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Ultrastructural Studies on Changes in Poultry Muscles Caused by High Voltage Electrical Stimulation Using a Specific Installation

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Abstract: The results of favourable micro structural changes in the muscles of older poultry subjected to High Voltage Electrical Stimulation (HVES) have been presented. Samples were drawn from the breast muscle and then they were prepared as appropriate for evaluation in scanning electron (JEOL S1) and transmission (Tesla - BS 613) microscopes. The muscle samples subjected to Electrical Stimulation (ES) showed on the electron microscope image the deep morphological changes consisting in failure of myofibril structures what resulted in the improvement of meat quality factors in comparison to unstimulated control samples (C). The environmentally friendly plant for high voltage electrical stimulation of poultry carcasses has also been presented. The poultry slaughter requirements have been taken into account in plant design and the plant have been adjusted for running in process line. The productivity of the system is 120 pieces per hour at power demand of 6 kW.

Key Words: Plant for High Voltage Electrical Stimulation, Electrical Stimulation, Poultry Meat, Tenderness

Introduction

The usability and processing values of poultry meat depend on many factors connected with living conditions i.e. age, type, race, nutrition, technique and technology of meat procurement and processing to off - the shelf product. Meat obtained from older poultry is dry and tough. (Krala, 1992; Potemkowska, 1983 and Sams, 1999).

The forecasts concerning development of the required quality changes and new technological possibilities allowing for rational utilization of poultry meat subjected to High Voltage Electrical Stimulation (HVES) are very promising (Li *et al.*, 1993; Owens and Sams, 1998; Sams, 1999; Szorc and Korpal, 2000; Szorc and Ringel, 1997). The knowledge about an effect of HVES parameters on poultry meat changes, including micrographic ones, allows for the better process control (zorc and Ringel, 1997).

The poultry industry operates on various technical and technological levels and it affects, among others, the quality of electrical treatment of poultry carcasses. The technical and technological levels of poultry meat production as well as its quality can be raised by implementation of the research results into practice. A new, own, quick and cheap method and device allowing for new technological possibilities of improvement of poultry meat quality (Lesiów,1991; Szorc and Korpal, 2000 and Tyszkiewicz, 1995), presented in our paper, can be an example of such a behaviour. An effect of HVES on the qualitative changes of poultry meat has been investigated and then a new HVES method and technique have been tested on domestic poultry under the industrial conditions and scale in the aim to prove the operational effectiveness of the industrial plant for HVES of poultry carcasses.

Materials and Methods

The experimental material for determination of changes in muscle fibres were breast muscles obtained from carcasses. The carcasses were obtained from laying hens of Lenghorn type, about 10 months old and of mean weight approx. 1.6 kg. The living features, i.e. age, breeding, nutrition of the hens subjected to slaughter were identical. The poultry in amount of 240 pieces were subjected to experimental slaughter and 120 pieces were selected at random from that series. Slaughter and post-slaughter processing were carried out according to PN-A/86/520 standard. The mean carcass weight after slaughter was about 1.17 kg (F=0.166). 60 pieces of poultry selected from the chosen series of 120 pieces were electrically stimulated and the remaining 60 pieces were the control material. From each carcass, a sample from breast muscle was drawn for evaluation of micrographic changes in muscles.

The scanning electron (JEOL S1) and transmission (Tesla-BS 613) microscopes were applied for micrographic evaluation of muscle fibres subjected to Electrical Stimulation (ES) with alternative current (voltage U = 250V, frequency f = 80 Hz, time t_{ES} = 120s, impulse course R - sinusoidal, half sinusoid saturation G = 65%, amperage I = 0.8 A) and without electrical stimulation (C). The samples (1cm x 1cm x 0.5cm) for evaluation by scanning microscopy method were drawn from breast muscle, fixed in glutaric aldehyde (2.5 %) prepared on cacodylate buffer (pH = 7.4), placed in atmosphere of osmium tetraoxide for 2 h, dehydrated in acetone series of concentration within the range from 30% to absolute. Then, they were dried in CO_2 critical point and covered with carbon and gold in vacuum sublimer.

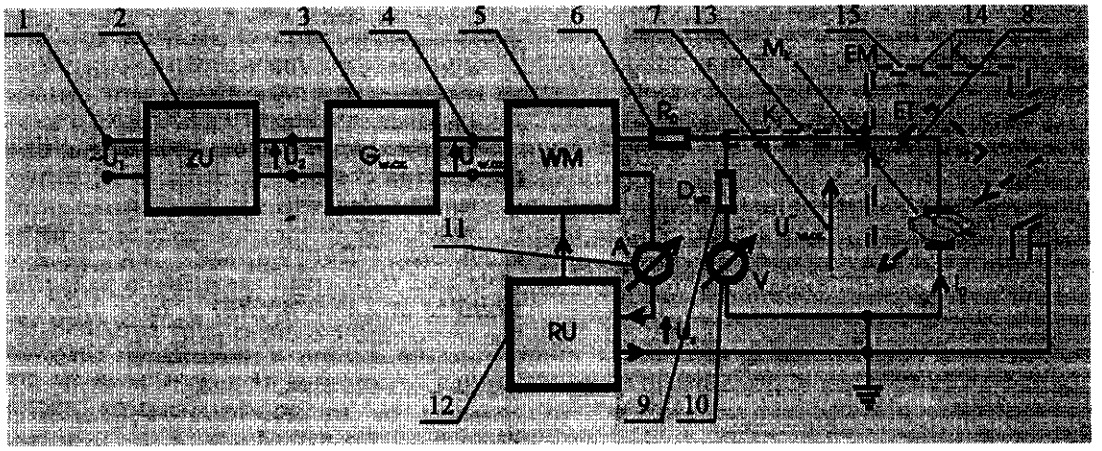


Fig. 1: Diagram of Electrical System of Plant for Poultry Carcasse Stimulation: 1 - Voltage Supply, 2 - Supply System Forming Generator output Voltage U_2, 3 - High Frequency Oscillator, 4 - High-Frequency Voltage, 5 - High-Frequency Power Amplifier, 6 - Resistor Limiting Current I_0, 7 - High-Frequency Voltage on Screens, 8 - Electrodes, 9 - Voltage Divider U''_{hf}, 10 - Voltmeter, 11 - Ammeter, 12 - Voltage Control Unit U''_{hf} with Current Coupling at U_s Voltage, 13 - Screen Cable, 14 - Technological Chamber with Automatically Opened output and input Windows T_d, 15 – Electromagnetic Screen of K_t Chamber

The samples for evaluation by transmission microscopy method were fixed in glutaric aldehyde (5%) on phosphate buffer (pH = 7.2) at temperature of 4°C, then, washed in saccharose solution (7.5%) and placed in atmosphere of osmium tetraoxide (1%) on cacodylate buffer (pH = 7.2). After dehydratation in ethanol - autonic series, they were sealed in eponic mixture. After evaluation of half-thin cuttings stained with azure II and methylene blue, the ultra-thin cuttings were prepared and contrasted using lead citrate and uranyl acetate.

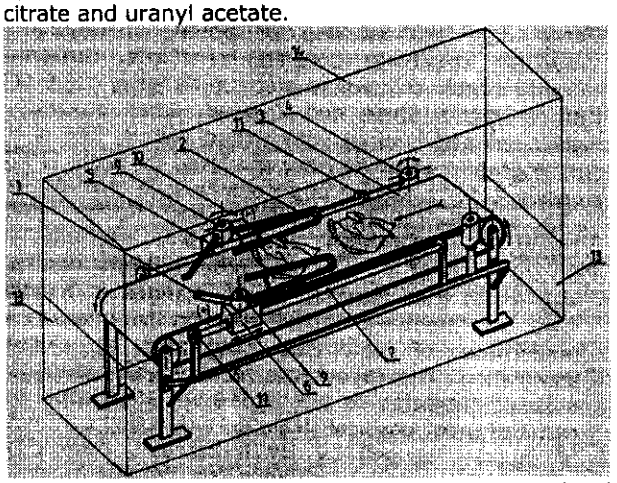


Fig. 2: Diagram of Plant (end view): 1 - Steel Electrode, 2 - Copper Electrode, 3 - Belt Conveyor, 4 - Coiling Machine, 5 - Copper Electrode Trolley, 6 - Steel Electrode Trolley, 7- Guide, 8 - Poultry Carcass, 9 - Swing Sleeve, 10 - Elastic Element, 11 - Resistance Bumper, 12 - Front Shield, 13 Back Shield, 14 - Side Shield

Industrial Plant for HVES of Poultry Carcasses: Technological advantages resulting from HVES application can be realized only by the use of the special plants (Szorc and Ringel, 1997; Szorc, 1987). The plant should form, intensify, measure and emit the determined electrical impulses on poultry carcasses as well as it should also ensure save and environmentally friendly conditions of work.

The requirements of poultry industry were taken into consideration in brief foredesign of HVES plant (Fig. 1, 2, 3) and moreover, they were adjusted for running in poultry slaughter line.

The plant consists from two parts: electrical system (Fig. 1) and mechanical unit (Fig. 2 and 3).

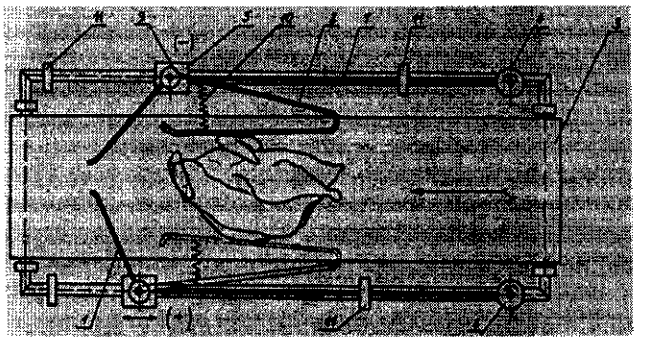
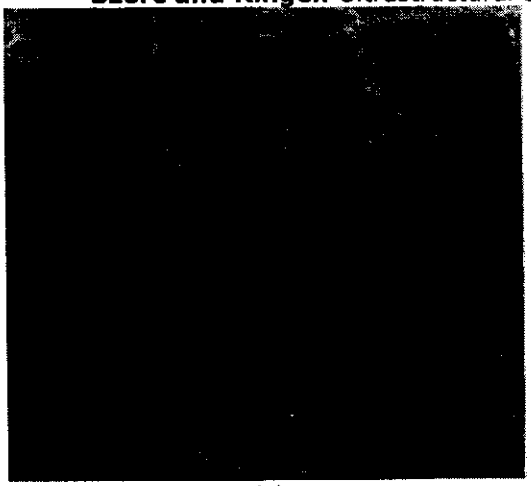
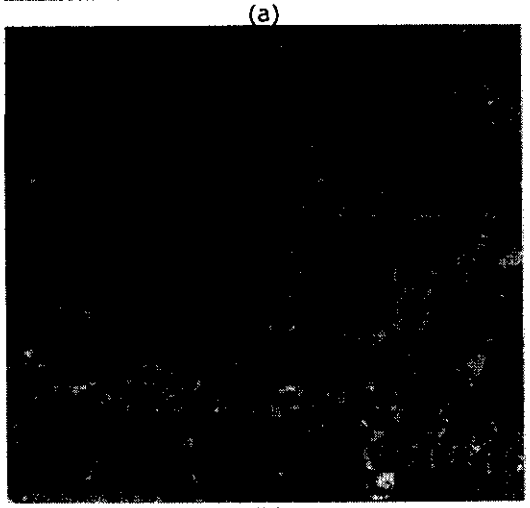


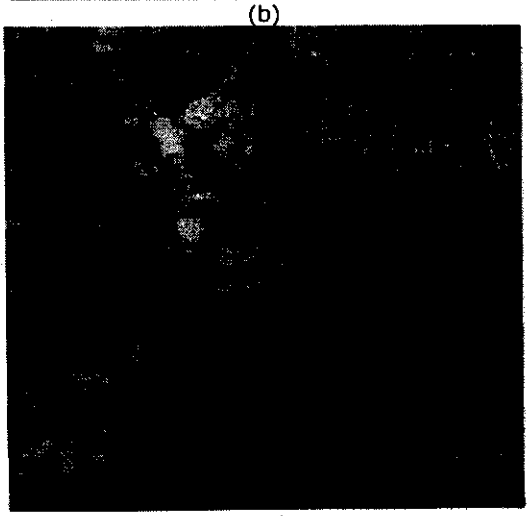
Fig. 3: Diagram of Plant (top view): 1 - Steel Electrode, 2 - Copper Electrode, 3 - Belt Conveyor, 4 - Coiling Machine, 5 - Copper Electrode Trolley, 6 - Steel Electrode Trolley, 7 - guide, 8 - Poultry Carcass, 9 - Swing Sleeve, 10 - Elastic Element, 11 - Resistance Bumper



(a)



(b)



(c)

Fig. 4: Preparations from Breast Muscles; Longitudinal Section: A - Controls (C) x 4750, B - Electostimulated (ES) x 4750, C - Electostimulated (ES) x 14400

Technical Data of Plant

- productivity up to 120 pieces per hour
- power demand 6 kW
- power supply 220 V
- voltage $6 \leq V \leq 700$ V
- frequency $10 \leq 100 \leq$ Hz
- sinusoide saturation $10 \leq K \leq 90\%$
- impulse course: triangle, rectangular, sinusoidal

Dimensions of plant:

- length - 2500 mm
- width - 800 mm
- height - 1200 mm

Results and Discussion

The micrographic changes in muscle fibres after HVES are presented in Fig. 4. Preparations observed by SEM are presented in Figs. 4A and 4B, however, preparation observed by transmission electron microscope is presented in Fig. 4C.

The ultrastructure of meat before HVES was characterized by well-kept sarcoplasm structure and characteristic distinct structure of muscle fibres (Fig. 4A). The fibres with regular outline were observed by SEM on longitudinal section of breast muscles (C) (Fig. 4A). The arrangement of myofibrils in the most of fibres was compact with distinct cross-banding, nucleus were placed circumferentially, the most of fibres have the similar colour.

However, the irregular spaces among fibres, the breakings of sarcoplasm and discontinuity of fibres were observed in muscles subjected to Electrical Stimulation (ES) (Fig. 4B). In part of the fibres, the loosening of comb-out type occurring in myofibril system and obliteration of cross-banding were observed. The most of fibres were characterized by pale colour.

The following features were found on transmission electron microscope image on longitudinal section (ES) (Fig. 4C): the swelling of fibres, obliteration of myofibril structure, loosening of fibres, clusters of grainy matter of medium electron density, obliteration of contractile fibres and Z band, small amounts of glycogen and centres with wrong colour. The similar micrographic changes were observed by Krala (1992), Lesiów (1991), Ostoja and Korzeniowski (1992), Szorc and Korpal (2000), Birkhold and Sams (1993), Thompson *et al.* (1987).

On the basis of our own and other authors' results, it was found that microstructural changes in miofibrils were an important factor allowing to improve the tenderness of carcasses subjected to electrical stimulation. The favourable technological changes in muscles subjected to electrical stimulation could be a result of great physical strain during violent contraction of muscles caused by HVES process, destructional action of electrical stimulus or fragmentation by endogenic proteolytic enzymes. Tenderness can result from expanding of the fibre area lying on the both sides of contraction bands what is related to the fact that muscle filaments become less tangled and consequently less resistant (Birkhold and Sams, 1993; Birkhold and Sams, 1995; Li *et al.*, 1993; Mikami *et al.*

1990; Ostoja and Korzeniowski, 1992; Szorc and Korpal, 2000; Szorc, 1984; Żywica *et al.*, 1995).
The plant applied for HVES of poultry carcasses may have a great applicability value in
poultry industry. The plant design is characterized by some original solutions which ensure
the required functionality and operational safety (Figs. 1 - 3).

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