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LIPID PEROXIDATION AS A MARKER OF ANIMAL AND POULTRY HEALTH

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Lipid peroxidation (LPO) is an important biochemical process that plays a significant role in the physiology and pathology of living organisms. This phenomenon is the result of the action of reactive oxygen species (ROS) on unsaturated fatty acids that are part of biological membranes. The main radicals that can cause oxidative stress are superoxide anion (O_2^-), hydroxyl radical (OH^-), singlet oxygen ($^1O_2$) and hydrogen peroxide (H_2O_2). These radicals are highly reactive and can cause damage to cellular structures, including lipids, proteins and DNA. Increased ROS intensity is a sign of oxidative stress and can be used as a marker of animal and poultry health. Oxidative stress, caused by an imbalance between the production of free radicals and the efficiency of antioxidant systems, is a key factor in the development of various pathological conditions in farm animals and poultry, including metabolic disorders, reduced productivity, reproductive dysfunction and susceptibility to infectious diseases [5]. Long-term oxidative stress can cause chronic liver disease, cardiovascular disorders, and neuroendocrine dysregulation.

The process of LOS goes through three main stages: initiation, promotion and termination. Initiation involves the formation of free radicals that attack polyunsaturated fatty acids (PUFAs), leading to the formation of primary lipid peroxides. During the propagation stage, a chain reaction occurs that significantly increases the level of VFAs, leading to the formation of more secondary and end oxidation products such as malondialdehyde (MDA) and 4-hydroxynonenal (4-HNE). The final stage, termination, involves the neutralisation of free radicals by the body's antioxidant systems, such as superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx).

Superoxide dismutase (SOD) is a key antioxidant enzyme that catalyses the dismutation of superoxide anion (O_2-) into hydrogen peroxide (H_2O_2) and molecular oxygen (O_2), thereby reducing the toxic effects of superoxides. Catalase (CAT) further breaks down H_2O_2 into water and oxygen, preventing the accumulation of hydrogen peroxide, which can form hydroxyl radical (OH-), one of the most aggressive oxidants

[7]. Glutathione peroxidase (GPx) is an important component of the cell's defence system that neutralises organic and inorganic peroxides using glutathione (GSH) as a cofactor. The action of these enzymes is interrelated, and their efficiency determines the body's ability to withstand oxidative stress. It is the efficiency of these antioxidant enzymes that determines the degree of protection of cells from oxidative stress and plays a critical role in maintaining physiological balance.

High levels of ROS affect vital biological processes, including disruption of cell membrane structure and function, enzyme inactivation, mutagenesis and cell apoptosis. Oxidative damage to membranes leads to loss of cellular integrity, ionic imbalance and destabilisation of metabolism. Studies show that excessive lipid oxidation can contribute to the development of chronic inflammatory diseases, such as mastitis in cows, pulmonary pathologies in poultry, hepatitis and nephropathy. In particular, the accumulation of ROS products in animal liver tissues contributes to impaired detoxification functions, which leads to an increase in the level of endotoxins in the blood. In the cardiovascular system, lipid oxidation can lead to endothelial dysfunction, increased vascular permeability and the development of hypoxic conditions [6].

In addition, it has been found that high levels of lipid peroxidation are associated with impaired oxygen transport across red blood cell membranes, which can negatively affect the overall homeostasis of the body. As a result, the level of tissue oxygenation may decrease, which causes an energy deficit in cells and leads to a general weakening of the body. In poultry, the activation of ROS is associated with an increased susceptibility to infectious diseases due to impaired immune defence, as well as a decrease in reproductive capacity. Long-term oxidative stress has a negative impact on the quality of livestock products, reducing meat and milk production due to disruptions in the biochemical composition of tissues and deterioration of metabolic processes.

Various methods are used to assess the level of lipid peroxidation, including determining the concentration of MDA, which is one of the main markers of lipid peroxidation stress [11, 12]. Other methods include measuring the level of lipid hydroperoxides, determining the ratio of antioxidant enzymes, and analysing the level of 4-HNE. In addition to biochemical methods, modern technologies allow for spectrophotometric and chromatographic analyses that improve measurement accuracy and allow for a detailed assessment of oxidation processes at the cellular level.

Preventing excessive ROS and maintaining the health of livestock and poultry involves the use of antioxidants, which can be endogenous (enzymatic and non-enzymatic systems) or exogenous (vitamins A, E, C, selenium, polyphenols, carotenoids) [8–10].

Endogenous antioxidants are natural components of the body that play a role in protecting cells from oxidative stress. These include enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx), which neutralise reactive oxygen species, preventing damage to cell membranes and intracellular structures. Non-enzymatic endogenous antioxidants include glutathione (GSH), coenzyme Q10 and uric acid, which are involved in the regulation of the antioxidant balance in the body.

Exogenous antioxidants are ingested through food or special feed additives. These include fat-soluble vitamins (A, E, K) and water-soluble vitamins (C), which play an important role in maintaining the functional activity of the antioxidant system. For example, vitamin E is a powerful protector of cell membranes, preventing the oxidation of polyunsaturated fatty acids, and vitamin C effectively reduces oxidised forms of vitamin E. Trace elements such as selenium play a critical role in the functioning of glutathione peroxidase, and polyphenols and carotenoids have additional protective properties by stabilising the level of free radicals in the body [1–4].

Studies have shown that the addition of antioxidants to feed can significantly reduce ROS levels and increase the body's resistance to stressors, reducing the risk of chronic disease and improving performance. In particular, vitamin E and selenium play a key role in protecting cell membranes from damage caused by free radicals, while polyphenols and carotenoids have anti-inflammatory and immunomodulatory properties.

Thus, lipid peroxidation is an important biochemical indicator of animal and poultry health, which allows to assess the level of oxidative stress. The use of antioxidant additives in the diet helps to reduce the negative effects of ROS and increase animal productivity. Further research in this area may contribute to the development of new approaches to monitoring and correction of oxidative stress in veterinary practice, which may be of great importance for the intensification of animal husbandry and improvement of product quality. Another important area of research is the genetic aspects of sensitivity to oxidative stress, which can help to create more stress-resistant breeds of farm animals.

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