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INFLUENCE OF PRESLAUGHTER STRESS ON POULTRY MEAT

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Abstract

In the present article the authors consider the importance of issue of the poultry meat quality. The increasing demand for poultry meat provides for the rapid growth of industrial stock of poultry, which contributes to appearance of meat with various defects in muscle tissue: PSE meat, that features low pH, pale color, soft and watery texture, and DFD meat — it is more dense and drier, of dark saturated color. Till now, the causes and mechanisms of appearance of those anomalies still haven't been unambiguously formulated, however, a large number of publications prove the influence of the genetic characteristics of modern crosses of broilers and turkeys on disturbances in Ca^{2+} metabolism process in the sarcoplasm of muscle fibers. The uncontrolled release of calcium along with the high temperature of slaughtered poultry carcasses immediately after slaughter provokes an intense decrease in pH and launches denaturation processes in proteins. The numerous studies have shown deterioration in functional and technological properties of meat in stress-sensitive poultry, such as moisture-binding capacity and high acidity, which increases loss of meat juice during its storage and its weight during heat treatment. Recent publications have been devoted to development of a strategy for use of PSE poultry meat and search for efficient processing of PSE poultry meat, since the scientific community does not provide direct evidence on possibility of genetic adjustment of the poultry in order to exclude the occurrence of PSE quality of meat.

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Introduction

Poultry meat is one of the important sources of full-range animal protein for nutrition of a most part of the population. Relatively low prices in comparison with the other types of meat, the absence of cultural or religious food prohibitions, the dietary and nutritional properties of poultry meat provide for its high demand. Current forecasts and predictive researches confirm the further expansion of the poultry meat market.

According to foreign studies [1,2], the increasing demand for poultry meat determines the rapid growth of the poultry industrial herds. Large number of the poultry contributes to the appearance of meat with various defects in muscle tissue: PSE quality — pale, soft and exudative texture, and DFD quality — dark, firm and dry meat of dark saturated color [3,4]. As a result of intense breeding selection, broiler chickens are the most efficient in terms of meat productivity and growth rate. However, the meat of broiler chickens raised in intensive industrial conditions, feature quality defects most often. According to Karunanayaka D. S. et al. [5] the rate of detection of PSE broiler meat is about 70%.

PSE poultry meat, in addition to defects in color and texture, is characterized by pretty low water-holding capacity and increased loss of muscle juice during its cooling and processing. The quality features of PSE meat increase the probability of significant economic losses during sale of these raw materials, including sale the separate parts of carcasses, chilled and frozen semi-finished products [6]. According to Alvarado C. [7], the value of PSE meat is limited, and it cannot be considered as a full-fledged culinary raw material and it is not advisable to send it to retail shops. According to the researchers, DFD poultry meat also has limited use, as it is prone to rapid microbiological deterioration due to high pH level > 6.3, even when it initially had a relatively low level of microbial contamination [8,9]. The purpose of the research is to summarize the available data on pre-slaughter and post-slaughter factors contributing to the production of poultry meat with abnormal course of autolysis (PSE, NOR and DFD meat). The research is also aimed to show the effect of abnormal autolysis on pH value and color properties of poultry meat.

Causes of poultry meat with an abnormal course of autolysis

In this regard the study of the qualitative features of PSE and DFD poultry meat has great scientific and practical interest, as well as the reasons of their appearance.

The causes contributing to occurrence of PSE and DFD poultry meat have not yet been fully determined. As evi-

denced by numerous publications [10,11,12,13,14], there is a number of factors, which influence the quality of broiler meat. Those factors include the influence of genetic characteristics and influence of stress. Stress is provoked by environmental factors and poultry keeping conditions — temperature and humidity, air flow velocity, exposure to thermal radiation. Stress can be also caused by the pre-slaughter factors, like rest and activity mode, mode of watering and starvation, inadequate conditions of keeping, transportation conditions, length of rest and season of the year. According to data obtained by some researchers (Abdullah A. Y. et al., 2010) [15], the influence of slaughter conditions and arrangement of post-slaughter processing shall also be taken into account.

One of the factors that affect the quality of the obtained meat is the linear targeted selection of poultry, which contributes to the development of stress syndrome (PSS — porcine stress syndrome). Some researchers [16] believe that genetically determined growth of muscle mass leads to deterioration of meat quality. Those issues are associated with muscles stiffness, poor muscle fiber connectivity and deterioration in color and water-holding capacity of the muscle tissue. The connective tissue in poultry like that (endomysium), associated with individual muscle fibers, does not keep pace with the rapid growth of muscle fibers and, as a result, becomes less developed and immature, which leads to a deterioration in tissues fibers connectivity [17].

Genetic mutation in RYR1 gene proteins makes the poultry quite perceptible to drugs that reduce the sensitivity of muscles to anesthetics like halothane. Stress syndrome in the pectoral muscles of poultry is caused by a mutation in guarding proteins of the calcium channel (ryanodine receptors, RYRs), which control the release of Ca^{+2} from the sarcoplasmic reticulum. It is known that many biological processes, which are controlled by intracellular calcium signals, depend on intracellular reserves that provide controlled release of calcium into the cytoplasm. The concentration of intracellular calcium in the sarcoplasm of muscle fibers is regulated by the absorption and release of calcium from the sarcoplasmic reticulum due to formation of channel by the ryanodine receptor (RYR) [18].

The increase of calcium ions in the cell sarcoplasm accelerates metabolism. If the carcass is exposed to the elevated temperatures immediately after slaughter, it leads to a violation of the ABB of the carcass [12]. That launches another stress syndrome — the malignant hyperthermia (MH). Calcium imbalance caused by unregulated flow of calcium ions into various parts of the muscle cell can dramatically alter energy metabolism and muscle activity due to point mutations in the Ca^{2+} release channel (RYR) embedded in the sarcoplasmic reticulum. However, the authors believe that the influence of genetic factors is not obvious for commercial lines of turkeys and broiler chickens, and at the moment the genetic factors should be perceived as background, which is capable of manifesting itself depending on exposure to various stress factors.

Later studies [19] showed a relationship between the concentration of calcium ions in the sarcoplasm of the broiler pectoral muscles and manifestations of PSE meat quality. The results of the cationic elements analysis found an excessive amount of Ca^{2+} in the sarcoplasm of pectoral cells of abnormal quality meat during the initial period of autolysis. At the same time, thermogravimetric analysis with inductively coupled plasma optical emission spectrometry showed that the mass fraction of moisture in PSE meat is 4% lower than in the meat of normal quality.

Percival A. L. et al. [20] showed that, unlike pigs, the skeletal muscle tissue of poultry contains two forms of the RYR protein, each of which form has two replicas. All identified variants can be either normal or defective, but due to the greater number of proteins potentially susceptible to mutations, the probability and number of defective combinations significantly increases. When the mutated RYR replicas are present in the poultry meat, the poultry will be susceptible to the influence of stress factors, while the mechanism of ionized calcium circulation in the cells will be disturbed and the intensity of metabolism will be changed.

While researching the differences in RYR activity in poultry of different crosses, the authors [21] showed that in turkeys of commercial line the affinity for ryanodine is three times higher than the studied indicator in the control genetically unimproved group of poultry. The binding of ryanodine by the sarcoplasmic reticulum is recognized by a wide number of authors as a method for determining the stress sensitivity of animals and poultry. Post-mortem hypermetabolism of turkey skeletal muscles defines the development of PSE meat quality. According to the review given by the authors in the research [22], the cause of change in the autolysis dynamics is a disturbance in exchange of calcium ions in the cell due to the RYR1 point mutation at nucleotide 1843.

It follows from the published data [23] that an excess of calcium ions in the sarcoplasm of PSE meat enhances the activity of proteinase (calpain), which manifests itself in the destruction of myofibrils and the disorganization of Z-lines in the muscle fiber sarcomere. The contribution of increased concentration of Ca^{2+} ions to the degradation of the membranes of the main cellular structures of muscle tissue with autolysis deviations was reported by Kuchenmeiser U. et. al. [24].

Myopathy of the pectoral muscles, expressed as the weakened or impeded motor activity of the muscles, also leads to pale soft and exudative breast meat of broiler chickens. Recently it has been found that the PSE defect of meat builds up and manifests itself as white stripes on the section of the pectoral muscles due to presence of lighter muscle fibers or as a result of pectoral muscle hardening (so called “wooden” breast defect), as well as in the form of connective tissue defects manifested in the form of low connectivity of fibers in the structure of the pectoral muscles (so called “spaghetti meat” defect). Those anomalies of

muscle tissue quality significantly reduce the commercial marketability of poultry meat, deteriorate nutritional, functional and technological properties of muscle tissue [25,26].

Van Laack R. L.J.M. et al. [27] showed that protein solubility in pectoral muscles of PSE meat is lower than in normal ones, which indicates increased protein denaturation in exudative meat. The authors believe the low final pH of *pectoralis pallidum* and its high temperature to be the main factors determining the poor water-binding capacity of the meat.

According to some researchers [28], the prevalence of pathological conditions of meat indicates that a further increase in the efficiency of poultry meat production may be limited by the physiological capabilities of broiler chickens, since their internal organs, vascular system and skeleton are close to their functional limit.

Preslaughter and post-slaughter factors affecting the quality of poultry meat

According to some authors [29], the delivery of poultry for slaughter and its further processing do contribute to the formation of muscle tissue defects [29]. However, some researchers believe that transportation, which lasts no more than 3 hours, and unloading do not influence significantly on the quality of the pectoral muscles of turkey and chicken [30].

Pre-slaughter stresses like heat stress, fighting, packing to cages, transporting, cancellation of feed and delivery to the slaughter point are common in poultry processing facilities. So, it was found in the researches of Debut M. et.al. [31], that stress in broiler chickens is inevitable during the suspension of the poultry, which increases the rate of pH drop and increases the intensity of the color of the breast muscles.

The PSE and DFD defects of poultry meat can develop as a result of short-term and long-term poultry stress [32]. So Owens S. M. et al. [33] point to the significant importance of ambient temperature as a stress factor. Referring to earlier work, the authors conclude that large-size and faster growing poultry are more susceptible to heat stress.

Studies have shown [34] that heat stress (day temperature 38 °C/night temperature 32 °C) causes the low pH value of pectoral muscles, their pale color and higher losses of weight during cooling of broiler chicken carcasses in comparison with muscles obtained from slaughtered poultry not exposed to heat stress.

Studies [35] are devoted to the effect of the cooling rate of poultry carcasses in the post-slaughter period on quality of the obtained meat. It has been established that post-slaughter elevated temperatures of carcass (up to 37–41 °C) in the first 15–20 minutes after slaughter accelerate the breakdown of ATP and contribute to hydrolysis of glycogen to lactic acid, which leads to the formation of pale, soft, exudative pectoral muscles of turkeys and chickens. Slow cooling or insufficiently low cooling temperatures (30–40 °C) may promote the development of PSE meat in normal or rapidly glycolyzing pectoral muscles of the poultry.

According to Molette C. et.al. [36], high post-slaughter temperature (about 40 °C) of turkey muscles activates protein kinase (AMPK), which leads to accelerated glycolysis and results to PSE meat.

Influence of the nature of autolysis on relation between pH value and the color parameters of the poultry meat

Deviations in the rate and depth of pH decrease in the autolyzing pectoral muscles are associated with changes in their color. Color is the most important consumer characteristic of meat and it has the highest importance in the market perception of the product. Researchers [37] suggest that light and dark meat differ in density of packing of structural elements of muscle tissue — transverse structural packing of myofibrils and muscle fibers, longitudinal shrinkage of sarcomeres, and different protein composition of sarcoplasm and extracellular space. According to Hughes J. M. et al. [38] color is determined chromatically by myoglobin (measured by its shade and chromaticity) and achromatically — by scattering of light by the tissue structure (measured by luminosity).

Kralik G. et.al. [39] established a relation between color, final pH value and meat juice loss in broiler chicken breasts. Based on the value of the luminosity index (L), breast meat was classified into DFD ($L < 44$), NOR ($L = 44–53$) and PSE ($L > 53$). The PSE breast meat had a higher luminosity value (L), a lower final pH (pH_f) and a higher loss of meat juice in comparison with normal meat (NOR). Opposite results were obtained for DFD-quality meat. A negative correlation was established between the L and pH_f values and a positive correlation between the L values and the loss of meat juice.

Similar studies were carried out by Freitas A. S. et al. [1]. Basing on the obtained data, the authors came to the conclusion that in order to classify pectoral muscles of chickens into qualitative groups the threshold values of the luminosity index L and the values of the final RNA should be determined. These values for PSE meat were as follows — $L > 51.0$ and $pH_f < 5.9$; for NOR meat — $5.9 < pH_f < 6.2$ and $45.0 < L < 51.0$; and for DFD meat quality — $L < 45.0$ and $pH_f > 6.2$.

The luminosity index of meat of broiler chickens ($L > 54$) provides over 47% reliable detection of PSE meat with low pH and increased moisture loss during meat storage and heat treatment. According to the authors, sorting meat by its color under industrial conditions does not pose a serious challenge, since fillet sorting is already introduced and being run at enterprises, but according to other criteria [40,41].

The recent publications [42–46] are devoted to the development of a strategy for PSE meat using and to search for efficient processing of PSE poultry meat, since in the

scientific community there is no direct proof on genetic adjustability of the poultry in order to exclude the occurrence of PSE meat.

Conclusion

The analysis of the cited references proves that most authors recognize the problem of PSE quality in poultry meat. The study of the mechanisms of occurrence of this anomaly still has not been unambiguously formulated, however, a large number of publications show the influence of the genetic characteristics of modern crosses of broilers and turkeys on disturbances in the mechanism of Ca^{2+} metabolism in the sarcoplasm of muscle fibers. The uncontrolled release of calcium, combined with the high temperature of poultry carcasses immediately after poultry slaughter, provokes an intense decrease in pH and launches denaturation processes. As a result, numerous studies have shown a decrease in the functional and technological properties of meat in stress-sensitive poultry, such as loss of meat juice during its storage and loss of meat weight during heat treatment due to its poor water-binding capacity.

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