



Inactivated glutathione yeast action on the activity of quails' antioxidant system

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Antioxidant system is a key element maintaining the metabolic homeostasis in poultry, as it provides the control of active oxygen species and prevents damage to cell structures. Disruption of this balance leads to oxidative stress, accompanied by intensification of lipid peroxidation, decreased enzyme activity, and reduced productivity. Quails (*Coturnix coturnix japonica*) are particularly sensitive to such changes, as they have a high metabolic rate combined with low resistance to zootechnical and environmental stress. In this regard, it is important to find natural products that can maintain antioxidant balance. One of these is inactivated glutathione yeast. For example, EnzActive Protein Powder is a yeast-based supplement, containing high concentrations of reduced glutathione, peptides, β -glucans, and mannan oligosaccharides, which can activate endogenous antioxidant defense mechanisms. The aim of the study was to evaluate the effect of feeding quails with different doses of inactivated glutathione yeast (0.3% and 0.5%) on the activity of antioxidant system enzymes: glutathione peroxidase (GPx), superoxide dismutase (SOD), catalase (CAT), the level of reduced glutathione (GSH), and the malondialdehyde (MDA) content. The experiment was conducted on 45 Manchurian quails, which were divided into three groups (control, T1, T2) according to the analogue principle. Biochemical blood tests were performed on the 14th and 48th days. The results showed that EnzActive Protein Powder promoted an increase in the GPx, SOD, and CAT activities by 9.3–17.9%, an increase in the GSH levels by 7.8–14.5%, and a decrease in the MDA concentration by 11.1–19.5% compared with the control. The obtained data indicate a stimulating effect of the yeast product on the enzymatic and nonenzymatic links of the antioxidant system. The effect was dose-dependent: more changes were observed when using a dose of 0.5%. Thus, feeding the quails with EnzActive Protein Powder contributed to the increased antioxidant enzyme activity, stabilization of redox homeostasis, and reduced lipid peroxidation. The results obtained confirm the relevance of using inactivated glutathione yeast as a natural treatment for oxidative stress in intensive poultry farming. Further research prospects include studying the effects of inactivated glutathione yeast on performance indicators, immune status, and morphofunctional state of the liver in quails.

Keywords: quail; inactivated glutathione yeasts; antioxidant system; glutathione; glutathioneperoxidase; superoxide dismutase; catalase; malondialdehyde; oxidative stress.

Introduction

The antioxidant system of birds is one of the key links ensuring the stability of metabolic processes and physiological homeostasis. It regulates the level of active oxygen species (AOS) and lipid peroxidation products (LPP) in cells, preventing the development of oxidative stress. An imbalance between the free radical formation and the body's ability to neutralize them leads to destructive changes in membranes, impaired enzymatic activity, and weakened immunity, resulting in reduced poultry productivity (Surai et al., 2019; Oke et al., 2024). Among domestic poultry species, Japanese quails (*Coturnix coturnix japonica*) are characterized by an extremely high metabolic rate and, accordingly, increased sensitivity to stress factors. Even slight fluctuations in the temperature, stocking density, or feed quality can cause oxidative imbalance in them. Therefore, it is strongly important for quails to provide effective antioxidant support, which promotes adaptation to intensive farming conditions and maintains high productivity (Abbas et al., 2022).

The antioxidant system of birds comprises enzymatic and nonenzymatic components. Enzymatic components include superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) – enzymes that act sequentially, neutralizing superoxide anion and hydrogen peroxide, converting them into water and oxygen. Nonenzymatic components include reduced glutathione (GSH), tocopherol, ascorbate, carotenoids, and other low-molecular-weight antioxidants that stabilize

cell structures and prevent lipid peroxidation (Ighodaro et al., 2018). Especially important in this system is glutathione, a general intracellular antioxidant that maintains redox homeostasis and participates in protein glutathionylation reactions and regeneration of other antioxidants. The strengthening of the glutathione link in antioxidant protection is directly related to increased GPx activity and more effective control of LPO processes (Marković et al., 2018; Hou et al., 2020). By contrast, the accumulation of malondialdehyde (MDA) is considered an indicator of the intensity of lipoperoxidation and a marker of oxidative damage to cell membranes (Marković et al., 2018).

Modern strategies for preventing oxidative stress in poultry farming are based on the use of natural antioxidants – tocopherol, ascorbic acid, plant-derived polyphenols (Ding et al., 2021), as well as organic forms of trace elements, primarily selenium (Hou et al., 2020). In recent years, microbial bioproducts, in particular the *Saccharomyces cerevisiae* yeasts, have been attracting interest. These microorganisms are a natural source of protein, β -glucans, mannan oligosaccharides, peptides, and a number of antioxidant compounds that can comprehensively affect the immune response, intestinal barrier properties, and antioxidant status of the body (Wang et al., 2021).

Recent studies have shown that yeast autolysates and cell walls of *S. cerevisiae* stimulate the activity of GPx, SOD, and CAT, reducing MDA levels in broilers and quails (Liu et al., 2018; Reda et al., 2021). Selenium-containing yeast, in turn, activates the glutathione-thioredoxin system and increases the tissue antioxidant resistance (Hou et al.,

2020; Abbas et al., 2022). Ukrainian scientists also confirm the high biological activity of yeast preparations. Thus, Romanovych et al. (2019) found a decrease in the intensity of oxidative modification of proteins and a stabilization of antioxidant status in the broiler chickens under the *S. cerevisiae* action, and Prudyus et al. (2016) noted an improvement in lipid metabolism and an increase in the activity of antioxidant enzymes in the poultry when they were fed the biologically active supplement Activo.

Recently, there has been a growing scientific interest in inactivated glutathione yeast, which produces increased amounts of reduced glutathione, yeast peptides, and cell wall polymers, thereby promoting the activation of hepatoprotective and detoxifying effects, including the Nrf2-dependent transcription activation of antioxidant genes (Uchida et al., 2024). However, the scientific literature offers limited systematic data regarding the effects of such products on quails, particularly concerning the dose-dependent responses and the temporal dynamics of changes within the GPx–SOD–CAT–GSH–MDA system.

EnzActive Protein Powder is obtained through a specially developed fermentation process of a unique *S. cerevisiae* strain, which allows yeast cells to synthesize and accumulate glutathione naturally. The supplement is a natural source of high-quality protein, B vitamins, and minerals (calcium, phosphorus, potassium, magnesium, copper, iron, zinc, manganese, and chromium). Yeast protein is well balanced in terms of amino acid composition, making it a valuable component in animal feed. In addition, the yeast cell wall contains β -glucans and mannans, which have an immunomodulatory effect, stimulate the body's natural defenses, and are capable of binding toxins in the digestive tract.

Studies of the glutathione bioavailability in encapsulated yeast, conducted using an artificial digestion model and intestinal cells (Caco-2, HT29-MTX) showed that glutathione encapsulated in yeast cells is preserved during passage through the digestive tract, is partially released in the gastrointestinal environment, and can penetrate intestinal epithelial cells. Thus, the yeast cell acts as a natural biocapsule that protects glutathione from destruction in the acidic environment of the stomach and ensures its gradual release and effective absorption. In fact, this method of antioxidant administration is the most effective (Musatti et al., 2014).

As part of animal diets, glutathione yeast can:

- strengthen the body's antioxidant system;
- reduce oxidative stress during heat, metabolic, or transport stress;
- improve liver function and intestinal barrier integrity;
- stimulate immune stability and increase nutrient absorption;
- promote feed efficiency and stimulate animal performance, especially during stressful stages of growth and development.

Thanks to these properties, glutathione yeast has high potential as a natural bioactive feed additive that promotes animal health and performance.

The objective of the study was to determine the effect of the inactivated glutathione yeast EnzActive Protein Powder on the activity of antioxidant system enzymes (GPx, SOD, CAT), the level of reduced glutathione (GSH), and the content of malondialdehyde (MDA) in quails. Furthermore, we assessed the dose-dependence of the effect at levels of 0.3% and 0.5% in the feed composition.

Materials and methods

The study was conducted under the conditions of the industrial complex of the individual entrepreneur Kharyna, Lviv Oblast. The object of the study was the Manchurian meat-egg quail. For the study, three groups were formed (using the analogue principle): control (C), trial 1 (T1), and trial 2 (T2) of 15 birds each (Table 1). The birds had free access to feed and water and consumed the same compound feed balanced in terms of nutrients and biologically active compounds. From the 20th day of life, the trial groups were given inactivated glutathione yeast in the form of the EnzActive Protein supplement, T1 receiving 0.3% and T2 receiving 0.5% per 1 ton of compound feed.

EnzActive Protein Powder contains inactivated yeasts based on a specially selected *Saccharomyces cerevisiae* strain, which (thanks to a

developed fermentation process) is able to naturally accumulate glutathione, one of the key antioxidants that can reduce the effects of stress.

EnzActive Protein Powder is a product in the form of a finely dispersed powder with the following main nutritional characteristics: humidity – < 8.0%, protein \geq 55.0%, beta-glucans \geq 13.0%, mannonoligosaccharide complexes \geq 12.0%, glutathione \geq 1.8%.

Glutathione yeast is highly stable and versatile, making it easy to incorporate into any type of feed, including compound feed, premixes, and functional additives. Thanks to a special manufacturing technology, EnzActive Protein Powder is a heat-resistant product and retains its nutritional and biologically active properties during storage, transportation, and technological processes such as granulation or extrusion. In the recommended dosages, glutathione yeast is suitable for all types of productive and domestic animals and can be used as an additional source of high-quality, easily digestible protein, B vitamins, trace elements, and bioactive components with pronounced antioxidant and immunomodulatory effects.

The EnzActive Protein Powder supplement was introduced into the basic diet of the poultry according to the following scheme (Table 1).

Table 1
Experimental design

Group	Number of birds	Diet
Control	15	Base diet (OP)
Trial 1	15	OP + 0.3% EnzActive Protein
Trial 2	15	OP + 0.5% EnzActive Protein

Blood samples from seven animals from each group were taken for biochemical studies on the 14th and 48th days of the experiment. The content of protein carbonyl groups (PCG) in blood plasma was measured using 2,4-dinitrophenylhydrazine (DNPH) as an indicator of protein oxidation. This involved assessing the formation of additional carbonyl groups and calculating their amount per 1 mg of protein (Lushchak et al., 2004). The content of lipid hydroperoxides (HPL) was determined with the method of V. V. Myronchuk; the TBA-active products in blood plasma were measured using the malondialdehyde (MDA) color reaction with thiobarbituric acid (Korobeynikov, 1989); and the reduced glutathione level (GSH) in erythrocytes was determined according to E. Beutler, O. Dubon, and B. Kelly (Methods for determining ..., 1982). The superoxide dismutase (SOD, 1.1.15.1) activity was measured using the method based on the reduction of nitroterazolium by superoxide radicals and was expressed in conventional units per 1 mg of protein (Dubinina et al., 1983). The catalase (CAT, 1.1.6) activity was determined according to the ability of hydrogen peroxide to form a stable colored complex with molybdenum salts (Korolyuk et al., 1988). The glutathione peroxidase (GP, 1.11.1.9) activity was determined by the rate of oxidation of reduced glutathione and was expressed in $\mu\text{mol}/\text{min}$ per 1 mg of protein (Moin, 1986). The glutathione reductase (GR) activity was measured spectrophotometrically by the glutathione reduction rate in the presence of NADPH, expressed in $\mu\text{M NADPH}/\text{min} \times \text{mg protein}$ (Vlizlo et al., 2012).

The statistical analysis of the study results was performed using one-way ANOVA with Bonferroni correction, as well as one-way Tukey analysis. For this purpose, the StatPlus program (AnalystSoft Inc., USA) was used. The results are presented as Mean \pm SD (mean standard error). Differences among the groups of animals were considered statistically significant at $P < 0.05$.

Results

The first signs of antioxidant system activation in the quails were observed two weeks after the start of intake of the inactivated glutathione-enriched yeast (Table 2). An increase in the reduced glutathione (GSH) level was recorded in blood of the birds of the experimental groups: 4.1% in T1 and 9.3% in T2 ($P < 0.01$), compared with the control. This indicates that the body started to accumulate internal resources to protect against oxidative stress. A higher level of glutathione is one of the first signals of activation of the redox system that helps cells maintain a balance between oxidation and reduction processes. The glutathione peroxidase (GPx) activity in the quails also in-

creased. In the group T1, this parameter exceeded the control by 4.7%, and in T2 – by almost 10% ($P < 0.01$). Glutathione peroxidase is known to work together with glutathione and prevent the accumulation of lipid peroxides, so the increase in its activity can be considered a clear sign of increased antioxidant protection in the early stages of the supplement effect.

Table 2

Biochemical parameters of antioxidant system in blood of quails on 14th day of intake of the inactivated glutathione yeast (% , $x \pm SD$; $n = 7$)

Parameters	Control	Trial 1	Trial 2
Reduced glutathione (GSH), $\mu\text{mol/L}$	1.72 \pm 0.07 ^a	1.79 \pm 0.06 ^{ab}	1.88 \pm 0.05 ^b
Glutathione peroxidase (GPx), nkat/mL	84.31 \pm 2.71 ^a	88.25 \pm 3.02 ^{ab}	92.14 \pm 3.11 ^b
Superoxide dismutase (SOD), U/mL	55.32 \pm 1.84 ^a	58.11 \pm 2.02 ^{ab}	60.27 \pm 1.96 ^b
Catalase (CAT), mkat/L	34.55 \pm 1.38 ^a	35.92 \pm 1.41 ^a	37.98 \pm 1.27 ^b
Malondialdehyde (MDA), nMol/mL	5.71 \pm 0.22 ^a	5.43 \pm 0.21 ^{ab}	5.08 \pm 0.19 ^b

Note: different letters within the same parameter denote selections that differ significantly from each other according to the Tukey test ($P < 0.05$).

Catalase (CAT) reacted more moderately. In T1, only a tendency toward growth was observed, while in T2, the enzyme activity was significantly higher by 9.9% ($P < 0.05$). This sequence is quite logical, since catalase acts after superoxide dismutase, decomposing hydrogen peroxide formed during its operation. Thus, a balanced antioxidant system gradually forms in quails when the enzymes work in a coordinated chain.

The most noticeable changes were related to malondialdehyde (MDA), an indicator of the lipoperoxidation intensity. Its level in the blood decreased by 4.9% in T1 and by 11.0% in T2 ($P < 0.01$) compared with the control. This indicated a decrease in the free radical production and a stabilization of cell membranes. In other words, the quails that received the supplement had reduced oxidative stress – one of the main causes of cell damage and reduced poultry productivity.

Generally, the first positive changes in the antioxidant system functioning in the quails could be seen as early as the 14th day. The body gradually adapted to the yeast bioactive components contained in EnzActive Protein Powder and responded to them by activating glutathione cycle enzymes and improving the overall redox balance. These results indicate that even short-term use of the supplement triggers the body's natural defense mechanisms against oxidative stress.

Table 3

Biochemical parameters of the blood antioxidant system of the quail on 48th day of consuming the inactivated glutathione yeast (% , $x \pm SD$; $n = 7$)

Parameters	Control	Trial 1	Trial 2
Reduced glutathione (GSH), $\mu\text{mol/L}$	1.79 \pm 0.06 ^a	1.92 \pm 0.07 ^b	2.05 \pm 0.05 ^b
Glutathione peroxidase (GPx), nkat/mL	90.23 \pm 2.84 ^a	98.11 \pm 3.15 ^b	104.67 \pm 3.22 ^c
Superoxide dismutase (SOD), U/mL	57.86 \pm 1.83 ^a	62.94 \pm 2.01 ^{ab}	66.48 \pm 1.95 ^b
Catalase (CAT), mkat/L	36.72 \pm 1.45 ^a	39.58 \pm 1.37 ^{ab}	41.12 \pm 1.29 ^b
Malondialdehyde (MDA), nmol/mL	5.47 \pm 0.21 ^a	4.92 \pm 0.18 ^{ab}	4.41 \pm 0.16 ^b

Note: see Table 2.

The superoxide dismutase (SOD) activity increased by 8.8% in the T1 quails and by 14.9% in the T2 quails ($P < 0.05$). This means that even after a month and a half of supplementation, the antioxidant system remained not only sufficient, but even worked more actively. The enzymatic link continued to steadily neutralize the excess active oxygen species, which is important for maintaining cellular integrity.

Catalase (CAT) also showed an upward trend – its activity in T1 exceeded the control by 7.8% and in T2 by 12.0% ($P < 0.05$). Such consistency in the work of SOD and CAT enzymes indicates the effective functioning of a unified enzymatic defense system aimed at converting active forms of oxygen into harmless compounds.

The level of malondialdehyde (MDA) in the quails' blood decreased by 10.1% in T1 and by 19.4% in T2 ($P < 0.01$), compared with the control. This is direct evidence of a decrease in the intensity of lipid peroxidation and a stabilization of cell membranes. The decrease in MDA indicates that the antioxidant system not only became more active but also began to effectively inhibit the processes of lipoperoxidation. We can sum up that by the 48th day of action of inactivated glutathione yeast, the enzymatic and nonenzymatic links of antioxidant protection in the quails were fully formed. The most pronounced effect was observed in the T2 group, indicating a dose-dependent effect of the supplement. The data obtained confirm that inactivated glutathione

Similar changes were observed for superoxide dismutase (SOD). The enzyme activity increased by approximately 5% in T1 and by 8.9% in T2 ($P < 0.05$). This means that on the 14th day, the quails demonstrated an increase in the first line of enzymatic defense, which is responsible for neutralizing the most aggressive oxygen forms.

After 48 days of feeding the quails with inactivated glutathione yeast, the effect was more visible than at the beginning of the experiment (Table 3). By this time, a stable antioxidant background had formed in the birds' bodies, as confirmed by reliable changes in almost all of the studied parameters.

The reduced glutathione level (GSH) was 7.3% higher in blood of the group T1 quails than in the control group ($P < 0.05$), and 14.5% higher in the group T2 ($P < 0.01$). Compared with the 14th day, this parameter showed a more sustained increase, indicating the accumulation of glutathione compounds in cells and an increase in the total antioxidant capacity of plasma. Such dynamics indicate that the birds' bodies have adapted well to the action of the bioactive components of the yeast supplement.

The activity of glutathione peroxidase (GPx) increased most significantly. In the T1 quails, it exceeded the control by 8.7% ($P < 0.05$), and in T2 – by 16.0% ($P < 0.01$). This indicates an increase in enzymatic detoxification of peroxides, which is the main mechanism for reducing oxidative stress. The higher GPx levels combined with the increased GSH content confirm the effectiveness of glutathione cycle activation, which ensures neutralization of lipoperoxidation products.

thione yeast not only activates the redox systems of the body, but also contributes to maintaining their stable functioning over a long period.

Discussion

The results obtained convincingly demonstrate that feeding quails with the EnzActive Protein Powder supplement, based on inactivated glutathione yeast, had a positive effect on the functioning of antioxidant system. Just a few weeks after the start of the supplement intake, we observed an increase in the activity of the main antioxidant defense enzymes in the birds' blood – glutathione peroxidase, superoxide dismutase, and catalase, as well as an increase in the reduced glutathione level and a decrease in the malondialdehyde content. This indicates the restoration of redox homeostasis and effective neutralization of active oxygen species. The observed changes were dose-dependent: in the group T2, the effect of EnzActive Protein Powder was more intense than in T1, which is fully consistent with the data of other authors who proved the stimulating effect of yeast products on the enzymatic link of the antioxidant system (Surai, 2019; Hou et al., 2020).

Glutathione yeast extract is rich in L-glutathione. It is used as nutritional and feed additives. It exhibits antiaging property, enhances immune system, and improves livestock quality. It acts as an antioxi-

dant. It is used as a supplement for people with metabolic disorders and is also used in the treatment and prevention of angina symptoms and chronic fatigue syndrome. It may help in relieving chronic bronchitis symptoms, and it supports immune system. Yun-Ho Kim et al., 2017 showed that dry-YE containing component glutathione (GSH) may act as a potent antioxidant by antagonizing ROS production. In addition, there was no cytotoxicity observed in $\leq 50 \mu\text{g/mL}$ dry-YE-treated bronchial epithelial cells.

Glutathione yeast is considered an innovative biotechnological product suitable for the use in animal husbandry, crop production, and microbial nutrition. According to the description of the invention, such products are capable of providing balanced nutrition, improving digestion and nutrient absorption, stimulating growth, as well as boosting the body's immunity and reducing the risk of disease. Therefore, glutathione yeast can be considered a universal bioactive supplement for improving the health and productivity of animals, plants, and microorganisms, which highlights its high potential in modern feed and biotechnological solutions (WO2023125992A1, Glutathione yeast, preparation method and use of product).

The increase in the reduced glutathione content and glutathione peroxidase activity in our experiments has a clear biochemical explanation. Yeast cells contain natural precursors of glutathione (cysteine, glycine, glutamic acid, and peptides), that activate its synthesis in hepatocytes. As noted by Ighodaro & Akinloye (2018), glutathione is the main intracellular reductant that maintains the balance between oxidation and reduction processes, preventing damage to cellular structures. Similar effects of increasing GPx and SOD while decreasing MDA have been described in the studies by Hou et al. (2020) and Chen et al. (2017) using selenium-containing yeast in broiler feed.

The increase in SOD and CAT activity in our quails also confirms the activation of the enzymatic link in the antioxidant defense. These enzymes work sequentially: SOD converts superoxide anion to hydrogen peroxide, and catalase further decomposes it into water. The coordinated action of these enzymes prevents the formation of highly reactive radicals and ensures the stability of cell membranes. Similar results were reported by Liu et al. (2018) and Marković et al. (2018), in particular an increase in the activity of antioxidant enzymes and an improvement in the redox status of tissues when yeast products were used in poultry.

Interestingly, Aydin et al. (2022) observed similar patterns, where the intake of combined probiotic and enzyme supplements by the quails also contributed to an increase in the GPx, SOD, and CAT activity and a decrease in the MDA levels. This confirms the universality of the biochemical response of quails to natural antioxidant factors, regardless of the source of the active components.

The reduction in the malondialdehyde content in our trials deserves special attention. Since MDA is the end product of lipid peroxidation, its reduction directly indicates the inhibition of free radical processes and membrane stabilization. Reda et al. (2021) and Abbas et al. (2022) observed a similar trend during the study of the effects of yeast autolysates in quails and ducks. The effect we obtained is most likely due to the synergistic action of enzymatic (SOD, CAT, GPx) and nonenzymatic (GSH) components of the antioxidant system, which interact to control free radical reactions.

The gradual increase in the effect up to 48 hours can be explained by the activation of the Nrf2 transcription factor, a key regulator of antioxidant enzyme gene expression (Surai, 2019). It is known that glutathione and its oxidized forms can act as signalling molecules that activate Nrf2-dependent pathways and stimulate the GPx, SOD, and CAT synthesis. This indicates that EnzActive Protein Powder acts not only as a source of external antioxidants but also as an inducer of intracellular defense mechanisms.

Our results are consistent with Ukrainian scientific data. Prudius et al. (2016) found that the biologically active additive Activo increased the activity of SOD and GPx in the broilers, while Romanovych et al. (2019) showed a decrease in the intensity of oxidative proteins modification and a redox system stabilization under the action of the yeast *S. cerevisiae*. Hunchak et al. (2018) found that the inclusion of microelement supplements in the diet of the quails improved the protein metabolism and increased productivity. Thus, the results of our

work are consistent with domestic studies and complement them with new data on the mechanisms of action of inactivated glutathione yeast.

The observed dose-dependence ($T2 > T1 > \text{control}$) is consistent with the reports of Hou et al. (2020), who showed that increasing the yeast level or selenium-containing products is accompanied by increased antioxidant responses. Therefore, the effect of EnzActive Protein Powder is due to a combination of direct antioxidant action and stimulation of endogenous glutathione synthesis.

From a practical point of view, increasing antioxidant potential is an important precondition for quail resistance to zootechnical and environmental stress, stabilization of metabolic processes, and maintaining productivity even under intensive rearing conditions (Surai et al., 2019; Reda et al., 2021). Thus, the results of the study confirm the feasibility of using inactivated glutathione yeast as a natural, safe, and effective product to increase the antioxidant status of quails and prevent oxidative stress.

Conclusion

Feeding the quails with the supplement EnzActive Protein Powder, based on inactivated glutathione yeast, contributed to the activation of the body's antioxidant system. On the 14th day, we observed an increase in the level of reduced glutathione (GSH) and antioxidant defense enzymes (GPx, SOD, CAT) and a decrease in malondialdehyde (MDA), which indicate the formation of an adaptive redox response of the body to the bioactive components of the supplement.

On the 48th day, the effect of EnzActive Protein Powder increased: GPx and SOD activity exceeded the control by 8.7–16.0% and 8.8%–14.9%, respectively, and the MDA level decreased by 10–19%. This indicated the accumulation of glutathione, the coordinated action of the enzymatic and nonenzymatic links of the antioxidant system, and the stabilization of cellular redox homeostasis.

The revealed dose-dependent effect ($T2 > T1 > \text{control}$) confirms that the effectiveness of EnzActive Protein Powder increases with higher inclusion levels in the diet. The optimal effect is manifested with long-term use, when the glutathione cycle is activated and the intensity of lipid peroxidation decreases.

Inactivated glutathione yeast is considered a promising natural product to prevent oxidative stress in quails. Its use contributes to increasing antioxidant resistance, improving metabolic processes and potentially poultry productivity under intensive breeding conditions.

The authors state that they have no conflict of interests.

References

- Abbas, A. O., Alaqil, A. A., Mehaisen, G. M. K., & El Sabry, M. I. (2022). Effect of organic selenium-enriched yeast on relieving the deterioration of layer performance, immune function, and physiological indicators induced by heat stress. *Frontiers in Veterinary Science*, 9, 880790.
- Aydin, Ö., Duma, Y., Yildiz, G., Merhan, O., Ulufer, S., Önk, K., Baran, M. S., & Kaplan, O. (2022). Feeding Japanese quail diets supplemented with probiotics and enzymes. *South African Journal of Animal Science*, 52(3), 383–391.
- Chen, F., Zhu, L., Qiu, H., & Qin, S. (2017). Selenium-enriched *Saccharomyces cerevisiae* improves growth, antioxidant status and selenoprotein gene expression in Arbor Acres broilers. *Journal of Animal Physiology and Animal Nutrition*, 101(2), 259–266.
- De Vero, L., Bonciani, T., Verspohl, A., Mezzetti, F., & Giudici, P. (2017). High-glutathione producing yeasts obtained by genetic improvement strategies: A focus on adaptive evolution approaches for novel wine strains. *AIMS Microbiology*, 3(2), 155–170.
- Desbruslais, A., & Wealleans, A. L. (2022). Oxidation in poultry feed: Impact on the bird and the efficacy of dietary antioxidant mitigation strategies. *Poultry*, 1(4), 246–277.
- Ding, X. M., Mu, Y. D., Zhang, K. Y., Wang, J. P., Bai, S. P., Zeng, Q. F., & Peng, H. W. (2021). Vitamin E improves antioxidant status but not lipid metabolism in laying hens fed an aged corn-containing diet. *Animal Bioscience*, 34(2), 276–284.
- Dubiniina, E. E., Salnikova, L. Y., & Efimova, L. F. (1983). Activity and isoenzyme spectrum of erythrocytes superoxide dismutase. *Laboratorna Robotika*, 10, 30–33 (in Ukrainian).

- Gunchak, A. V., Medvid, S. M., & Sirko, Y. M. (2018). Intensyvniŭ proteynovoho obminu v orhanizmi perepilok ta yikhnya nesuchist' za vykorystannya mikroelementnykh dobavok do ratsioniv [Intensity of protein metabolism in quails and their egg production when using microelement additives in diets]. *Tavriskiyi Naukoviyi Visnyk, Silskohospodarski Nauky*, 102, 94–99 (in Ukrainian).
- Hou, L., Qiu, H., Sun, P., Zhu, L., Chen, F., & Qin, S. (2020). Selenium-enriched *Saccharomyces cerevisiae* improves the meat quality of broiler chickens via activation of the glutathione and thioredoxin systems. *Poultry Science*, 99(11), 6045–6054.
- Ighodaro, O. M., & Akinloye, O. A. (2018). First line defence antioxidants – superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx): Their fundamental role in the entire antioxidant defence grid. *Alexandria Journal of Medicine*, 54(4), 287–293.
- Korobeynikov, Y. (1989). Modifikatsiya metodu vyznachennia produktiv perekysnoho oksyennia lipidiv u reaktsiyi z tiobarbiturovoyu kyslotoyu. *Laboratorna Robota*, 7, 8–10 (in Ukrainian).
- Korolyuk, M. A., Ivanova, L. I., Mayorova, I. H., & Tokarev, V. Y. (1988). Metod vyznachennia aktyvnosti katalazy. *Laboratorna Robota*, 1, 16–18 (in Ukrainian).
- Liu, N., Wang, J., Liu, Z., Wang, Y., & Wang, J. (2018). Effect of supplemental yeast cell walls on growth performance, gut mucosal glutathione pathway, proteolytic enzymes and transporters in growing broiler chickens. *Journal of Animal Science*, 96(4), 1330–1337.
- Lushchak, V. I., Bahniukova, T. V., & Lushchak, O. V. (2004). Pokaznyky oksydatyvnoho stresu. 1. Produkty, shcho reahuyut' z tiobarbiturovoyu kyslotoyu, ta karbonil'ni hrupy bilkiv. *Ukrayinskyyi Biokhimichnyi Zhurnal*, 76(3), 136–141 (in Ukrainian).
- Marković, R., Ćirić, J., Drljačić, A., Šefer, D., Jovanović, I., Jovanović, D., Milanović, S., Trbović, D., Radulović, S., Baltić, M., & Starčević, M. (2018). The effects of dietary selenium-yeast level on glutathione peroxidase activity, tissue selenium content, growth performance, and carcass and meat quality of broilers. *Poultry Science*, 97(8), 2861–2870.
- Mironchik, V. V. (1984). Sposib vyznachennia lipidnykh hidroperekysdiv u biolohichnykh tkanyakh. Patent SRSR № 1084681, MKV G №33/48, (SRSR) №3468369/28-13. Zayavl. 07.08.1982; Opubl. 04.07.1984, Byul. №13 (in Ukrainian).
- Moin, V. M. (1986). A simple and specific method for determining the activity of glutathione peroxidase in erythrocytes. *Laboratorna Robota*, 12, 724–727 (in Ukrainian).
- Oke, O. E., Akosile, O. A., Oni, A. I., Opowoye, I. O., Ishola, C. A., Adebisi, J. O., Odeyemi, A. J., Adjei-Mensah, B., Uyanga, V. A., & Abioja, M. O. (2024). Oxidative stress in poultry production. *Poultry Science*, 103(9), 104003.
- Pascual, A., Pauletto, M., Giantin, M., Radaelli, G., Ballarin, C., Birolo, M., Zomeño, C., Dacasto, M., Bortoletti, M., Vascellari, M., Xiccato, G., & Trocino, A. (2020). Effect of dietary supplementation with yeast cell wall extracts on performance and gut response in broiler chickens. *Journal of Animal Science and Biotechnology*, 11, 40.
- Perricone, V., Sandrini, S., Irshad, N., Savoini, G., Comi, M., & Agazzi, A. (2022). Yeast-derived products: The role of hydrolyzed yeast and yeast culture in poultry nutrition – A review. *Animals*, 12(11), 1426.
- Prudyus, T. Y. (2025). Feed additive “Activo” influence on several antioxidant defense system parameters of sows and their progeny. *Biolojiya Tvaryn*, 27(1), 48–52 (in Ukrainian). <http://doi.org/10.15407/animbiol27.01.048>
- Prudyus, T. Y., Kyrlyiv, Y. I., & Barylo, B. S. (2016). Vplyv biolohichno aktyvnoyi kormovoyi dobavky Aktyvo na pokaznyky lipidnoho obminu ta antyoksydantnyi stan kurchat-broileriv [Effect of biologically active feed additive Activo on lipid metabolism and antioxidant status of broiler chickens]. *Naukoviyi Visnyk Lvivs'koho Natsional'noho Universytetu Veterynamoyi Medytsyny ta Biotekhnolohiyi imeni S. Z. Gzhytskoho*, 65 (in Ukrainian).
- Reda, F. M., Alagawany, M., Sabry, R., & El-Mekawy, M. (2021). Does dietary yeast extract improve the performance and health of quail breeders reared under high stocking density? *Journal of Animal and Poultry Production*, 12(12), 409–418.
- Romanovych, N. N., Kurtyak, B. M., Romanovych, M. S., Vishchur, O. I., Mudrak, D. I., & Matiukha, I. O. (2019). Dynamika intensyvnosti oksydneyi modyfikatsiyi proteiniv i stan antyoksydantnoho zakhystu kurchat-broileriv za diyi drizhdzhiv *Saccharomyces cerevisiae* [Dynamics of oxidative modification of proteins and antioxidant defense status of broiler chickens under the action of *Saccharomyces cerevisiae* yeast]. *Biolojiya Tvaryn*, 21(1), 48–54 (in Ukrainian).
- Surai, P. F. (2020). Antioxidants in poultry nutrition and reproduction: An update. *Antioxidants*, 9(2), 105.
- Surai, P. F., Kochish, I. I., Fisinin, V. I., & Kidd, M. T. (2019). Antioxidant defence systems and oxidative stress in poultry biology: An update. *Antioxidants*, 8(7), 235.
- Uchida, Y., Ferdousi, F., Takahashi, S., & Isoda, H. (2024). Comprehensive transcriptome profiling of antioxidant activities by glutathione in human HepG2 cells. *Molecules*, 29(5), 1090.
- Wang, T., Cheng, K., Yu, C. Y., Li, Q. M., Tong, Y. C., Wang, C., Yang, Z. B., & Wang, T. (2021). Effects of a yeast-derived product on growth performance, antioxidant capacity, and immune function of broilers. *Poultry Science*, 100(9), 101343.
- Zhao, H., Chen, Y., Wang, S., Wen, C., & Zhou, Y. (2021). Effects of dietary natural vitamin E supplementation on laying performance, egg quality, serum biochemical indices, tocopherol deposition and antioxidant capacity of laying hens. *Italian Journal of Animal Science*, 20(1), 2254–2262.