Use of antioxidants in poultry farming (review)

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Abstract. An analysis of the literature sources, where the main results of the use of antioxidants in the poultry industry is given in the review article. Adaptation of a bird occurs due to its use of exogenous and endogenous antioxidants under stress. Scientists put forward the natural concept of antioxidant protection of cells. The essence of this protection lies in the fact that antioxidants prevent the leakage of free electrons in the mitochondria of cells by purifying the original radicals. Biologically active compounds, which include antioxidants, are divided into two groups: natural and synthetic. Natural antioxidants in poultry farming are safer, cheaper and can prevent oxidative reactions in food during storage and do not cause metabolic diseases in animals and birds, are a good alternative to synthetic ones.

1. Literature Analysis

The feeding factor for poultry should satisfy physiological needs as much as possible, which directly depends on its usefulness. Negative external technological factors lead to a decrease in productive indicators for growing poultry. The following types of stress factors can be distinguished: temperature, light effects, noise and chemical effects, drug use, feed change, transport effect, technological, biological and experimental factors, mental (rank). Under stress, the adaptation of poultry is due to its use of organic acids, betaine and other natural antioxidants, and therefore, the possibility of providing additional poultry rations with a set of important nutrients can be considered as one of the main elements for successfully combating stress factors [1].

The bird's body is completely deprived of protection from stress factors. During evolution, living organisms developed special antioxidant defense mechanisms. This is called “antioxidant system” in the world scientific literature. The antioxidant system is diverse and responsible for protecting cells from the action of free radicals and includes the following components: natural fat-soluble antioxidants (vitamins A and E, ubiquinones, carotenoids, etc.), water-soluble antioxidants (vitamin C, taurine, uric acid, etc.), antioxidant enzymes: (glutathione peroxidase (GSH-Px), catalase (CAT) and superoxide dismutase (SOD) and a thiol-redox provide maximum cell protection system consisting of glutathione and thioredoxin system. Protective antioxidant compounds are located in organelles, subcellular compounds or extracellular space [2].

Thus, the antioxidant system of a living cell includes three main levels of protection [3, 4]. At the first level, the formation of free radicals is prevented by removing free radical precursors with antioxidant enzymes, SOD, glutathione, GSH-Px and metal binding proteins. The second level of antioxidant protection consists of vitamin E, ubiquinol, carotenoids, vitamin A, ascorbic acid, uric acid,
and some other antioxidants. Hydroperoxides obtained in the reaction of vitamin E with peroxyl radicals are toxic and, if they are not removed, the structure of cell membranes and their functions are disturbed. That is why hydroperoxides should be removed from the cell in the same way as $\text{H}_2\text{O}_2$, but catalase is not suitable for detoxifying these compounds, only selenium-dependent GSH-Px turns hydroperoxides into non-reactive products. However, vitamin E does only half of the work to prevent lipid peroxidation by purifying radicals and the formation of hydroperoxides. The third level of protection is based on systems that eliminate and repair damaged molecules and includes lipases, peptidases or proteases and other enzymes. During this period almost all forms of free radicals are oxidized by methionine residues of proteins consisting of a mixture of R and S isomers of methionine sulfoxide [4].

Thus, scientists are propose the concept of antioxidant protection of cells, the essence of which is that the protection that is activated by incoming antioxidants is based on preventing the leakage of free electrons in the mitochondria of cells by purifying the original radicals. At the final stage, metal ions are bound by metal binding proteins and transformed into non-radical (non-toxic) product. The intermediate radicals are purified, fatally damaged molecules are removed, the synthesis of protective molecules is activated [5].

Consumers pay great attention to the quality of animal products. So the main task of the food industry is based on the quality of meat, for example, in a large store had high visual image characteristics. These indicators include texture, appearance, flavor, tenderness, juiciness and other subjective characteristics [6]. Buyers also prefer fresh meat with good water-holding capacity during processing and cooking, so the water-holding capacity of meat, as well as the color and lack of extraneous odors are the most important indicators of meat [7].

Tactile indicators of meat quality depend on muscle biochemistry and modern processing technologies. [8]. For example, grinding increases the inclusion of oxygen in the muscles, and culinary treatment affects the physical removal of iron bound to the protein of meat in the intracellular space. [9]. Due to the fact that the formation of free radicals causes destruction of the cell membrane structure, muscle tissue in this case could be fuzzy in texture for example, dry, or smeared, or can be a pale in color, or, conversely, too bright red, etc. [10].

One of the approaches to increase the oxidative stability of meat is to add antioxidants during the period of feeding or directly during processing. [11].

Natural tocopherols in the form of extracts of rosemary, green tea and grape seed were added in a total concentration of 100 to 200 mg per 1 kg of feed in order to study the oxidative stability of white meat. The use of natural antioxidants in case of broilers feeding has shown its effectiveness along with synthetic ones. [12, 13]. For example, the inclusion of grape seeds at the feeding stage reduces rancidity and improves the shelf life of chilled semi-finished meat products. [14].

Thus, biologically active compounds, which include antioxidants, are divided into two groups: biological (vitamins, coenzymes, trace elements) and synthetic (diludin, ionol, phenozan, santochin, phenoxane, etc.) [15, 16].

In addition to exogenous antioxidants, the body relies on endogenous defense mechanisms to protect against free radicals. These enzymes metabolize free radicals in the presence of such important micronutrient cofactors as selenium, copper, iron, manganese and zinc. It has been suggested that insufficient intake of these trace elements with food may jeopardize the effectiveness of antioxidant defense mechanisms. The absorption of these elements decreases with age. Figure 1 shows the main physiological antioxidants.

Thus, internal antioxidants presented in the body, but the severity of their action depends on the correct interaction of the components of antioxidant protection, on their concentration, reactivity towards free radicals, and the status of the antioxidants with which it interacts. [13].

Interest in natural antioxidants in the poultry industry in recent years has been increasing. This fact is due that synthetic antioxidants (butylated hydroxyanisole, butylated hydroxytoluene), despite the effectiveness of their use, can provoke the occurrence of various chronic diseases among both consumers and animals and birds, which significantly limits their use. A good alternative to synthetic antioxidants
are natural ones which are safer, cheaper, they are also able to prevent oxidative reactions in products during storage and do not cause metabolic diseases in animals and birds.

Natural antioxidants affect not only the metabolism in the body of the bird during the growing period, but also the oxidation of lipids in meat after slaughter during storage. Poultry meat usually becomes unusable during storage for two main reasons: deterioration of the chemical composition or growth of the microbial population. The most common factor is the so-called chemical wear, meat rancid that is caused by lipid oxidation, or oxidative rancidity, which can vary greatly, from changes in taste to loss of color and structural damage of proteins. Lipid oxidation is the most important problem in animal products: oxidative degradation of lipids damages biological membranes, enzymes and proteins in meat, which can pose a direct threat to human health. [17]

Figure 1. Antioxidant defense system of the body by M. Percival, 1998 [13].

A large proportion of the polyunsaturated fatty acids in poultry meat are susceptible to lipid oxidation. Lipid oxidation is initiated by the fraction of unsaturated fatty acids by auto-oxidation. Compounds formed by lipid oxidation (aldehydes, ketones, acids, alcohols, etc.) are toxic to humans and can cause various chronic diseases [18].

The adding of natural antioxidants to feed is a natural way to increase the internal concentration of antioxidants that slow down the oxidative effects in meat.

Among the sources of natural antioxidants for the poultry industry is, for example, rosemary (Rosmarinus officinalis L.), which affects the further preservation of poultry meat and semi-finished products made from it [19]. The antioxidant properties of natural phytobiotics are mainly related to their phenolic content, thus, their action is similar to synthetic phenolic antioxidants [20]. Green tea (Camellia sinensis) is well-known as an antioxidant that helps reduce the risk of a wide range of chronic diseases such as cancer, diabetes and cardiovascular diseases. Green tea contains epigallocatechin-3-gallate (EGCG), epigallocatechin (EGC), epicatechin-3-gallate (ECG), epicatechin (EC), and flavonoids. These antioxidants inhibit oxidative enzymes [21]. Detection of biologically active phenolic compounds in grape seed extract such as flavonols, plant polyphenols (flavan-3-ol), anthocyanins, tannins and derivatives of phenolic acid was documented [22]. Phenolic compounds in grapes are found both in
In the experiments in vivo it was found out that grape seed extract inhibits the lipid oxidation of poultry during gastric digestion [23]. Clove oil is a natural preservative: inhibits the growth of bacteria and mold. Japanese Chestnut (Castanea crenata), the nuts of which contain an abundance of phenols and hydrolyzable tannins, possess antimicrobial activity against several types of bacteria, including Staphylococcus aureus, Bacillus cereus and Salmonella Typhimurium. Cinnamon is a spice with strong antimicrobial and antioxidant activity. [24]. Colored berries (blueberries, black currants, blackberries, etc.) have become especially popular in the study of antioxidant protection in poultry farming in recent decades. For example, Vaccinium uliginosum L., also known as marsh blueberry, is a wild, short, deciduous shrub that is rich in anthocyanins and flavonols. Tomato is widely cultivated throughout the world. The presence of a high amount of lycopene in tomato, which is a natural red dye, is also an antioxidant. Sunflower seeds and pomegranate peel are good sources of tannins, anthocyanins and flavonoids [25].

The positive dynamics of growth and development of broiler chickens and laying hens was noted, when instead antibiotics, they obtained mandarin peel extract and crushed leaves of moringa oleifera. The improved feed conversion was noted. However, an increase in the moringa oleifera concentration to 15 g per 100 g of feed led to, unfavorable histopathological changes in the kidney tissue and lower egg production compared to the control group; the inclusion of moringa oleifera leaves at a concentration of up to 5 g per 100 g of feed made a yolk color deeper [26]. These results indicate the following: before including components in feed mixtures that are considered safe, it is necessary to examine them carefully for possible anti-nutritional or side effects due to the presence of flavonoids in their composition. The live weight of broilers increases with the inclusion of clove essential oil at a rate from 300 to 500 mg per 1 kg of feed. [27]. An increase in the intestinal population of the Lactobacillus bacteria and the suppression of the Escherichia coli population in the cecum compared to control group of broilers after the introduction of eugenol (4-allyl-2-methoxyphenol), obtained from a tropical plant Eugenia uniflora L., has been reported [28].

The effective antioxidants for broilers that suppress the activity of Escherichia coli are: Echinacea purpurea extract (Echinacea purpurea (L.) Moench), containing β-glucan, shiitake mushroom extract (Lentinula edodes (Berk.) Pegler) that contains betaine and β-curcumin obtained from turmeric (Curcuma longa L.) [29]. However, as the authors note, none of the tested phytobiotics reliably reduced the percentage of chickens during the test period, and did not affect the degree of colibacteriosis damage.

Anticoccidial effect was observed when thymol and carvacrol (obtained from oregano leaves) were added to broiler food. There was a decrease in oocysts number in feces compared to the control group that received coccidioids [30]. The same authors demonstrated an increase in feed conversion: the antimicrobial properties of polyphenols were proven.

A number of researchers have noted the positive effect of using essential oils of oregano (Origanum sp.), leaves of laurel (Laurus nobilis L.), sage (Salvia triloba L.), myrtle (Myrtus communis L.), fennel (Foeniculum vulgare Mill) and citrus peel (Citrus sp.) in an amount of up to 24 mg per 1 kg of feed as a food additive for the production of quail eggs [31]. An unreliable increase in egg productivity was noted, but feed conversion improved. The use of lavender oil (Lavandula stoechas L.) for 21 days during the growth period of broiler chicken in an amount of 24 mg per 1 kg of feed led to an increase in live weight and a decrease in mortality in the experimental group. A mixture of essential oils containing capsaicin, carvacrol and cinnamon aldehyde on broilers in an amount of 400 mg per 1 kg of feed during the period of intensive growth and 150 mg per 1 kg of feed during the final stage of fattening (31 - 42 days) was applied. An increase in body weight and feed efficiency has been found. The authors link the observed trend with the fact that essential oils intensify the replacement of cells in the villi of the intestines, which blocks the intensity of the development of pathogenic microflora. Oskoueian E. et al. confirms the suppression of the vital activity of Campylobacter jejuni, which cause campylobacteriosis with bioactive phenols extracted from blackberry (Rubus fruticosus L.) and blueberry (Vaccinium corymbosum L.) [32]. Patra A.K. et al. [33] noted a positive effect on the overall health of a bird as a result of the consumption of extracts of cumin, anise, coriander and fennel.
Buo et al. [34], after analyzing the literature on the effectiveness of natural antioxidants in order to further improve the quality of poultry meat and eggs found that antioxidants such as vitamin E, ascorbic acid, selenium, polyphenols of oats, rosemary, sage, oregano and milk thistle extract [35] improve the antioxidant protection and preservation of broiler chickens.

Scientists have also attempted to systematize plant antioxidants and their effects. [36]. The results are summarized in table 1.

| Plant | Antioxidant compounds | Antioxidant action |
|-------|-----------------------|-------------------|
| Rosemary (Rosmarinus officinalis L.) | L-carnosine, carnosic acid, rosmadial, diterpenes (epirosmanol, isosmanol, rosmaridiphenol, rosmarichinon, rosmarinic acid) | Lipid antioxidant - acts on the radicals |
| Sage (Salvia officinalis L.) | Carnic acid, rosmanol, rosmadial, methyl and ethyl, rosmarinic acid | Free radical acceptor |
| Oregano (Origanum vulgare L.) | Rosmarinic acid, 3,4-dihydroxycinnamic acid, phenylpropionic acid; flavonoids - apigen, eridectil, dihydroquercetin; carvacrol, thymol | Free radical acceptor |
| Thyme (Thymus vulgaris L.) | Thymol, carvacrol, phenolic acids, phenolic diterpenes, flavonoids | Free radical acceptor |
| Ginger (Zingiber officinale) | Gingerols | Free radical acceptor |
| Turmeric (Curcuma L.) | Turmeric, 4-Hydroxycinnamoylmethane | Free radical acceptor |
| Black pepper (Piper nigrum L.) | Kempferol, ramnetin, quercetin | Free radical acceptor |
| Hot red pepper (Capsicum frutescens) | Capsaicin, capsaicinol | Free radical acceptor |
| Carnation (Dianthus caryophyllus L.) | Phenolic acids (gallic acid), flavonol glucosides, phenolic volatile oils (eugenol, acetylenol, isoeugenol), tannins | Free radical acceptor, metal chelator |
| Marjoram (Majorana majorana L.) | β-carotene, β-sitosterol, caffeic acid, carvacrol, eugenol, hydroquinone, rosmarinic acid, terpinen-4-ol | Free radical acceptor |
| Cumin (Carum carvi L.) | Kumin, γ-terpinene, pinocarveol, linalool, 1-methyl-2- (1-methylethyl) benzene, carotene | Free radical acceptor, metal chelator |

The actual problem is the form of the use of antioxidants. Antioxidants are not able to overcome the barriers of cell membranes because they have a low degree of solubility. Based on this fact, the liposomal form allows you to effectively transport vital structures: as water-soluble, liposoluble or combinations of various antioxidants. [37]. Antioxidants in the liposomal form increased the detoxification activity of the laying hens and reduced the content of xenobiotics, nitrates and nitrates; the accumulation of residual heavy metals presented in the diet was prevented due to their increased excretion from the body of chickens. Liposomal nanoform of silymarin at a dose of 200 g per 1 ton of feed in the diet of broiler chickens caused positive changes in the main physiological and productivity indicators. The
effectiveness of the use of liposomal forms of antioxidants has been proven by Russian scientists in other types of farm animals [38].

Thus, the use of liposomal forms of antioxidants is an important part of further agroecological research in the field of agricultural production aimed at ensuring environmental well-being during the further development of technologies in the agro-industrial complex [39].

2. Conclusion
According to the analysis of literary sources scientists put forward the concept of protecting cells with antioxidants. It is based on preventing the leakage of free electrons in the mitochondria of cells due to the purification of the initial radicals. During antioxidant protection, intermediate radicals are purified by peroxyl radicals (vitamins, glutathions, uric acid, bilirubin, ubiquinol, etc.), damaged molecules are restored and removed; synthesis of protective molecules in cells is activated.

World practice suggests that the quality of animal products is very important for consumers, so it must meet a high level of requirements: have good water-holding capacity during processing and preparation, the color of meat must correspond to the type of meat, the absence of foreign odors, texture, appearance, flavor, tenderness, juiciness and other subjective characteristics, which are the most important indicators characterizing meat. Antioxidants that come with food, ultimately, optimize lipid oxidation in meat after slaughter, because oxidative degradation of lipids in products of natural origin damage biological membranes, enzymes and proteins in meat, which can pose an immediate threat to human health.

The review of the literature sources cited in the article indicates the high interest of poultry scientists all over the world to natural sources of antioxidants. Feed additives from plants with their high content of natural antioxidants can improve the efficiency of growing poultry without compromising product quality. A number of plant sources of natural antioxidants play two important roles in the poultry industry. The first one - phenolic compounds and flavanoids in the composition of antioxidants prevent diseases in birds associated with oxidative stress and the second one – are inhibitors of pathogenic microflora. The liposomal form of antioxidants will allow the selective delivering of vital compounds to tissues in optimal concentrations.

The prospect of increasing export of domestic poultry meat, addresses the issue of obtaining environmentally friendly meat products minimal amount of veterinary drugs and feed additives on a chemical basis. The use of natural antioxidants is another step towards achieving this goal.

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