

# Food Structure

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Volume 9 | Number 2

Article 3

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1990

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### Recommended Citation

Velinov, P. D.; Zhikov, M. V.; and Cassens, R. G. (1990) "The Effect of Tumbling, Sodium Chloride and Polyphosphates on the Microstructure and Appearance of Whole-Muscle Processed Meats," *Food Structure*: Vol. 9 : No. 2 , Article 3.

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THE EFFECT OF TUMBLING, SODIUM CHLORIDE AND POLYPHOSPHATES ON THE MICROSTRUCTURE  
AND APPEARANCE OF WHOLE-MUSCLE PROCESSED MEATS

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Abstract

The properties of a whole-muscle processed meat were determined. The complex action of sodium chloride, polyphosphates and mechanical agitation caused extraction of myofibrillar protein, swelling of fibers and loss of cross-striations. A new functional ability was found for the extracted proteins to form a fine cover or membrane on the surface of the whole muscle during cooking. These changes produced a product with improved cooking yield and color appearance.

Introduction

Microscopical studies of processed meats have concentrated on two areas -- the structure of the so-called emulsion in products such as frankfurters and the structure of the protein matrix which binds together the pieces of meat in restructured products. In the former area, initial investigations elucidated the structure as being a dispersion of fat droplets embedded in a protein matrix (Hansen, 1960; Borchert et al., 1967; Schmidt, 1984). Subsequent work has been focused on relating quantitative measurements of the fat droplets to properties of the final product (Cassens and Schmidt, 1979; Hermansson, 1987), and interest continues in using microscopy of the raw emulsion as a predictive or quality control technique during the manufacturing process.

In regard to restructured products, effort has focused on the extraction and functionality of the muscle proteins as affected by mechanical agitation and composition of the added brine (Theno et al., 1978a). Theno et al. (1978b) have described the protein matrix at the interface of bound pieces of meat as being emulsion-like.

In Bulgaria, there are special meat products made from whole, intact muscles. These are made by incorporating a brine and then subsequently heating and smoking. Our objective was to study the internal microstructure and the surface characteristics of these products and to compare traditionally made products with products which had an improved brine composition and also received a period of mechanical agitation during manufacture. The aim was to determine if the complex action of the improved brine and mechanical treatment had an effect and if so if it could be used to improve the technological process.

Materials & Methods

The experiments were conducted on pork muscle from animals with a live weight of 100 to 110 kg. Thirty-five animals were slaughtered in the usual manner and the muscles were checked to insure they fell within the normal range of pH (5.5 to 6.0) and did not exhibit either pale or dark appearance. Longissimus dorsi muscles were

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Initial paper received November 21, 1989  
Manuscript received May 13, 1990  
Direct inquiries to R.G. Cassens  
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Key Words: Muscle, Mechanical Treatment, Processed Meat

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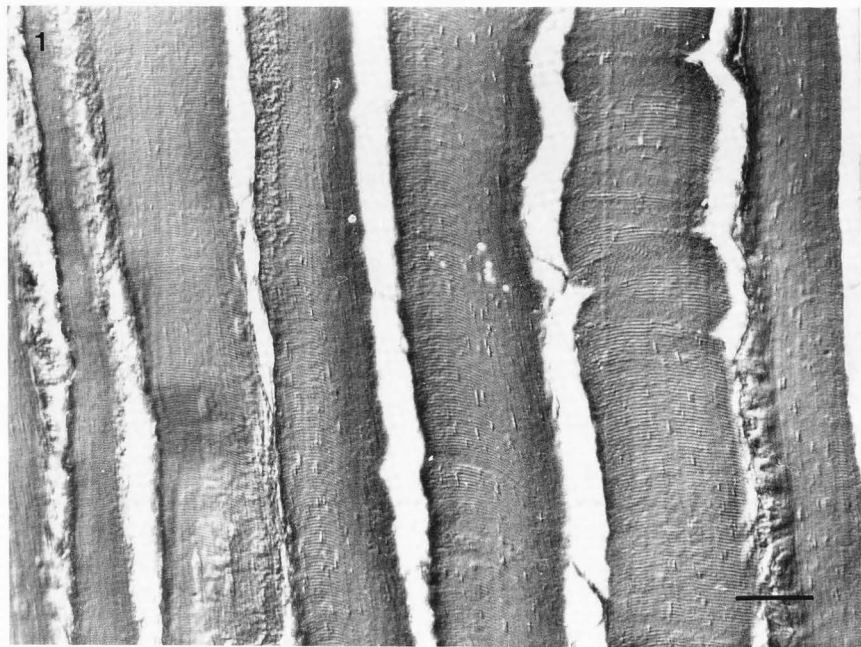


Figure 1: Microstructure of control muscle showing normal shrinkage and good preservation of banding pattern. Scale bar is 25 $\mu$ m.

removed intact from both sides of the carcass following 24 hr. of chilling at 4°C. The muscles from the left side of the carcass served as controls and those from the right side were treated.

The control muscles were immersed in brine for 5 days. The brine was a typical 15° brine prepared with 160 L of water, 30 kg sodium chloride, 0.8 kg sucrose, 0.6 kg sodium nitrite and 0.4 kg sodium nitrate.

The treated muscles were manufactured in a complete, complex line made by "Langen" of Holland. The injection of the muscles took place directly in the tumbling apparatus during a period of 30 minutes with a calculated brine uptake of 12%. In this case, the brine was made from a commercial preparation and contained sodium chloride, polyphosphate, sodium nitrite and sodium nitrate. The tumbling process took place under vacuum and over a 24 hr. period. Active tumbling was done intermittently for a

total of 150 min during the 24 hr.

All muscles were processed (at 85-90°C) to an internal temperature of 72° in a smokehouse with natural wood smoke. The muscles were chilled for 12 hr following removal from the smokehouse.

Frozen sections of muscle were prepared and stained with hematoxylin and eosin or with picric ponceau S. Sections were examined with a Zeiss microscope using interference optics. Color characteristics of the cut surface of the products were determined spectrophotometrically, and a visual assessment of the surface of the uncut whole muscle was made.

#### Results and Discussion

The microstructure of the control and treated samples is illustrated in Figures 1 and 2 respectively. The control muscle appears essentially normal. The interfiber spaces are apparently empty, and the fibers show cross

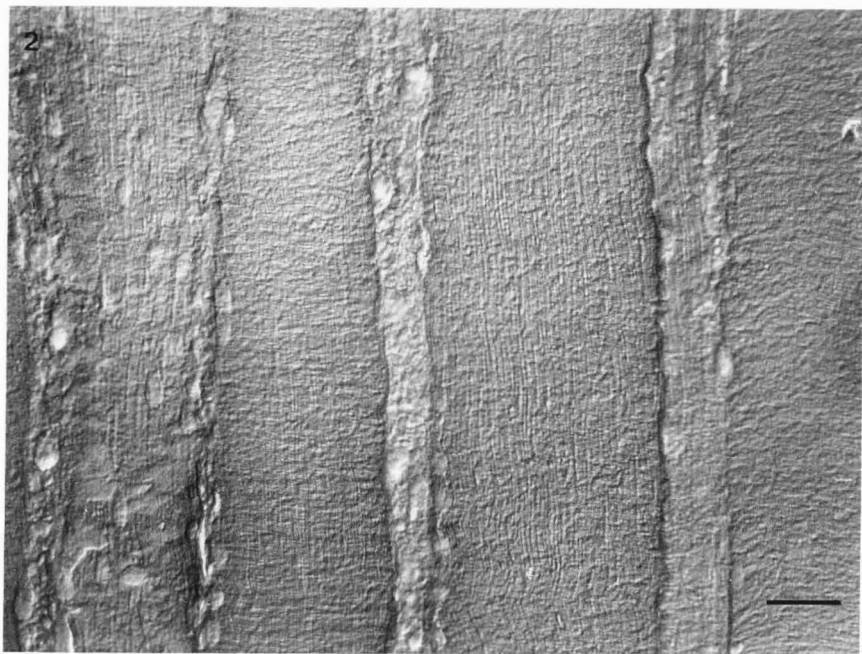


Figure 2: Microstructure of treated muscle showing swollen fibers, loss of striation and filling of intrafiber spaces. Scale bar is 25 $\mu$ m.

striations except in a few focal areas. On the other hand, the microstructure of the treated muscle is quite different. The fibers appear swollen and the cross striations are, for the most part, absent. In addition, the interfiber spaces appear to be filled with a substance which we concluded is extracted and coagulated protein.

It is apparent from the micrographs that the multi-needle injection and mechanical agitation of tumbling resulted in good distribution of brine in the treated samples. Further, the brine components (sodium chloride and polyphosphates) were then able to exert their extractive capabilities with the result that the structure of the muscle was partially disintegrated and the proteins brought into solution were able to move about within the framework of the remaining muscle. As a result of heating, the proteins were coagulated in the interfiber spaces.

In addition, the extracted proteins also found their way to the surface of the whole

Table 1. Effect of tumbling on color appearance and cooking loss.

	Treated	Control
Calculated "a" value <sup>1</sup>	19.4	15.4
Cooking yield in %	79.4	72.3

<sup>1</sup> Higher "a" value indicates redder color.

muscle. The structure of the coagulated protein at the surface resembles that of an emulsion. Objective measurement of the cut surface (Table 1) revealed that the treated samples had a more pronounced red color while the controls were less intense red and were lighter in appearance. Visually, the treated whole muscle had a darker red color. The coagulated protein layer on the surface obviously affects the color appearance.

The color difference observed may also be influenced, in part, by the observation that the intracellular spaces in the treated samples are filled with coagulated protein, and, in all likelihood, there is less free water present. The surface layer of coagulated protein may also play a role in shelf life stability of the treated samples.

The complex action of sodium chloride, polyphosphates and mechanical action resulted in the structural changes discussed above and affected cooking yield (Table 1). The higher cooking yield of the treated samples is due to the swollen fibers and the extracted protein which is more or less dispersed throughout the structure of the muscle. This, together with the surface layer of coagulated protein functioning to hold the water within the muscle during cooking.

Offer and Trinick (1983) concluded that changes in the volume of myofibrils affected meat color and cooking yields. Schmidt (1984) pointed out that swollen meat tissue has an enhanced ability to retain fat and water during heat processing. Lewis et al. (1986) concluded that increased yields are generally associated with increased dispersion of myofibrillar proteins.

In our case, the more efficient injection of the improved brine coupled with mechanical agitation resulted in a product with more attractive color and less cooking loss. The procedure is used now in commercial production.

#### Acknowledgements

The work reported here formed a portion of the Doctorate of Science thesis of P. D. Velinov entitled "Morphological Studies of Meat Products: The Effects of Proteases and Physical Treatment on Improving Processing Procedures and Quality Control". This process is a portion of innovation number 39326 of The INRA of Bulgaria. Appreciation is expressed to E. Atanasova for technical assistance.

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#### Discussion with Reviewers

S. H. Cohen: What is meant by a complete, complex line?

Authors: In this system, the injection and tumbling steps are combined. The tumbling apparatus contains injection needles and as the meat pieces are tumbled the needles pierce into the meat and achieve a better distribution of brine.

S. H. Cohen: Could the authors explain what the cross striations are?

Authors: The cross striations we refer to are the alternating dark and light bands, known respectively as A and I bands, in skeletal muscle as viewed in longitudinal section.

S. H. Cohen: How might the surface layer of coagulated protein affect shelf life stability?

Authors: We believe the surface covering or membrane may present a physical barrier to bacterial invasion and spoilage, and it may also retard oxidative changes.

A. M. Hermansson: It appears from the figures that the sample may have cracked during preparation. What were the conditions for freezing and sectioning?

Authors: The samples were frozen in isopentane precooled in liquid nitrogen and then sectioned at -20° C in a cryostat.

A. M. Hermansson: How do the authors know that the intrafiber spaces are filled with extracted and coagulated protein? This material may as well consist of partly melted collagen. How have myofibrillar proteins been differentiated from collagen/gelatin?

Authors: We concluded the intrafiber spaces in the treated muscle were filled with protein because of the staining density in the micrograph compared to the apparent absence of staining in the intrafiber spaces of the control muscle. We do not have any information about the exact composition of the proteins in question.

A. M. Hermansson: It is not apparent from one micrograph showing part of three fibres that there is a good distribution of brine in the heat treated sample.

Authors: Many more micrographs supporting our contention are shown in the thesis of Velinov.

A. M. Hermansson: What were the criteria for the resemblance of the surface structure to that of an emulsion? A micrograph is needed to show details of this structure.

Authors: The concept of using proteins, extracted by mechanical working of meat in the presence of a brine, as a binding agent in

restructured products is well known, and the references we cited by Theno et al provide structural details. Again, the thesis by Vellinov provides detail found by employing light, polarized light, interference and transmission electron microscopy.

G. W. Offer: The treated muscles differed from the controls, not only in the way the brine was introduced into the meat and in being tumbled, but in the chemical composition of the brines used. The brine used with the injected and tumbled samples contained polyphosphate, that used for the control muscles did not. We have shown (Voyle, C. A., Jolley, P. D., Offer, G. W. 1984, Food Microstructure 3, 113-126) that in the presence of polyphosphate the A-bands of muscles treated with brine are disrupted even in the absence of mechanical agitation. It is well known that polyphosphates enhance the solubilisation of myosin and reduce cooking losses, probably by forming a myosin gel which traps water (see Offer, G. & Knight, P. In : Developments in Meat Science-4 (Lawrie, R. ed.) Elsevier Applied Science pp 63-71). Is it not possible that the difference in appearance between the injected and tumbled samples and the control samples was largely due to differences in their chemical treatment rather than to differences in their mechanical treatment?

Authors: The basis for our work was to compare two different technologies under actual commercial manufacturing conditions. We used structural studies as one means to determine quality of the products produced. In Bulgaria, we need such information for improving old technologies and creating new and better products. So, our work was not conducted in a laboratory or using a model system but rather in a plant where we compared an older procedure with one combining new and advanced technologies. It is quite apparent that the information now available (ie effect of polyphosphates and mechanical agitation) does indeed give vast improvement in the resulting products.

H. J. Swatland: What apparatus was used for reflectance spectrophotometry and how were the "a values" calculated?

Authors: These studies were carried out with a Beckman DK2 with reflectance curves collected within the wave length range 550 to 750 nm. The color determination was conducted with the Y-axis selected method (BDS 10537-72) for 10 wave lengths within the range of the indicated scope. For calculations, we used the color difference formulas CIELAB as recommended by the International Lighting Committee.