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Productive and metabolic effects of yeast prebiotic feed additive in goose feeding rations

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Intensive farming technologies involve the use of a significant number of substances, particularly antibiotics and hormones, which can negatively affect the quality of meat products and overall animal health. This necessitates the development and implementation of new technologies and methods to optimize waterfowl diets that improve digestion and nutrient absorption. Therefore, our studies used a yeast prebiotic feed additive – Inactivated Dry Glutathione Yeast, to assess the effects of its optimal amount on the productivity, hematological, and biochemical blood parameters of Obroshyn white geese. The birds in the control group received the main ration in accordance with the farm's feeding standards. The geese from the three experimental groups were fed a prebiotic feed additive at 150, 200, and 250 g/t, respectively, in the compound feed. The experiment used modern zootechnical, physiological-biochemical, and statistical research methods. The conducted studies revealed that the best productivity indicators were those of the geese fed the prebiotic in a dose of 200 g/t of feed. They had higher egg production than the control. The results of egg incubation showed that fertilization increased by 7.2% and that gosling hatching increased by 7.2%. The analysis of the physiological state of the birds during feeding with the prebiotic supplement did not reveal a significant difference between the groups in the levels of the biochemical indicators studied, which remained within physiological limits. An improvement in the fractional composition of feather and down raw materials was observed in all experimental groups, indicating better quality during intensive molting (50 days). No significant difference was found for these indicators. However, it was noted that in the geese that received 200 g of the supplement with feed, feather and down qualities improved at a level of a tendency. The results obtained indicate the feasibility of using the prebiotic Inactivated Dry Glutathione Yeast as part of the main diet for the Obroshyn white geese, due to its ability to improve digestion processes and, therefore, metabolism, and to positively influence the productivity and reproductive performance. Based on the productive and metabolic effects, 200 g of the prebiotic supplement per 1 t of feed is the optimal dose for the feeding ration of geese.

Keywords: Waterfowl; feeding; yeast supplement; productivity; reproductive capacity; biochemical indicators.

Introduction

Goose farming plays a significant role in Ukraine's poultry industry. Geese can consume bulky feed with a high fiber content, are characterized by high precocity and growth intensity, are a source of meat with high taste qualities, and provide valuable raw materials such as feathers and down for various industries (Lewko et al., 2017; Wasti et al., 2020).

Research by domestic and foreign scientists shows that the genetic potential of poultry productivity can be successfully realized only if complete and balanced feeding is provided (Bratyshko et al., 2013). In recent years, to normalize metabolic processes in farm animals and poultry and increase their productivity, pro- and prebiotic preparations have been used as feed additives, which have a positive effect on the body by improving its intestinal microbial balance (Mountzouris et al., 2007; Ajuwon, 2016). A balanced system of standardized poultry feeding ensures effective energy metabolism, a complex of nutrients and biologically active substances (Ibatullin et al., 2016; Abd El-Hack et al., 2020; Taşkesen, 2020). Geese have a different digestive system and metabolism than other poultry species due to their ability to efficiently digest fiber, thanks to the unique microflora in their cecums that break down roughage (Gabriel et al., 2005). Therefore, feeding geese requires not only nutritionally balanced diets and high-quality compound feeds but also the use of special feed additives to optimize the quantitative and qualitative composition of the digestive tract microbiota (Chen et al., 2013). Good results are achieved by pro- and prebiotic feed additives, which improve feed intake and digestibility, increase body weight gain, and reduce morbidity and mortality (Grant et al., 2018; Abou-Kassem et al., 2019). Modern technologies for increasing the productivity of farm poultry and obtaining high-quality products, as well as intensifying metabolic processes in the body, include the use of natural growth stimulators in their feeding rations, such as enzyme preparations, probiotics, and prebiotics (Castellini et al., 2002; Meng et al., 2010; Liang et al., 2019).

Studies have shown that the use of probiotic and prebiotic supplements in diets stimulates the growth and development of lactic acid- and cellulolytic bacteria, and increases the intensity of growth, development, and meat productivity in farm animals and poultry (Abou-Kassem et al., 2019; Ferents et al., 2022).

Nontraditional feed additives, including probiotics and prebiotics, in geese diets enhance the body's natural immunity and resistance to stress (Kabir et al., 2004; Plaza-Diaz et al., 2019).

In recent years, in several countries, including our own, the use of probiotics and prebiotics has become widespread in poultry diets, including those of geese, as an alternative to feed antibiotics (Maldonado Galdeano et al., 2019; Abd El-Hack et al., 2020; Taşkesen, 2020). Particular attention is paid to biologically active additives—prebiotics—which selectively stimulate the growth and metabolic activity of probiotic microorganisms and thereby provide an overall positive effect on the macroorganism as a whole (Chernikova & Prokopenko, 2019). Prebiotics are a relatively new group of feed additives that enhance the action of probiotics. Prebiotics include organic compounds of small molecular weight, such as oligosaccharides and organic acids, which promote the development of beneficial microbes and suppress the action of harmful microorganisms. Prebiotics are nondigestible components of food products that are fermented by the microflora of the large intestine and increase the metabolic activity of several strains of normal intestinal microflora, in particular bifidobacteria and lactobacilli (Chernikova et al., 2016; Park et al., 2020).

The volume of production and the efficiency of the goose farming industry are largely determined by the reproductive abilities of the birds and the quality of the eggs produced. Several factors influence the egg quality, including feeding, housing conditions, and bird care. Egg laying in birds is associated with increased function of various body systems (Poleghenjka, 2019). The body of female birds loses a large amount of protein, carbohydrates, minerals, fats, and vitamins, especially during the period of intensive egg laying (Kozenko et al., 2016; Zaplatynsky & Fedorovych, 2017).

Analysis of recent publications on the use of prebiotics suggests their stimulatory effect on the natural microflora of the gastrointestinal tract, and their ability to regulate and restore digestive processes, and provides extensive information on their feasibility for use in poultry feeding. At present, the effectiveness of feed additives, namely prebiotics, on the productivity and reproductive qualities of Obroshyn white geese remains uncertain.

However, the literature contains sufficient data on the effectiveness of prebiotics, particularly the stimulating effect on the natural microflora of the gastrointestinal tract and the ability to regulate and restore digestive processes. Based on these data, this work aimed to determine the specifics of how different doses of the prebiotic feed additive Inactivated Dry Glutathione Yeast (IDGY) influences the productivity and reproductive ability of female Obroshyn white geese.

Materials and methods

All the procedures with the animals were conducted according to the *European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes* (Strasbourg, 1986) and the *General Ethic Principles of Experiments on Animals*, adopted by the First National Congress of Bioethics (Kyiv, 2001). The experiments were performed with adherence to the principles of humanity, outlined in the Directive of the European Community (Directive 2010/63/EU, 2010).

The objects of the research were the Obroshyn geese with white plumage and the prebiotic Inactivated Dry Glutathione Yeast (IDGY), produced by the company Enzym (Lviv).

Studies of the effectiveness and safety of the prebiotic supplement Inactivated Dry Glutathione Yeast (IDGY) were conducted according to modern methodological approaches and in compliance with current requirements and standards used in domestic and international practice, without harming the health of the birds. One control and three experimental groups (10 individuals in each) were formed. The geese in the control group were fed the main diet according to the norm during the experimental period. The prebiotic Inactivated Dry Glutathione Yeast (IDGY) was added to the diets of the geese in the experimental groups in the doses of 150 g, 200 g, and 250 g per 1 ton of feed.

The feed additive was added to the main diet. A more detailed composition of the diet, in particular the recipe of the compound feed, is given in Table 1.

Table 1
Recipe for complete feed for geese during the productive period

Components	Share in the composition,%	Exchange energy, J	Crude protein, g/kg	Fiber, g/kg	Calcium (Ca), %	Phosphorus (P), %
Corn	20.0	2.8	18.0	4.4	0.1	0.5
Wheat	25.0	3.1	28.8	6.8	0.1	0.7
Oats	23.2	2.5	24.4	23.9	0.3	0.8
Sunflower meal	15.0	1.7	58.2	21.2	0.5	1.5
Soybean meal	9.0	0.9	37.8	6.6	0.4	0.7
Premix	2.5	0.0	0.0	0.0	0.0	0.0
Chalk	3.8	0.0	0.0	0.0	12.5	0.0
Monocalcium phosphate	1.5	0.0	0.0	0.0	2.6	4.0
Total	100.0	11.0	167.2	62.9	16.5	8.2
Norm	100.0	10.8	162.0	63.0	16.0	8.0

The norm of complete feed for adult poultry during the productive period is 350 g of feed per day.

The egg production was assessed by the number of eggs laid (laying rate). The laying rate was recorded daily, and the egg mass was measured; subsequent selection was based on this indicator during incubation. The selection of incubation eggs and control over their storage were carried out for up to 10 days. Based on the records, the laying rate and egg production indicators were determined.

The incubation performance was determined by their fertilizability, egg hatchability, and the yield of goslings. The yield of goslings is the ratio of the number of healthy goslings hatched to the number of laid eggs, expressed as a percentage. Egg hatchability is the ratio of the number of hatched, healthy young to the number of fertilized eggs, expressed as a percentage. Egg fertility is the ratio of fertilized eggs to the number of laid eggs, expressed as a percentage.

The physical parameters of eggs were evaluated, such as weight, length, and width, shape index, and shell thickness using generally accepted methods. The mass of eggs was determined by weighing on a scale with an accuracy of 0.01 g. The egg shape index was calculated as the ratio of the diameters along the long and short axes (measured with a caliper to 0.1 cm). The thickness of the shell with the subshell membrane was determined with a micrometer at the blunt and sharp ends and in the equatorial part of the egg (the average value was determined with an accuracy of 0.01 mm) (Vlizlo, 2012).

Blood was collected from the wing vein (*V. cutanea ulnaris*) in the morning before feeding, into two test tubes for each individual: with anticoagulant (heparin) – for erythrocytes and hemoglobin (whole blood), without anticoagulant - to obtain serum, in which total protein was determined.

Morphological and biochemical parameters of the blood of the experimental geese were determined by generally accepted methods: the number of erythrocytes and hemoglobin concentration – using the hemoglobin analyzer BC-2800Vet (Mindray, Shenzhen, China, 2014), total serum protein – refractometrically (Levchenko et al., 2004; Vlizlo, 2012).

The quality and composition of feather-and-down raw material obtained from breeding geese during the non-productive period were evaluated. For this purpose, samples from five birds in each experimental group were collected and placed in separate bags. The total weight of feather-and-down raw material was determined using an SF-400 electronic balance with an accuracy of 0.01 g. Subsequently, the samples were mechanically separated into feather, down, and impurity fractions. The weight of each fraction was recorded, and its proportion was expressed as a percentage of the total sample weight. The study was conducted in accordance with generally accepted zootechnical research methods (Vlizlo, 2012).

Biometric indicators were calculated between the studied mean values and are presented in tables as x ± SD (mean ± standard deviation). Differences between values in the control and experimental groups were determined using ANOVA, with $P < 0.05$ considered significant (corrected for multiple comparisons).

Results

At the beginning of the experiment, control geese were selected, with the average live weight of females at the onset of egg laying being 6.35–6.40 kg, and that of males measuring 7.92–7.78 kg. At the end of the experimental period, analysis of the studied parameters revealed that the control group had lower live weights: Females averaged 4.29 kg and males averaged 5.28 kg. By contrast, the prebiotic supplement Inactivated Dry Glutathione Yeast positively affected the physiological state and productivity of the Obroshyn white geese across all experimental groups.

High values were noted in all experimental groups, but the minimum dose (150 g/t) provided only a tendency to improve the indicators. Despite a slight improvement in the parameters relative to the control, the difference was statistically insignificant, which does not allow us to state the effectiveness of this prebiotic concentration unequivocally. The most pronounced effect was achieved with the introduction of the prebiotic at a dose of 200 g/t of feed. In this group, both males and females exhibited statistically significant increases in the parameters, measuring 15.5% and 15.4%, respectively, compared with the control.

An increase in the dosage to 250 g/t was also accompanied by positive dynamics relative to the control at $P < 0.01$ for males and $P < 0.05$ for females; however, in absolute values and the level of statistical probability, this group was inferior in indicators to the experimental group 2 (received 200 g of the supplement). This indicates that the optimal introduction is at a dose of 200 g/t of feed, since further increases in the prebiotic concentration did not result in a proportional increase in the productive parameters (Table 2). Thus, according to the results of the analysis of variance with the Bonferroni correction for multiple comparisons, the use of the specified drug Inactivated Dry Glutathione Yeast at a dose of 200 g/t during the productive period is the most optimal for breeding stock of geese. This indicates that the specified drug normalizes the geese's metabolism, improves feed digestibility, and maintains the birds' productivity at a high level.

During experimental research, we established the effectiveness of Inactivated Dry Glutathione Yeast as a prebiotic on the egg production of the Obroshyn white geese, as well as the incubation parameters of their eggs (Table 3).

Table 2
Live weight of geese during the productive period, kg ($x \pm SD$, n = 10)

Groups of geese		At the beginning of the period	At the end of the period
Control	males	7.92 ± 0.32^{g}	5.28 ± 0.45^{c}
	females	6.35 ± 0.23^{ef}	4.29 ± 0.41^{a}
Inactivated Dry Glutathione Yeast, 150 g/t	males	7.78 ± 0.33^{g}	5.62 ± 0.37^{cd}
	females	6.37 ± 0.31^{ef}	4.56 ± 0.22^{ab}
Inactivated Dry Glutathione Yeast, 200 g/t	males	7.85 ± 0.28^{gh}	6.10 ± 0.39^{e}
	females	6.35 ± 0.18^{ef}	4.95 ± 0.36^{b}
Inactivated Dry Glutathione Yeast, 250 g/t	males	7.82 ± 0.32^{gh}	5.84 ± 0.41^{d}
	females	6.40 ± 0.28^{f}	4.71 ± 0.42^{ab}

Note. Different letters within a column indicate that the data sets differ significantly ($P < 0.05$) from each other according to Tukey's test with Bonferroni correction.

Table 3
Egg production indicators of the geese ($x \pm SD$, n = 10, duration of experiment – 110 days)

Groups of geese	Duration of oviposition, day	Average bearing capacity, eggs	Average weight eggs, g
Control	96.2 ± 4.8^{a}	38.9 ± 1.1^{a}	153.5 ± 2.3^{a}
Inactivated Dry Glutathione Yeast, 150 g/t	98.4 ± 4.9^{ab}	39.1 ± 1.5^{a}	157.6 ± 2.2^{a}
Inactivated Dry Glutathione Yeast, 200 g/t	103.6 ± 5.2^{b}	40.8 ± 1.6^{b}	156.2 ± 2.4^{a}
Inactivated Dry Glutathione Yeast, 250 g/t	96.2 ± 5.1^{a}	39.5 ± 1.3^{ab}	158.2 ± 2.6^{a}

The best indicators were observed in the geese fed 200 g/t IDGY, with an average egg production of 40.8 eggs, which was 4.9% higher than that of the control ($P < 0.05$). The egg production of the geese fed IDGY at 150 and 250 g/t doses was slightly lower, measuring 39.1 and 39.5 eggs, respectively. This indicator was lowest in the control group, accounting for 38.9 eggs, with an average egg weight of 153.5 g. All experimental groups showed an increase in egg mass, ranging from 156.18 to 158.29 g, at $P < 0.05$ and $P < 0.01$.

The assessment of egg productivity was studied by taking egg measurements (length and width), from which the egg shape index was determined (Table 4). From the data in Table 4, the egg shape index was within the normal range of 65.41% to 66.46%.

It was found that the prebiotic in the amount of 200 g/t had a positive effect on the morphological parameters of the eggs. In particular, the length and width of the eggs in this group significantly increased compared with the control ($P < 0.01$), which provided an optimal shape index (66.46%). On the other hand, neither a decrease (150 g/t) nor an increase (250 g/t) in the supplement improved these parameters, confirming the choice of a dose of 200 g/t as optimal for improving the quality of eggs.

The results of the study of the effect of Inactivated Dry Glutathione Yeast on incubation performance are given in Table 5. The study of the incubation qualities of the eggs revealed the lowest fertilization in the control group, accounting for 80.21%. At the same time, the highest fertilization was observed in the experimental group 2 (which consumed IDGY 200 g/t of feed), accounting for 87.24%. In the geese that consumed IDGY 150 and 250 g/t of feed, it was within 84.13–84.35%.

Table 4
Physical parameters of eggs ($x \pm SD$, n = 10, duration of experiment – 110 days)

Groups of geese	Shell thickness, mm	Egg length, mm	Egg width, mm	Shape index, %
Control	0.50 ± 0.04^{a}	85.21 ± 0.15^{ab}	56.31 ± 0.19^{b}	66.09 ± 0.17^{ab}
Inactivated Dry Glutathione Yeast, 150 g/t	0.48 ± 0.08^{a}	84.65 ± 0.19^{a}	55.74 ± 0.16^{ab}	65.98 ± 0.18^{ab}
Inactivated Dry Glutathione Yeast, 200 g/t	0.57 ± 0.03^{b}	85.87 ± 0.15^{b}	57.02 ± 0.17^{c}	66.46 ± 0.15^{b}
Inactivated Dry Glutathione Yeast, 250 g/t	0.49 ± 0.05^{a}	84.46 ± 0.14^{a}	55.26 ± 0.14^{a}	65.41 ± 0.19^{a}

Table 5
Results of incubation of goose eggs (%, $x \pm SD$, n = 1583)

Groups of geese	Fertilization	Blood ring	Dead embryos	Stillborn	Egg hatchability	The yield of goslings
Control	80.21 ± 0.19^{a}	0.57 ± 0.21^{a}	5.25 ± 0.19^{c}	8.58 ± 0.26^{c}	85.60 ± 0.31^{a}	70.10 ± 0.21^{a}
Inactivated Dry Glutathione Yeast, 150 g/t	84.13 ± 0.18^{b}	0.89 ± 0.32^{b}	3.40 ± 0.18^{b}	5.80 ± 0.22^{b}	89.91 ± 0.27^{ab}	74.13 ± 0.24^{bc}
Inactivated Dry Glutathione Yeast, 200 g/t	87.24 ± 0.21^{c}	0.54 ± 0.28^{a}	2.00 ± 0.16^{a}	4.54 ± 0.19^{a}	92.92 ± 0.32^{b}	75.45 ± 0.19^{c}
Inactivated Dry Glutathione Yeast, 250 g/t	84.35 ± 0.25^{b}	1.14 ± 0.29^{c}	5.20 ± 0.19^{c}	5.26 ± 0.17^{b}	88.45 ± 0.31^{ab}	73.22 ± 0.20^{b}

The studies have established a positive effect on the reproductive performance in all experimental groups, produced by the feed additive Inactivated Dry Glutathione Yeast (IDGY) for feeding female geese during the productive period. However, the most significant results were obtained with the prebiotic at a dose of 200 g/t, which not only increased the fertilization to 87.24% ($P < 0.01$) but also significantly optimized the embryonic development. In particular, a significant decrease in the number of dead embryos and stillbirths was observed ($P < 0.01$), resulting in the highest gosling hatching rate – 75.45%, which was 5.35% higher than the control. The data obtained confirm the hypothesis that the use of the feed additive improves the metabolic state of the female geese and directly indicates a higher offspring viability.

When studying the feathers and the productivity of geese, two live pluckings were conducted during the nonproductive period, and the fractional composition of the obtained raw materials was investigated (Table 6). Analyzing the data presented in Table 6, it should be noted that geese across all experimental groups in the nonproductive period showed better parameters of feather and down productivity, as measured by plucking during life. Higher down and feather indices were observed in all experimental groups, indicating better quality of their feather-down raw materials during intensive molting (50 days). The quality of feather-down raw materials during the specified period was better in geese of group 2 (which were fed IDGY at a dose of 200 g/t), as evidenced by the litter index: 0.72% less at the first and 0.81% less at the second plucking compared with their control counterparts.

Table 6
Fractional composition of feather and down raw materials obtained by live plucking geese (%, x ± SD, n = 5)

Indicator	Groups of geese	Feather		Down		Clogging, %
		mature	immature	mature	immature	
Nonproductive period, first plucking, %	control	58.32 ± 1.71[a]	3.92 ± 0.64[a]	32.02 ± 0.04[a]	2.92 ± 0.02[d]	2.82 ± 0.52[b]
	Inactivated Dry Glutathione Yeast, 150 g/t	57.92 ± 1.64[a]	3.81 ± 0.62[a]	32.91 ± 0.02[b]	2.62 ± 0.01[c]	2.74 ± 0.48[b]
	Inactivated Dry Glutathione Yeast, 200 g/t	59.15 ± 1.82[a]	3.42 ± 0.59[a]	33.12 ± 0.01[bc]	2.21 ± 0.05[ab]	2.10 ± 0.34[a]
	Inactivated Dry Glutathione Yeast, 250 g/t	59.00 ± 1.96[a]	3.64 ± 0.61[a]	31.92 ± 0.03[a]	2.43 ± 0.03[b]	3.01 ± 0.42[b]
Nonproductive period, second plucking, %	control	58.20 ± 1.85[a]	3.72 ± 0.62[a]	32.63 ± 0.03[b]	2.63 ± 0.03[c]	2.82 ± 0.54[b]
	Inactivated Dry Glutathione Yeast, 150 g/t	58.98 ± 1.67[a]	3.64 ± 0.59[a]	33.05 ± 0.05[bc]	2.23 ± 0.02[ab]	2.10 ± 0.49[a]
	Inactivated Dry Glutathione Yeast, 200 g/t	59.06 ± 1.78[a]	3.52 ± 0.56[a]	33.29 ± 0.04[c]	2.12 ± 0.01[a]	2.01 ± 0.37[a]
	Inactivated Dry Glutathione Yeast, 250 g/t	58.65 ± 1.82[a]	3.72 ± 0.63[a]	32.91 ± 0.01[b]	2.21 ± 0.04[ab]	2.51 ± 0.44[ab]

In the raw materials obtained during the first plucking from the geese of group 2, there was a slightly higher percentage of mature feathers and down ($P < 0.01$) and a lower percentage of immature feathers. In the same group (200 g/t), the highest percentages of mature down were observed – 33.12% (first plucking) and 33.29% (second plucking).

Analysis of the fractional composition of feather and down raw materials showed that the prebiotic stimulates the processes of plumage formation. The best parameters were obtained when feeding 200 g of the prebiotic per 1 t of feed: The proportion of mature down from both pluckings increased significantly compared with the control ($P < 0.01$). At the same time, the amount of immature fractions significantly decreased. This indicates an intensification of metabolic processes in the geese's skin under the influence of yeast components, enabling the production of higher-quality raw materials with lower contamination levels ($P < 0.05$).

An important internal indicator that characterizes the physiological state of poultry, their metabolism, thus reflecting their productivity, is blood. Therefore, to assess the physiological state of the geese, we collected blood from five individuals per group to examine the hematological picture. During the experiment, we analyzed the changes in the total number of erythrocytes, hemoglobin content, and total serum protein, which are given in the Table 7. From the data in Table 7, it is clear that the hematological and biochemical blood parameters of the geese corresponded to physiological norms. Our studies showed that different doses of the prebiotic in diets affected hematological parameters differently, but the differences between the groups were not significant. We noted that during the productive period, the numbers of erythrocytes, hemoglobin, and total protein increased compared with the nonproductive period, which is natural. However, it is the prebiotic that helps the goose's body to withstand the exhausting period of egg laying more easily, while maintaining a high metabolic rate.

Table 7
Hematological and biochemical blood parameters of geese (x ± SD, n = 5)

Indicator	Periods	Control	Inactivated Dry Glutathione Yeast, 150 g/t	Inactivated Dry Glutathione Yeast, 200 g/t	Inactivated Dry Glutathione Yeast, 250 g/t
Hemoglobin, g/L	productive period	158.42 ± 0.14[ab]	162.75 ± 0.11[b]	169.52 ± 0.19[c]	163.14 ± 0.12[b]
	nonproductive period	155.34 ± 0.15[a]	158.91 ± 0.15[ab]	163.73 ± 0.16[b]	156.74 ± 0.15[a]
Erythrocytes, T/L	productive period	4.43 ± 0.08[a]	4.51 ± 0.12[a]	4.56 ± 0.18[a]	4.52 ± 0.19[a]
	nonproductive period	4.41 ± 0.10[a]	4.50 ± 0.17[a]	4.50 ± 0.13[a]	4.42 ± 0.21[a]
Total protein, g/L	productive period	54.95 ± 0.19[a]	57.64 ± 0.17[b]	58.06 ± 0.14[b]	57.84 ± 0.11[b]
	nonproductive period	54.06 ± 0.18[a]	57.02 ± 0.13[ab]	56.93 ± 0.15[ab]	57.16 ± 0.12[ab]

It should also be noted that in the body of geese that were fed IDGY 200 g/t of feed, the hemoglobin values were higher by 7.00% in the productive period and 5.40% in the nonproductive period. The number of erythrocytes during the productive period was higher by 2.93%, but the difference was not statistically significant. In the nonproductive period, these indicators were slightly lower. The total protein level was higher by 5.66% in the productive period, and by 5.31% in the nonproductive period. The introduction of the IDGY prebiotic to the diet at a dose of 200 g/t of feed contributed to the improvement of protein metabolism and the enhancement of redox reactions and, as a result, had a positive effect on the viability and productivity of the geese. In particular, increases in hemoglobin and total protein levels were observed in all experimental groups ($P < 0.01$), with the highest values observed in the birds receiving 200 g/t of the supplement. The absence of statistically significant changes in the number of erythrocytes against the background of an increase in hemoglobin indicates an improvement in the respiratory function of blood, which is the physiological basis for the abovementioned results regarding the productivity and reproductive ability of geese.

Considering the physiological state of the birds in the experimental groups and the hematological and biochemical parameters of their blood when fed the prebiotic supplement, it is advisable to use Inactivated Dry Glutathione Yeast at 200 g/t in the diets of breeding flocks.

Discussion

Several researchers have studied and continue to study the effectiveness of prebiotics in feeding various species of animals and poultry, as well as the use of feed additives of various origins, which significantly affect the processes of digestibility and absorption of nutrients (Liu et al., 2020; He et al., 2022). According to the studies, adding yeast prebiotics to the diet improves growth performance, increases nutrient absorption, and modulates the immune system of geese (Gao et al., 2008; Zhang et al., 2022). This is also confirmed by our previous studies, which established the high effectiveness of using yeast feed additives in the diets of other age groups of geese (Petriv et al., 2024).

The health of poultry largely depends on the composition of the feed, as its individual components influence the development of the gastrointestinal tract microflora, which plays an important role in the complete breakdown and absorption of nutrients, as confirmed in the studies of Rutkowski et al. (2017) and Park et al. (2020).

In our studies, the introduction of the Inactivated Dry Glutathione Yeast prebiotic into the diet of geese improved their metabolism and hematopoiesis, enhanced redox reactions, and, as a result, positively affected their viability and productivity. Our results are generally consistent with those of Abou-Kassem et al. (2019), who found that pro- and prebiotic additives improve feed intake and digestibility. In addition, the data obtained in our experiment are consistent with those of the study by Ajuwon (2016), who used prebiotics to normalize metabolic processes in the bodies of farm animals and poultry. Similar studies were conducted by other researchers (Chernikova & Ponomarenko, 2016; Zhang et al., 2022), who noted the positive effects of prebiotics on the productivity of farm poultry, in particular the intensification of metabolic processes in the body. Researchers believe that the modern approach to increasing the productivity and reproductive capacity of farm poultry and obtaining quality products is the use of natural growth stimulators, such as enzyme preparations, probiotics, and prebiotics. The research by Liang et al. (2019) found that the dietary vitamin A supplementation of the diet of geese during the period of intensive egg laying (due to stimulating the processes of the body's antioxidant status) ensures the quality of egg hatching and plays an important role in the development of embryos (Zhang et al., 2020). The development of the bird embryo is completely dependent on the nutrients contained in the egg, in particular the yolk, which is the main source of energy and biologically active substances, as also confirmed by Ma et al. (2020) and Fiyalovych & Kyryliv (2016). Studies have shown that female birds in the period of intensive egg laying require additional intake of nutrients and biologically active substances that are necessary for the formation of egg quality and their hatchability (Kozenko et al., 2016; Zaplatynsky & Fedorovych, 2017). The results of our study indicate the effectiveness of the Inactivated Dry Glutathione Yeast prebiotic on the egg production and incubation qualities of female Obroshyn white geese. All experimental groups, where the female geese received IDGY during the productive period, exhibited higher productivity parameters compared with the control group that did not receive the additive. The optimal productive effect was observed in the geese fed IDGY at a dose of 200 g/t of feed.

The significant improvement in the egg production of female geese and in the incubation qualities may be associated with the ability of prebiotics to selectively stimulate the growth and metabolic activity of probiotic microorganisms, and thereby exert an overall positive effect on the macroorganism as a whole, which is consistent with the results of other researchers (Chernikova & Prokopenko, 2019).

The experimental studies have shown that live plucking of geese yields 100–125 g of feather and down raw materials from one individual, which can be plucked 2–3 times a year (Sakhatskyi, 2012). Such down or down with small feathers (which can also be obtained during live plucking) exhibits the best quality indicators. The studies we have presented on the use of the prebiotic supplement in feeding Obroshyn geese indicate an improvement in the quality of their feather and down raw materials during a rapid plumage cycle of 50 days, evidenced by 0.72% lower clogging indicators at the first plucking and 0.81% lower at the second plucking.

It was also established that hematological parameters are significantly influenced by feeding conditions, ration composition, and the physiological state of the bird. Biochemical blood parameters are indicators of the bird's physiological state and metabolism, and therefore reflect its productivity (Ho et al., 2015). Tereshko et al. (2008) and Kozenko et al. (2016) found that biochemical blood parameters change with age. Thus, with age, the number of erythrocytes, hemoglobin content, and total protein in blood serum of birds increase. This process is especially intensified during egg laying. Zaplatynsky & Fedorovych (2017) found that the morphological and biochemical blood parameters of Obroshyn geese depend on their reproductive period. The results of our research indicate that erythrocyte count, hemoglobin, and total protein increase during the productive period compared with the nonproductive period.

A number of scientists have studied the effect of supplements on hematological parameters of poultry. In particular, Chudak et al. (2021) reported that the use of a mineral supplement in poultry feeding increases the level of hemoglobin and erythrocytes, which is consistent with our studies.

Analysis of the results also indicates that in the birds fed Inactivated Dry Glutathione Yeast at a rate of 200 g/t of feed, the hemoglobin level was higher by 7.00% in the productive period and by 5.31% in the nonproductive period. The number of erythrocytes during the productive period was also 2.93% higher compared with the control group. In the nonproductive period, these indicators were slightly lower. The analysis of total protein content in blood revealed that the level was within the physiological norm but higher during the productive period, particularly by 5.66% in this experimental group.

Summarizing the results, it should be noted that the Inactivated Dry Glutathione Yeast prebiotic, provided at the studied doses, had a positive effect on the productivity of Obroshyn geese with white plumage. In particular, IDGY at 200 g/t of feed proved to be optimal, improving indicators of the reproductive ability, viability, the physiological condition of the females, and also the feather and down qualities.

Conclusion

The conducted studies revealed that the highest rates of egg production were observed in the geese of the experimental group that consumed feed containing Inactivated Dry Glutathione Yeast at a dose of 200 g/t, with the average egg production of 40.8 eggs, the average egg weight of 156.2 g, and the egg production duration of 103.6 days, which was 4.9% higher than their control counterparts. The egg production of the geese in the experimental groups that consumed IDGY at the doses of 150 and 250 g/t of feed was slightly lower: 39.1 and 39.5 eggs, respectively. This indicator was lowest in the control group – 38.9 eggs, with the average egg weight of 153.5 g, and the egg production duration of 96.2 days. In the geese of other experimental groups (IDGY 150 and 250 g/t of feed), the average egg weight was within 157.6–158.2 g.

According to the incubation results, the best fertility indicators were observed in the experimental group 2 (87.24%) and were 7.03% higher than in the control group. Furthermore, the hatching of goslings in this group exceeded that of the control group by 5.35%. The analysis of feather and down raw materials showed a positive trend in improving quality indicators and the molting rate (50 days).

Based on the productive and metabolic effects, it is advisable to introduce the prebiotic Inactivated Dry Glutathione Yeast (IDGY) to the diet, as it positively affects the general condition of the body, the viability, and the productivity of the geese in the breeding stock. The most optimal is to introduce 200 g of prebiotics per 1 ton of feed into the diet of breeding geese.

Prospects for further research. Elucidation of the effect of the prebiotic supplement Inactivated Dry Glutathione Yeast on the fattening and meat qualities of the Obroshyn white geese.

The authors declare that there is no conflict of interest.

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