

# THE ELECTROHYDRAULIC METHOD FOR MEAT TENDERIZATION AND CURING

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## Abstract

The paper examines the problem of meat raw material curing in production of whole-piece meat products. The intensification methods for the process of penetration and distribution of curing ingredients throughout a product are described. Design of the equipment for meat tenderization URM-1 and URMP-1 is proposed, which ensure electrohydraulic tenderization of the structure of whole-piece (1500–2000 g) and portioned (80–120 g) meat semi-finished products and accelerate a process of brine distribution, which will allow reducing product strength characteristics by 51–53 kg/cm, reducing raw material losses, increasing labor productivity by 8–11%, shortening the duration of the technological process and reducing energy expenditure upon heat treatment by 18–20%. As a result of the experimental investigations, it was established that an electrohydraulic impact (frequency of pulses  $\nu = 0.5\text{--}1.0$  pulse/sec., number of pulses from 150 to 200) can be used for tenderization of muscle connective tissue and tendons both of chilled (core temperature of 0 °C to 4 °C) and subfrozen (–2 °C to 3 °C) meat.

## Introduction

Due to their palatability and nutritional quality, whole-piece semi-finished products are in great demand among the population. Prime cost reduction and assurance of required quality are important requirements for producers and consumers of such products. The development of new technologies will allow increasing output and broadening an assortment of semi-finished products.

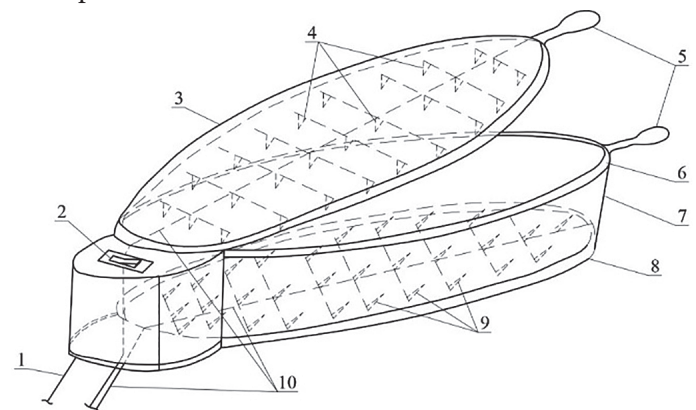
Taking this into consideration, the authors developed a technology of meat semi-finished products in pieces treated in brine by the electrohydraulic method. Raw material curing is one of the most complex and durable technological processes when producing whole-piece products. During curing, mass exchange takes place in the system brine-meat between curing ingredients and meat components. To accelerate mass transfer and improve functional-technological properties of meat raw materials, different intensification methods for the curing process are used: biochemical, physical, mechanical and acoustic [1,2,3,4,5]. Analysis of publications on this question also indicates the use of electrophysical and physico-mechanical methods of meat treatment [6,7,8]. Methods based on pulsed energy impacts can be promising for accelerating the process of meat raw material curing [9,10].

The aim of the work was to create equipment for electrohydraulic tenderization and curing of whole-piece products and develop technological parameters of processing.

## Materials and methods

Meat from pork, beef and mutton shoulder and reindeer loin was used as objects of research. To process portioned pieces with a weight of 0.08–0.12 kg, we used the

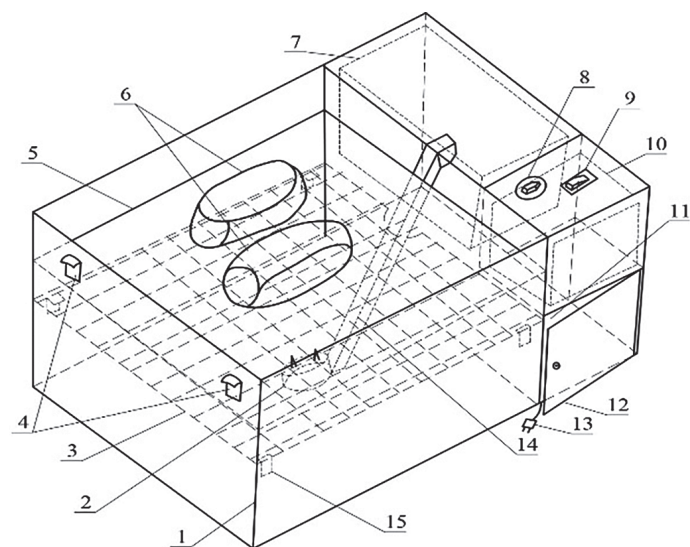
URM-0.1 unit (Figure 1) [11,12,13,14,15,16,17,18,19], which works as follows. Samples are placed into the body 7 of the unit; the electrodes 9 located at its bottom penetrate the tissue structure at a depth of 3–5 mm. Then, the cover 3 is closed up to the tight contact with the skirt 6, which allows electrodes 4 to penetrate the structure of a semi-finished product from the top to the depth of 3–5 mm. Using the switch 2, electric energy is supplied and the source of pulse voltage is made operational. Discharge pulse comes to the electrodes by the pulse buses 10. A spark occurs inside a semi-finished product and discharge pulsed treatment takes place.



**Figure 1.** A scheme of the unit for meat tenderization URM-1: 1 — grounding; 2 — switch; 3 — cover; 4, 9 — electrodes; 5 — handle; 6 — skirt; 7 — body; 8 — base; 10 — pulse buses

The URMP-1 unit (Figure 2) was used to process large pieces (1–1.5 kg). Semi-finished products were placed on the grid 3, which was put into the container 1 and covered with brine. High voltage pulses that created discharges in brine were applied to discharge contacts, which resulted in

their distribution from the cavity to the grid and a product, where they lost their energy. This ensured appearance of a mechanical impact, which tenderized tissue and significantly accelerated penetration and distribution of brine throughout a meat piece.



**Figure 2.** A scheme of the unit URMP-1 for tenderization of whole-piece meat semi-finished products: 1 — container; 2 — discharge contacts; 3 — grid; 4 — hinges; 5 — brine; 6 — whole-piece meat semi-finished products; 7 — high-voltage transformer; 8 — timer; 9 — switch; 10 — surge current generator; 11 — storage place for wires; 12 — door; 13 — electric wires; 14 — conductor; 15 — fastener

Technical characteristics of the URM-1 unit for meat electrohydraulic tenderization and curing: voltage 220–230 V, current 1 A, power 450 W, current frequency 50 Hz. Technical characteristics of the URMP-1 unit:  $VWCh = 0.1 \text{ m}^3$ , voltage 15 kV, current 1 A, power 1 kW, current frequency 50 Hz.

URM-1 is used for portioned semi-finished products with treatment duration of 5–7 sec. and discharge interval of 20–30  $\mu\text{s}$ .

For a large piece, URMP-1 is used with treatment duration of 2–3 min., discharge interval 30–50  $\mu\text{s}$ , spark speed 4300 m/s.

## Results and discussion

The proposed method for tenderization of intramuscular and intermuscular connective tissues and muscle fibers uses the impact of electrical discharges (an electrohydraulic impact — EHI), that occur in the inner layers of a product with a frequency of  $f = 50 \text{ Hz}$  and duration of 20–30  $\mu\text{s}$ . This facilitates sharp expansion of liquid in a semi-finished product and development of a gas channel that ensures the first hydraulic impact. The channel is closed under an effect of elasticity of water and meat muscles, then the second EHI takes place and so on. With that, the pressure in the discharge area and at a distance of 1.5–2 cm reaches a few tens of  $\text{kgf/cm}^2$  and more.

Each following electrical discharge increases tissue destruction. With that, there is an increase in a number of free surfaces (concentrates of energy), where breaking

strain and rupture of the tissue structure occur upon reflection of falling shockwaves. At constant generation of a series of electrical discharges, each preceding discharge creates additional free planes as a result of tissue rupture creating new slots. As a result, a degree of using the energy of voltage waves increases more and more, and resistance of connective tissue inclusions decreases. Muscles of the internal structure of a semi-finished product are dislocated to a distance of 3–8 mm. Strength characteristics of a meat semi-finished products are reduced.

It is necessary to note that released energy from EHI is selective to the places with increased strength of meat tissues, which ensures meat tenderization [21,22,23,24,25,26,27,28,29].

The developed method realizes the effect of the electrohydraulic impact that ensure accelerated penetration and distribution of curing ingredients throughout a product due to loosening the structure of meat tissues [17,18,19,29,30,31,32,33,34].

As publications [21,22,23] show, the proposed method reduces drip losses, increases assimilability of meat products due to disruption of protein bonds and extension of intercellular space, improves structural-mechanical properties of products with a simultaneous increase in product stability to the development of microorganisms (in raw materials and finished products).

Figure 3 presents the parameters and technological scheme of producing cured meat semi-finished products using URM-1 and URMP-1.

The technological process includes the following operations: preparation of initial meat raw materials and brine. Thawed or chilled half-carasses are trimmed, divided into cuts and deboned; large piece semi-finished products and portioned semi-finished products are separated. When processing bone-in products, a cut is divided into pieces with a weight of 1–1.5 kg.

The proposed technology includes three stages: electrohydraulic action on the meat structure; separation of whole-piece semi-finished products into portions and storage.

Figure 4 presents the microstructure of a meat semi-finished product after processing using EHI (200 pulses during 100–120 sec.) with penetration of electrodes into a product to a depth of 3–5 mm. As a result of the action of electrical discharges, the connective tissue layers and muscle structure are destructed. Due to brine penetration into meat, muscle fibers swell and their volume increases.

The results of the experimental study on the mechanical processing of semi-finished products from pork, beef and mutton using the electrohydraulic impact are presented in Table 1 and Table 2.

The obtained data indicate that the electrohydraulic impact on meat raw materials increases volumes of samples compared to initial by 47–61%, the thickness of connective tissue layers increases by 3.3–7.5 times and the weight of semi-finished products increases by 5–10%.

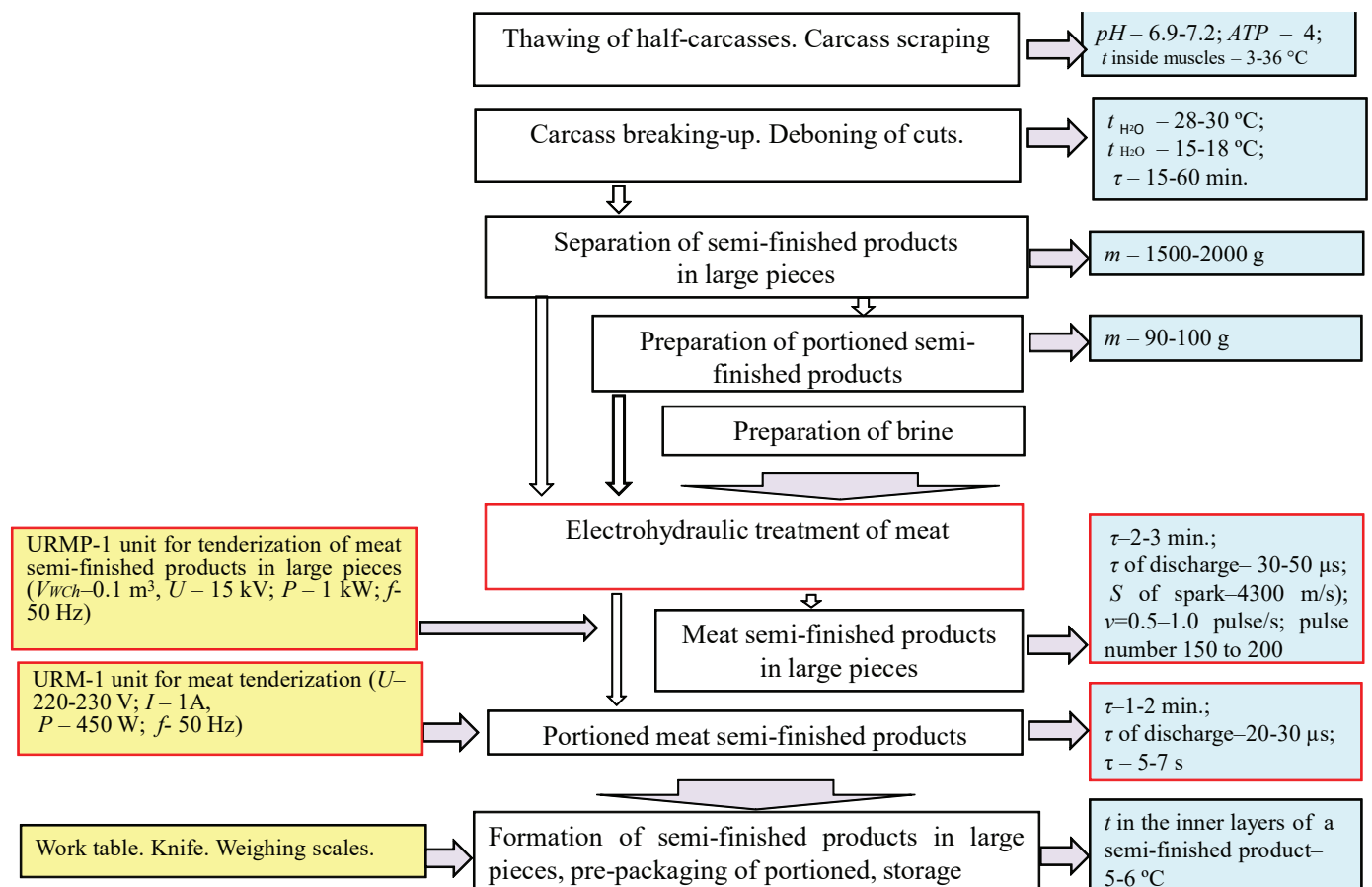


Figure 3. Technological scheme for production of cured meat semi-finished products

#### Destruction of interfiber collagen binding (main hydraulic resistance)

#### Destruction of meat tissue structure

#### Softening of fibers

#### Partial rupture of fiber structure of tough tissues and partial changes in fiber shape to goffered and wavy

#### Swelling of muscle fibers due to intensive penetration and distribution of salt inside meat and destructive effect of electrohydraulic impacts on muscle tissue structure

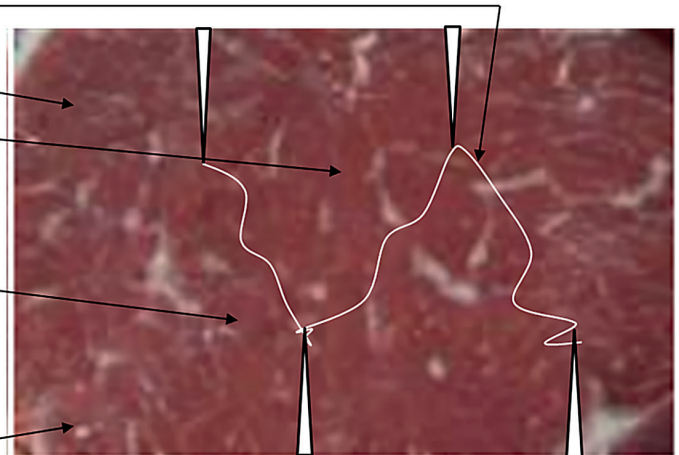


Figure 4. Microstructure of the cured semi-finished product after mechanical action of the electrohydraulic impact

Table 1. Changes in the product characteristics as a result of the electrohydraulic impact

Indicators	Meat type		
	Beef, 1st category	Pork, 1st category	Mutton, 1st category
Thickness of meat semi-finished product, mm			
initial raw material	17–18	16–18	17–19
after EHI	25–28	26–29	24–25
Thickness of softened collagen layers, mm			
initial raw material	About 0.7 mm	About 0.8 mm	About 0.6 mm
after EHI	2–4 mm	4–6 mm	2–4 mm
Weight of semi-finished products, g			
initial raw material	101±2	102±2	104±2
after EHI	106–109	109–112	109–110
Increase in portion weight, %	5–8	7–10	5–7
Color of semi-finished products	Insignificantly decolorized		



Table 2. Comparative characteristics of the nutritional value of portioned semi-finished products processed by the traditional and proposed methods

Indicators	Content in portion			
	Initial raw materials	Traditional method	Tenderization in URM-1	Magnification
Caloricity, kcal	168	96	163	+ 67
Proteins, g	20	12	19.4	+7.4
Fats, g	9.8	6	9.7	+3/7
Water, g	69.2	45.2	68.8	+ 23.6

Table 2 presents the nutritional value of experimental semi-finished products and those produced by the existing technology.

After corresponding treatment, meat semi-finished products can be used both for storage (freezing) and for cooking (heat treatment).

Experimental studies on electrohydraulic tenderization and simultaneous curing of portioned meat semi-finished products from the inner part of reindeer loin with a weight of 80–120 g and whole-piece meat semi-finished products with a weight of 1000–1500 g that were not subjected to trimming are presented in Figure 5.

The obtained data show that as a result of reindeer loin treatment using EHI, shear force decreased by 27–32% and breaking force by 18–23%.

### Conclusion

Electrohydraulic treatment of meat using the URM-1 unit or URMP-1 unit allows decreasing product losses, increasing tenderness and reducing curing process duration compared to curing in the mechanical equipment.

For practical implementation, it is recommended to use the proposed equipment to process semi-finished products in large pieces with a weight of 1–1.5 kg and portioned semi-finished products with a weight of 0.08–0.120 kg. This will allow reducing product strength characteristics by 51–53 kg/cm, decreasing raw material losses, increasing labor productivity by 8–11%, shortening technological process duration and decreasing energy expenditure upon heat treatment by 18–20%.

The electrohydraulic impact (frequency  $\nu = 0.5$ –1.0 pulse/sec., number of pulses from 150 to 200) can be used for muscle and connective tissue tenderization of both chilled (core temperature of 0°C to 4°C), and sub-frozen (–2°C to 3°C) meat.

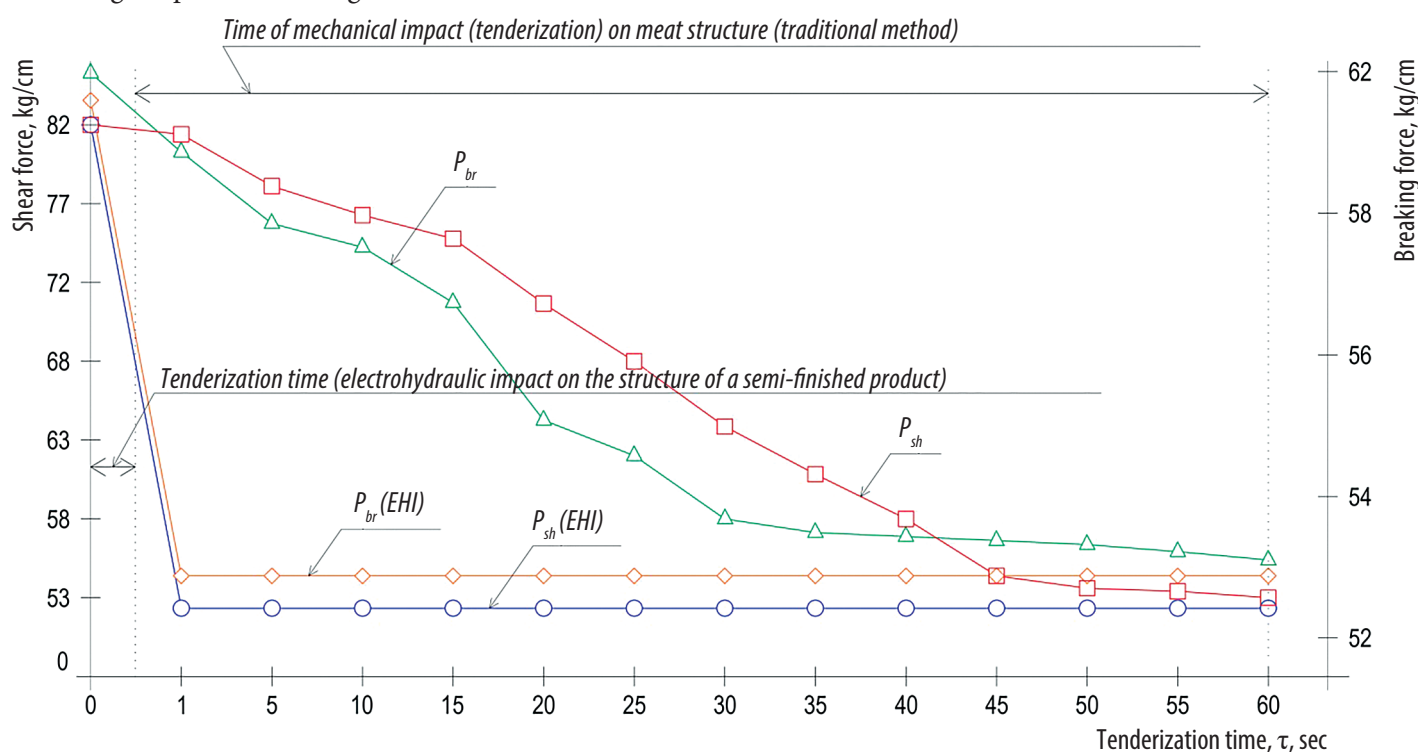


Figure 5. An effect of electrohydraulic treatment on strength properties of muscle and connective tissues of reindeer loin

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