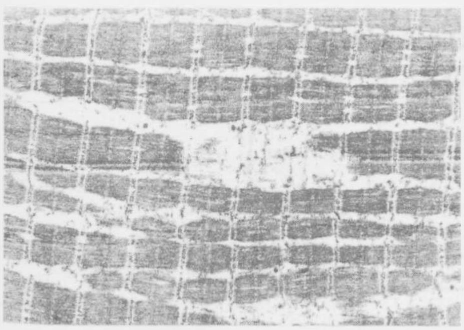

Fig. 9. Longitudinal section through part of a muscle fibre from finished ham. Myofibrils are not sufficiently swollen. (x 4750)

Fig. 10. Longitudinal section of muscle from finished ham. Strongly pronounced destructive changes along the length of muscle fibres. (x 50)

structive changes in muscle fibres and the conversion of big sections within them into a finely granular protein mass (Fig. 10).

Conclusions

(1) The mechanical treatment of meat in the presence of sodium chloride and polyphosphates induces definite micro- and ultrastructural changes in muscle fibres, on the basis of which, microstructural criteria can be formed for the assessment and control of mechanical treatment and the technologies applied, in terms of three degrees: insufficient, optimum, and overoptimum.
(2) The multiple sticking of meat pieces by a system of needles in the process of tumbling causes additional disruption of muscle fibres and increases the quantity of extracted myofibrillar proteins. This has a positive impact on tenderness and the binding of the individual muscle pieces in the finished product.

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