ABOUT THE QUALITY OF MEAT WITH PSE AND DFD PROPERTIES

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Abstract: The use of modern technologies in meat production often leads to the formation of raw meat with uncharacteristic course of autolysis, one raw meat being characterized by a low pH value (less than 5.2), it is pale, flabby and watery (Pale, Soft, Exudative (PSE) with a loose consistency. Meat juice is allocated and meat has a sour smell. Other meat has a high ultimate pH (more than 6.2), it is dark, tough and dry (Dark, Firm, Dry (DFD) with coarse fiber and sticky. One of the quality indices enabling to identify meat into PSE and DFD groups is color. The pH of meat correlates with the loss of meat juice and color. Pork protein with PSE defect is characterized by a small amount of fractions with a high molecular weight and a large proportion of protein fractions with the molecular weight from 100 to 50 kDa. During meat production the technological solution for the rational use of raw meat with deviations in the autolysis process can be modes of heat treatment and the use of food additives. Stress causes a significant impact on the meat quality of slaughtered animals. The appearance of meat with PSE quality is associated with the animal susceptibility and its response to the stressful situation, and the specificity of biochemical processes in pork is caused by the development of a stress syndrome PSS (Porcine Stress Syndrome), the syndrome of poor adaptation. The meat quality is affected by breed, for example, hybrid pigs are superior to pure bred in technological properties and meat productivity. The meat of pigs of large white x Landrace x Duroc refers to NOR meat, which makes it more valuable. Due to the fact that the susceptibility of pigs to stress is inherited as a single recessive gene, the pigs are divided by genotype into two groups: stress sensitive and stress resistant. It has been shown that the activity of antiperoxide enzymes is higher in stress resistant broiler chickens than in stress sensitive ones.

Keywords: Meat quality, reasons of forming the nontraditional meat quality, autolysis, antioxidant system, lipid peroxidation

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INTRODUCTION

Modern technologies of feeding cattle and pigs enable to provide the realization of a genetic potential of meat productivity [1]. But during the intensification of livestock there appear some problems connected with the formation of raw meat with uncharacteristic course of autolysis, in particular, with a low pH value (less than 5.2). Such meat is pale, flabby and watery (Pale, Soft, Exudative (PSE) with a loose consistency, meat juice allocation and sour smell. The meat with a high ultimate pH (more than 6.2) is dark, tough and dry (Dark, Firm, Dry (DFD) with coarse fiber and sticky. [2] notices that the realization of pale, soft and exudative pork leads to the annual loss of $100 million for pig-breeding.

Characteristics, formation reasons and the rational use of raw meat with PSE and DFD properties.

The important identified index of meat with uncharacteristic course of autolysis is color which significantly affects the other characteristics and culinary and technological properties. Dark color is typical for DFD meat and the consumers consider it of poor quality by the visual observation.

[3] states that the index of light meat depends on the content of common pigments and the surface condition, and the yellowness and redness of meat depend on the ratio of myoglobin derivatives. Myoglobin in contact with the air oxygen turns into oxymyoglobin (MbO) which gives bright pink meat. Metmyoglobin (MetMb) is formed under the influence of light and air and meat acquires brown-grey color which indicates DFD evidence. It has been established that lightness of meat is a more stable parameter, less subjected to the action of external factors. Hence, it is more objective when determining raw meat into the definite quality group.

[4] recommends to break up meat into quality groups using the lightness index L, the value of which correlates with the change of pH value and the quantity of heme meat proteins. The scale "lightness pH24" has been proposed to identify the quality group of beef. The complex of pH indices, lightness (L) and redness index «A/B» can be used in addition to it.

To identify meat the reflection coefficient is used which reveals the real differences between PSE meat and DFD one.

A significant drawback of meat with DFD properties along with dark color is the fact that it is susceptible to spoilage because of high pH value and water binding capacity of meat.

The content of high molecular weight fractions increases during the storage of meat with high pH value, and there are no essential changes of the actin myosin fraction which maintain a relatively high and stable hydrophilicity level of this meat during the storage. This determines a high index value of water binding capacity of DFD meat [5].

A rapid breakdown of glycogen and increased accumulation of lactic acid take place in meat with PSE properties within the first hours after slaughter. It leads to the pH shift to the acid side and to the favorable background of microbiological contamination, but the low water binding capacity and color saturation make the technological processing difficult and decrease the yield of finished products [6].

[7] state that the products made of PSE meat possess a bad texture and bad water binding capacity. Therefore, to improve the quality it is necessary to investigate the texture and water binding capacity. Then, the amount of PSE pork included in the product can be increased.

[8] say that the ultimate pH values are the most convincing predictor of the meat quality. It is connected with a high degree of correlation between pH24 and water binding capacity [9]. The final pH between 5.5 and 5.7 is used to differentiate PSE meat from other indices. The correlation coefficients are calculated for the quality indication. Obviously, the highest correlation coefficients are observed between the ultimate pH value, the loss of meat juice and color of meat (paleness).

[10, 11] discovered a pattern in the ratio of the original and final pH values and the loss of meat juice in the samples of male pigs. The ratio of the final pH value and the loss of meat juice was described with the help of the linear equation. The loss of meat juice equals 33.6728 – 5.04 x pH24.

[12] notices that the reduction of meat freshness degree is associated with the accumulation of hexamethylcyclotrisiloxane (15.6–62.8 mg/kg), ethinyl ethylbenzene (32.1–40.0 mcg), cyclocycloheptatrien (82.6–94.9 mg/kg), ethylbenzaldehyde (9.9–31.9 kg/kg), diethylbenzene (0.9 – 20.5 mg/kg) and other substances. This causes the most pronounced changes in PSE and DFD meat. With a practical point of view the use of the method for the determination of histamine provides a more objective sorting of raw meat according to the freshness degree especially with signs of PSE and DFD defects.

[6] states that for pork with PSE properties the shear stress and increased cutting across the fibers are higher (89.4 kPa and respectively 1.55×10^{-5}) in comparison with NOR pork (57.2 kPa and respectively 1.51×10^{-5}). For DFD beef they are lower (57.4 kPa and respectively 1.45×10^{-5}) as compared with NOR beef (68.3 kPa and respectively 1.57×10^{-5}).

Decrease in the quality of meat occurs unequally in different parts of the carcass: the most affected are muscles of back and rounds that make up the most valuable meat parts of the carcass [13].

Muscle fibers are generally divided into three groups depending on their biochemical and functional properties:

– 13% of STO (slowly twitching and oxidizing) red fibers.

– 17% of FTO (fast twitching and oxidizing), they can be both white and red fibers.

– 70% of FTG (fast changing glycolysis) white fibers.

Clear differences in the muscle structure have been found between pigs of different stress tolerance in several studies [9, 10].

Pork protein with PSE defect is characterized by a small amount of fractions with molecular weight higher than 210 kDa and a large proportion of protein fractions with molecular weights from 100 to 50 kDa. The same is observed with regard to the protein fractions having a molecular weight from 50 to 15 kDa [14, 15].

Sixteen clearly defined protein fractions and four minor fractions are distinguished in the thermally processed PSE pork. Thus, with a molecular weight less than 100 kDa one can visualize two clearly defined protein fractions and one minor, from 50 to 100 kDa there are four protein fractions, one of which is minor. The largest amount of protein fractions is located in the area with molecular weights from 20 to 50 kDa, they are eleven. Two protein fractions one of which is minor can be marked in the area of low molecular weight protein fractions <20 kDa [16].

During meat production the technological solution for the rational use of raw meat with deviations in the autolysis process can be modes of temperature treatment and the use of food additives.

The destructive changes of proteins occur more intensively in meat of PSE group. For this meat it is necessary to find a way of lowering the end point of temperature treatment. [17] proposes to regulate the mode of thermal treatment to lower the denaturation changes of proteins and, as a result, to reduce the loss of mass, and to improve the tenderness and juiciness of PSE pork products. The emphasis should be on the critical temperature – 55°C in terms of denaturation and qualitative changes of proteins. For example, the mode of temperature treatment of pork with autolysis defects "Low temperature - longtime (LT - LT)" is a long thermal treatment of raw meat at low temperatures.

In addition to the appropriate thermal treatment, the technological solution for the rational use of raw materials with PSE and DFD properties may be the use of gums and other hydrocolloids, vegetable proteins.

Since the proteins possess the increased functional characteristics (formation and stabilization of emulsions, formation of gels), the use of vegetable protein to meet the challenges of raw PSE and DFD meat is very effective [18]. During the processing of meat with DFD properties it is recommended to apply low molecular regulators of pH medium (phosphates, GDL and others) and whey.

But at the same time the phosphate mixtures contribute to pH increase and water binding capacity of stuffing, but they do not solve the problems associated with other properties of raw materials, namely, emulsifying ability and intense color. Moreover, they add new problems (deterioration of the muscle tissue structure, the surface becomes slippery).

Whey is considered to be the best source for the nutritional value of people, but its application may be limited only because of its cost.

[18] considers that the alternative to the concentrated protein whey can be dairy protein complex highly functional additive "Newmil", produced by "Partner M" company according to Dutch technology.

Additionally, to improve the color characteristics and color stability of the product it is recommended to use HARMIX, the natural protein product from blood plasma of SONAC drug company. It is very beneficial to improve the color of the product, especially when using DFD meat, as it gives the natural color to the products, improves perception and emphasizes the contrast between fat and muscle tissues.

Furthermore, color stability ensured with the help of HARMIX is significantly higher than that created by the natural meat pigment myoglobin and its derivatives reacting with nitrite, it is used in cooked meat products [18].

The formation reasons of nontraditional meat quality are various: the impact of stressors, loading, transporting, unloading of animals for slaughter, joint keeping of cattle of different sexes for slaughter, the violation of the recommended duration period before slaughter, failure to comply with the parameters of electrocution, unbalanced diet, change of diet, genetic predisposition, and others.

Belgian researchers [7] have revealed the tendency of increasing meat with PSE properties during spring, summer and autumn months (April - September) compared with the winter period (December-March) on the basis of changes in pH meat, electrical conductivity and water binding capacity in 30 minutes and 24 hours after slaughter. Keeping animals for slaughter in summer for 2 and 4 hours and in winter for 2 hours reduces the share of PSE pork.

[19] notices that the composition of the diet, its balance in basic food and biological indices are an important factor in forming the quality of meat. The imbalance of diet in proteins affects the quality of meat, the autolysis speed is broken, pH changes, there appear PSE or DFD defects.

Stress causes a significant impact on the meat quality of slaughtered animals. Long distance transportation of animals for slaughter without feeding promotes the deterioration of the meat quality. Studies conducted in Spain [11] have shown that 3 hours for rest are sufficient to relieve fatigue from stressful transportation. Based on the research results carried out by [20] one can say that even the place within the trailer during the transportation can affect the meat quality of pigs.

It has been found that the appearance of PSE meat is associated with the animal susceptibility and its response to a stressful situation, and the specificity of biochemical processes in pork is due to the development of a stress syndrome PSS (Porcine Stress Syndrome), the syndrome of poor adaptation.

Pre-slaughter stress leads to the increased ante-mortem breakdown of glycogen and to the slight decrease of pH value in the muscle tissue during autolysis, while pH level of dark dry meat is within 6.4–6.8 [21]. In contrast, [22] have established that the pre-slaughter stress provokes an accelerated breakdown of glycogen and a significant shift of pH to the acid side. Thus, in 45 minutes after slaughter pH is 5.4 resulting in the formation of meat with PSE symptoms.

The accelerated glycolysis is associated with the damage of sarcoplasmic grid in PSE muscle tissue and release of Ca^{2+} according to [23].

Furthermore, [24] consider that in PSE muscle tissue during autolysis the calcium ions are released from the sarcoplasmic reticulum not so as in the NOR meat. This also prevents the development of rigor mortis in the exudative muscle tissue.

There is a reactionary attitude to the problem of meat with PSE and DFD properties instead of a warning one in the meat industry. Although it is possible to minimize the deterioration of meat quality by preventing the formation of raw meat with defects during autolysis, for example, by eliminating the stress before animal slaughter and by assessing the meat quality of each carcass with the information provided to optimize breeding stock [22].

[23] states that the use of anti-stress drugs enables to avoid the formation of meat with PSE signs, contributing to the normalization of the process of post-mortem glycogen breakdown in the muscle tissue of animals.

Slaughter of animals is one of the most crucial stages of meat production, and the appearance of PSE and DFD defects depends on the duration of the stunning. [2] believes that to ensure the quality of meat, it is necessary to stun animals only to fainting but still maintaining the functioning of heart.

The cattle breed affects the quality of meat, for example, hybrid pigs are more superior in technological properties and meat productivity than purebred. Pig meat of Large White x Landrace x Duroc refers to NOR meat, making it more valuable [19].

Since the susceptibility of pigs to stress is inherited as a single recessive gene, pigs are divided into two genotype groups: stress sensitive and stress resistant. Breeds like Perten, Swedish and Yorkshire belong to the first genotype, and Large White, Duroc, Chester - to the second [8].

[25] has found that the most stress resistant breeds are: Large White, the new type of "large white Konstantinovskaya", Landars, Hampshire and also

breed combinations: Large White x Landars, Large White x Hampshire, Large White x Duroc and others.

Pig selection which provides the intensive production of meat according to the data of a Finnish researcher [24] leads to the increase of pale, soft, watery PSE meat having a low water binding capacity.

Meat pigs have genetically expressed lack of metabolism in muscles, which is the basis for PSE pork [26].

Genetic predisposition is an equally significant reason for PSE and DFD meat, because the peculiarities of post-mortem biochemical processes in the muscle tissue are determined by genetic factors, breeding and selection by 20–40% [21].

[26] has established that the uncharacteristic post-mortem changes in the structural and functional properties of skeletal muscles leading to the deterioration of the meat quality occur among some animals. PSE signs prevail in pigs and poultry. It is caused by a genetic predisposition for PSS (porcine stress syndrome).

Pork producers should use all the available information in determining PSS gene in their herd.

Today the detection methods of PSS susceptible animals have become more technologically accessible. One of the means used by manufacturers of PSS pigs to determine the status of breeding herd is molecular DNA test. [28] has developed a fast, simple and accurate molecular test for PSS, enabling to distinguish all three PSS genotypes (NN, Nn and nn) with the accuracy of nearly 100 percent. Molecular test has been conducted on DNA extracted from the muscle tissue, hair, fatty tissue and blood drops. The molecular test has been patented at the University of Toronto. Blood from all animals has been analyzed in order to identify stress sensitive pigs. DNA test for pigs with a stress syndrome has shown the presence of Ryanodine gene (RYR-1).

Ryanodine is RN-receptor. According to [27] it is a main gene influencing the final pH value of meat.

The ryanodine gene of receptors [RYR1] has been established to be the causal mutation for PSS. The investigation of the structure of the skeletal muscle of pigs with different RYR1 - genotypes indicates the difference in diameter of all three types of muscle fibers. Stress sensitive animals have an increased diameter of muscle fibers. Much attention is paid to the genome analysis in the current research of the reasons for the formation of meat with defects in the autolysis process. This might help improve knowledge about the muscle biology and define the criteria for the selection of farm animals and poultry with favorable meat quality.

[27] notice that PSS gene has a negative effect on the reproduction and the carcass quality, so meat manufacturers should acquire or produce sows without PSS gene and gradually replace the old ones.

The use of gene technology enables to regulate the final pH value and other indices of the meat quality in the pig population.

Thus, the response to stress factors is caused by genetics and it is the main reason of forming raw meat with defects in the autolysis process. At the same time stress is a trigger for developing the oxidative stress in the body. Although there is no common definition of the oxidative stress, some researchers believe that the "oxidative stress" is the intensification of processes of free radical oxidation.

[29] define the "oxidative stress" as an imbalance between the production of oxidants initiating the free radical oxidation and the activity of the antioxidant protection system of the body neutralizing these processes.

During stress the processes of lipid peroxidation (LPO) are activated, the displacement of prooxidant-antioxidant balance takes place with the products of lipid peroxidation being both inductors and primary mediators of stress.

The impact of lipid peroxidation and antioxidant system (AO) of slaughtered animals and poultry on the meat quality remains insufficiently studied. Chicken meat is known to be the most susceptible to lipid peroxidation due to its high content of polyunsaturated, monounsaturated fatty acids and nonheme iron Fe^{3+} and Fe^{2+} in comparison with other types of meat.

In this connection, we have carried out studies on the influence of LPO processes and AO system of broiler chickens with different stress stability on the meat quality.

RESULTS AND DISCUSSION

LPO includes diene conjugates (DC), which are formed in the fatty acid molecule. They are compounds with conjugated double bonds. The increase of DC number in the blood plasma indicates the intensification of lipid peroxidation process.

Products of free radical oxidation of lipids are Schiff base, in which there is a fragment of -N = C < [30, 31].

In the research conducted it has been stated that the content of polyene bases in the heptane fraction of lipids in stress resistant chickens is significantly lower by 8.6%, diene conjugates - by 7.2%, ketodienes with conjugated trienes - by 21.2%, Schiff base is lower by 20.0%.

The chicken body has a protective mechanism in the form of the antioxidant system to prevent excessive accumulation of lipid peroxidation products. According to the present views the system consists of two links (Fig. 1):

– Enzymatic presented with oxidoreductase (glutathione reductase and others) and anti peroxide (catalase), superoxide dismutase (SOD) and others) and enzymes;

– Non-enzymatic presented with polypeptides, water-soluble and fat-soluble vitamins, amino acids containing thiol, flavonoids, carotenoids and other compounds.

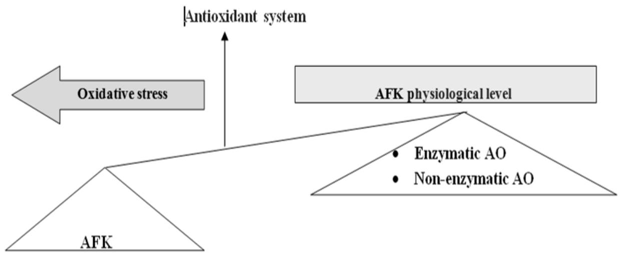

Fig. 1. Body antioxidant system.

The body antioxidant system is a complex of biologically active chemicals that can weaken the free radical oxidation of organic compounds by reactive oxygen (RO).

The figure shows that the enzymatic and non-enzymatic links of the antioxidant protection provide a stable physiological level of RO including free radicals, but if RO amount exceeds the norm, the oxidative stress occurs.

The study in the content of the main antioxidant enzymes, in particular, superoxide dismutase (SOD) and catalase (CAT) in chickens of different stress resistance has been conducted.

It is expedient to characterize the enzymes studied.

The role of SOD enzyme is to bind superoxide anion, wherein the transformation of highly reactive radicals is catalyzed into the less active hydrogen peroxide and molecular oxygen. The chemistry of the reaction is as follows:

$$\mathrm{M} \cdot \ \ \mathrm{n}+1 \ + -\mathrm{SOD} + \mathrm{O}_2 \cdot - \rightarrow$$
$$\rightarrow \mathrm{Mn} + -\mathrm{SOD} + \mathrm{O}_2,$$

$$\mathrm{Mn} + -\mathrm{SOD} + \mathrm{O}_2 \cdot - + 2\mathrm{H} + \rightarrow$$
$$\rightarrow \mathrm{M} \cdot \ \ \mathrm{n}+1 \ + -\mathrm{SOD} + \mathrm{H}_2\mathrm{O}_2,$$

where M is the transition metal ion (Cu (n = 1); Mn (n = 2); Fe (n = 2). The oxidation state of the cation metal oscillates between n and n + 1.

It should be noted that the superoxide anion is less toxic in comparison with other RO, but it is the primary product of the oxygen reduction and the precursor of other RO forms. Its involvement in the enzymatic reactions of the synthesis of prostaglandin and xenobiotic metabolism enables to consider SOD as an enzyme performing not only protective, but also a regulatory function, because SOD is a key link in the regulation system of the steady-state concentration of superoxide anion [30].

Catalase (Cat) is a heme-containing enzyme from the hydro peroxide group that catalyzes the redox reaction of hydrogen peroxide decomposition:

$$\mathrm{Cat} - \mathrm{Fe3} + \ + \mathrm{H}_2\mathrm{O}_2 = (\text{oxidized catalase}),$$

$$\text{oxidized catalase} \ + 2\mathrm{H}_2\mathrm{O}_2 =$$
$$= \mathrm{Cat} - \mathrm{Fe3} + \ + 2\mathrm{H}_2\mathrm{O}_2 + \mathrm{O}_2\,,$$

The Cat role in the antioxidant protection of the body is as follows: it prevents the accumulation of H_2O_2, therefore, it weakens the negative effect of oxidative stress on the cell [31, 32].

It has been established that the activity of antiperoxide enzymes in the stress resistant broiler chickens is higher than that in stress sensitive ones. Thus, the amount of catalase in the plasma of stress resistant chickens is higher by 17.1% and superoxide dismutase by 18.7%. The data obtained are consistent with the data on the formation of lipid peroxidation during the stress.

The main LPO substrate is mono- and polyunsaturated fatty acids (PUFA), which are a part of cell membranes and lipoproteins. The research has been conducted in the content of fatty acids in the meat of broiler chickens. It has been stated that the total amount of fatty acids including poly saturated and mono saturated ones in the meat samples of stress sensitive and stress resistant broiler chickens is not significantly different, therefore, the amount of mono saturated and poly saturated fatty acids does not affect the intensity of the meat oxidation.

The degree of the oxidative meat deterioration is judged by the peroxide value (PV).

The peroxide value in the meat samples increases during the meat storage. Thus, the peroxide value after 3, 5 and 7 days of storage in the samples of chilled meat of stress sensitive broiler chickens is 0.25; 0.38 and 0.78 mmol of active oxygen per 1 kg. The peroxide value in the meat samples of stress resistant broiler chickens is lower by 25.0%; 31.6% and 45.0% after 3, 5 and 7 days of storage, respectively.

The acid value is one of the main indices of the product quality. During meat production this index characterizes the depth of hydrolytic decomposition and during the storage it indicates the oxidative deterioration along with other characteristic indices.

The acid value of meat of stress resistant broiler chickens is lower by 14.3%; 28.0% and 32.5% after 3, 5 and 7 days of storage, respectively.

The marked increase of the oxidative spoilage of meat of stress sensitive broiler chickens reflects the actual oxidation at low activity of the antioxidant protection and high accumulation of lipid peroxidation products.

Thus, the results of the research conducted show that the degree of oxidative changes in the chilled meat depends on the reactivity of the antioxidant system of poultry and the formation of lipid peroxidation products. The weakening of the antioxidant activity and the activation of free radical oxidation of lipids in the blood plasma of broiler chickens increase the oxidation processes of meat.

There is a hypothesis that the level of intracellular enzymatic antioxidants is under the genetic control and it is caused by genetics. Hence, it can be assumed that the level of sensitivity to stress factors is controlled by genes. Based on the foregoing, it follows that the main reason of meat with defects in the autolysis process is stress. Since the development of stress is controlled by genes, then to prevent the formation of meat with PSE and DFD properties it is necessary to carry out the selection of farm animals and poultry not only in terms of productivity but also of the stress level.

CONCLUSION

The formation reasons of the nontraditional meat quality are various and they can occur both at the stage of production and in the processing. They are, in particular, the influence of stress factors, genetic predisposition, the violation of feeding rations and technological modes of farm animal breeding, and the stunning duration at slaughter. But the main reason for the formation of meat with PSE and DFD properties is the susceptibility of animals and poultry for slaughter to stress controlled by genes. Therefore, to prevent the formation of meat with defects in the autolysis process it is recommended to select farm animals and poultry not only in terms of productivity, but also of the stress level. It is necessary to include comprehensive nutritional additives in the formulation of meat products for the rational use of meat with PSE and DFD properties.

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