PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

EFICÁCIA DA APLICAÇÃO DE SAPROPEL EM DIETAS DE GANSOS

EFFECTIVENESS OF SAPROPEL APPLICATION IN DIETS OF GEESE

ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ САПРОПЕЛЯ В РАЦИОНАХ ГУСЕЙ

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RESUMO

Tornou-se uma prática para as indústrias avícolas usarem diferentes substâncias biologicamente ativas, reduzindo os custos gerais para aumentar a qualidade dos produtos avícolas. Infelizmente, nem todas as substâncias biologicamente ativas são seguras e têm preços razoáveis. O uso de sapropel para compensar a falta de substâncias minerais e vitamínicas nas dietas de gansos de diferentes faixas etárias ainda não foi estudado. Neste estudo, o efeito do suplemento mineral e vitamínico sapropel nas qualidades produtivas e reprodutivas dos gansos do rebanho parental foi estudado para encontrar sua taxa ideal na dieta dos ganso. O alvo da pesquisa foram os gansos brancos húngaros no segundo ano. Os pássaros foram divididos em quatro grupos com 50 cabeças cada. A dieta de cada grupo incluiu de 3,0% a 9,0% de sapropel. Os seguintes métodos de pesquisa foram utilizados no trabalho: zootécnico, fisiológico, biológico, hematológico, morfológico, estatístico e econômico. A melhor taxa de sapropel na dieta dos gansos do rebanho parental foi de 6,0% do peso das forragens. Proporcionou uma maior taxa de sobrevivência do rebanho em 2,0%, aumento da produção de ovos em 7,5%, taxa de eclosão em 5,4%, melhor composição morfológica do sangue, digestibilidade e utilização de nutrientes da dieta. A produção de gosling de um dia aumentou 17,5%, enquanto os custos de forragem por unidade de produção diminuíram. Como resultado, os indicadores econômicos da produção de carne de ganso aumentaram 9,8%.

Palavras-chave: *rebanho criador; aditivo alimentar; substâncias minerais; produtividade; sapropel.*

ABSTRACT

It has become a practice for poultry industries to use different biologically active substances while reducing overall costs to increase poultry product quality. Unfortunately, not all the biologically active substances are safe and have reasonable prices. The use of sapropel to compensate for the lack of mineral and vitamin substances in the diets of geese of different age groups hasn't been studied yet. In this study, the effect of the mineral and vitamin supplement sapropel on the productive and reproductive qualities of geese of the parent flock was studied to find its optimal rate in the goose diet. The research target was Hungarian white geese in their second year. Birds were divided into four groups with 50 heads each. The diet of each group included from 3.0% to 9.0% sapropel. The following research methods were used in work: zootechnical, physiological, biological, hematological, morphological, statistical, and economical. The best sapropel rate in the diet of geese of the parental flock was found to be 6.0% of the fodder weight. It provided a higher survival rate of the crowd by 2.0%, increased egg production by 7.5%, hatching rate by 5.4%, improved morphological blood composition, digestibility, and diet nutrient utilization. Day-old gosling production climbed by 17.5% while fodder costs per unit of production declined. As a result, the economic indicators of goose meat production increased by 9.8%.

Keywords: *breeder flock; feed additive; mineral substances; productivity; sapropel.*

АННОТАЦИЯ

В настоящее время перед лицом растущей конкуренции на мировом рынке наиболее остро стоит

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вопрос обеспечения продовольственной безопасности, где ключевую роль играет развитие аграрного сектора, в частности, птицеводства. Для повышения продуктивности и качества продукции птицы на фоне снижения общих затрат в практику промышленного птицеводства вошло использование различных по содержанию и действию биологически активных веществ, однако не все они обладают должной безопасностью и доступной стоимостью, поэтому в последнее время все больше внимания начали обращать кормовым добавкам природного происхождения, таким как бентониты и гуминовые соединения, среди них особый интерес представляет сапропель. В настоящее время не изученным является использование сапропеля для компенсации недостатка минерально-витаминных веществ в рационах гусей различных возрастных групп. Целью исследований, результаты которой представлены в этой статье, явилось изучение влияния минерально-витаминной добавки сапропель на продуктивные и воспроизводительные качества гусей родительского стада и установление оптимального уровня его включения в состав их рациона. Объектом исследования продолжительностью 130 дней выступили гуси белой венгерской породы второго года использования – четыре группы птиц по 50 голов в каждой с уровнем включения сапропеля от 3,0% до 9,0%. Методологической основой исследований послужили ранее проведенные работы зарубежных и отечественных ученых по изучаемой теме. При выполнении работы использовались общепринятые методы: эксперимент, сравнение, анализ, обобщение; специальные методы: зоотехнические, физиологические, биологические, гематологические, морфологические, статистические и экономические. По результатам исследований установлена оптимальная доза включения сапропеля в состав рациона гусей родительского стада в объеме 6,0% от массы комбикорма, что способствовало повышению сохранности поголовья на 2,0%, яйценоскости – на 7,5%, вывода гусят – на 5,4%, улучшению морфологического состава крови, переваримости и использования питательных веществ рациона, увеличению объема производства суточного молодняка на 17,5% при уменьшении удельных затрат кормов на единицу продукции, что в конечном счете, повысило экономические показатели производства мяса гусей на 9,8%.

Ключевые слова: *родительское стадо, кормовая добавка, минеральные вещества, продуктивность, сапропель*

1. INTRODUCTION:

Unlike other sectors of agriculture, poultry farming generates more and more annual output due to the growth of poultry population and a steadily improving productivity in addition to the intensification of the entire production process all around the globe (Burova *et al.*, 2019; Fisinin *et al.,* 2017; Gabitov *et al.,* 2018a, 2018b).

Fisinin *et al.* (2017) argue that higher production of eggs and poultry meat would ensure food independence and address the social issue of the availability of animal source proteins for all social strata.

Goose production is a branch of poultry farming that is prominent in terms of precociality, feed conversion, viability, and fattening capacity. The primary challenge it faces today, as well as the entire poultry industry, is to reduce production costs and increase productivity by providing a more comprehensive and useful use of essential nutrients in feed material (Gadiev *et al.,* 2019).

With a shift to high technologies in goose breeding, geese are deprived of replenishing natural biologically active substances, macronutrients, and micronutrients. It makes it necessary to balance poultry diets by adding vitamin and mineral supplements or manufactured premixes, which affects the cost of feed and, consequently, the finished product (Prasai *et al.,* 2016). There is a clear need for inexpensive and easy-to-use alternative sources of biologically active substances.

Sapropels are a good source of diet replenishment with the necessary nutrients for growing geese (Rumyantsev *et al.,* 2017; Shtin, 2005). Sapropels and their products are environmentally friendly, non-toxic, and contain essential nutrients (Stankevica *et al.,* 2016).

Sapropels (gyttja or dy) are centuries-old freshwater sediments, which contain up to 15% of organic substances (Kurzo *et al.,* 2004; Obuka *et al.,* 2015) and are formed of benthos, i.e., remnant phytoplankton and zooplankton, and fractions of soil humus (Kurzo, 2005; Rutina *et al.,* 2013; Vincevica-Gaile and Stankevica, 2018). Sapropels can only develop in stagnant fresh waters, at bottoms of stagnant lakes with reduced oxygen availability (Lacis, 2003; Obuka *et al.,* 2015).

According to Obuka *et al.* (2015) and Rumyantsev *et al.* (2017), sapropels or lake muck consists of detritus material, different kinds of plankton, insect chitin, and higher plant spores found in lake environments. The sapropel color vary from light pink to dark brown depending on the maximum content of certain substances. A high natural content of phosphorus makes it dark blue that turns light blue after drying. Sapropels can be found in shallow overgrown post-glacial lakes and vast river valleys while they are quite rare in permafrost meltwater reservoirs, mountainous areas, and drylands.

Sapropels are widely used throughout the world that makes them an essential natural resource. Lake muck is applied in agriculture, horticulture, forestry, animal husbandry, chemical and construction industries, spa services sector, production of beauty products, and coagulants (Stankevica and Klavins, 2013).

The widespread use of sapropels allows them to be used as a national strategic natural resource. In contrast, processed products of sapropels may be exported worldwide as fertilizers, feed additives, raw materials for chemistry and construction, medicinal clay, etc.

Sapropels are considered to be a kind of geological formations that occur at the bottom of a reservoir during the entire period of its existence. However, according to Leinerte (1988), the development of sapropels strongly depends on the lake type; their deposition can occur with substances in high energy environments, which is widely observed in autotrophic lakes.

Stankevica and Klavins (2013) and Stankevica *et al.* (2016) distinguish between autochthonous sapropels accumulated due to the lake biomass deposits and allochthonous ones, where sediments include a large amount of humic substances, which enter the lake from the surrounding areas and marshes. Autochthonous sapropels with maximum organic matter content are thought to be more valuable because the initial biomass, its biochemical degradation and conversion into organic substances do not create polycyclic aromatic hydrocarbons, such as benzo(a)pyrene, which is characteristic of soil, peat and, particularly, coal humic substances.

The global scientific community proposes multiple classifications of sapropels, depending on their composition. For example, Potenje (1920) identified two groups of sapropels, such as “sapropels” being thick fine-grained sediments containing 25% to 90% of organic matter and mineral deposits, and “sapropelites” consisting of diatomaceous earth, lime, iron, and sands.

Pidoplizko and Grisuk (1962) classify lacustrine sediments into the seven types as listed below:

– pastelike, heavy, gray, or bluish-gray, clayey gyttja with high mineral levels, usually deposited in lakes naturally;

– calcareous sapropels with an ash content of more than 35% (including 50% to 65% of CaO), found in groundwater discharge areas with high calcium concentrations; they are greenish-gray and usually form grayish-white incoherent mixture after drying;

– grained green or greenish-gray silicate sapropels with a higher ash content of more than 30%;

– mixed sapropels with the most top ash content (about 70% – 80%), which can contain large amounts of calcium and silicates, clay fractions and calcium; these mixed lacustrine sediments are formed of planktonic organisms and may be grayish, dark-green, blue-green, or grayish-brown;

– organic sapropels (fine detritus gyttja) with a low ash content no more than 30%. They are green, or greenish-brown, if they contain some hummus, and occur in water bodies lacking ample mineral matter supplies;

– coarse detritus gyttja with a low ash content, accumulated in lakes with plenty of aquatic plants in addition to plankton organisms; it is usually dark green with potential traces of higher aquatic plants;

– peat sapropels occurring when peat deposits come into contact with the lake, or as a result of overgrowing of autotrophic coastal water bodies; peat sapropels are brown transitional formations between sapropels and peats with residual material from bulrush, sedge grasses, horsetail and other plants, characterized by a very low ash content (8–10%) and a high level of decomposition (about 25–30%).

For years, sapropels have been deposited at bottoms of freshwater ponds and accumulated great amounts of different organic, mineral and biologically active substances. In terms of their composition, sapropels are a unique product containing proteins (up to 23%), minerals (calcium and phosphorous), trace elements (iron, manganese, magnesium, copper, sulfur, cobalt, etc.), vitamins, and humic compounds.

Quisenberry (1968) and Rumyantsev *et al.* (2017) find sapropels to be a functional feed additive for agricultural animals and poultry because of the high content of different macro- and trace elements.

As a substrate rich in minerals and vitamins, sapropels can be considered a good vitamin and mineral feed for poultry. Indeed, experiments conducted to add sapropels to poultry diets showed a significant increase in body weight, egg size, and life expectancy (Stankevica *et al.,* 2019).

Lake muck has been found to be an active feed additive in animal husbandry. However, there is still not enough knowledge of what effect sapropels can have on productive and reproductive characteristics of geese in different age and sex groups.

Based on the above, the aim of the given paper was to study the effect of the mineral and vitamin supplement sapropel on the productive and reproductive qualities of geese of the parent flock and to find its optimal rate in the goose diet.

2. MATERIALS AND METHODS:

2.1. Object and materials of study

Studies have been carried out on Hungarian white geese grown for two years at Bashkirskaya ptitsa, Limited Liability Company of Blagovarsky District, Republic of Bashkortostan. The study was conducted in accordance with the ethical principles approved by the Animal Experiments Ethics Committee of Federal State Budget Educational Institution of Higher Education «Bashkir State Agrarian University» (Protocol №5 of 14th December 2018).

Healthy poultry were collected for studies, based on their age, sex, fertility, body weight, and condition. Geese of parent flock were divided by analogy into one control and three experimental groups. Each group included 50 birds with one gander per 3 hens, this is the minimum number of birds to obtain reliable data. Geese of the control group were given complete feed without sapropel. The feed of experimental groups 1, 2, and 3 was supplemented with sapropel in the dose of 3.0, 6.0, and 9.0% of feed mass, respectively. The study lasted 130 days.

2.2. Conditions of the study

Geese of the control and experimental groups had identical feeding conditions and were raised according to the recommendations of the All-Russian Research and Technological Poultry Institute (Sergiyev Posad) except for the study factor. Poultry were kept in solar houses with deep-litter unchangeable nests. Nest cushions were filled with chaff.

2.3. Methods of study

The study was performed under standard methods, such as experiment, comparison, analysis, synthesis, and special ones: zootechnical, physiological, biological, hematological, morphological, statistical, and economical.

The survival rate (%) was analyzed by day-to-day control of dead and cull birds with the determination of mortality reasons; body weight (g) by monthly weighing during the laying period; egg-laying capacity of average bird by dividing the amount of laid eggs in a group for a specific time by an average goose stock for the same period of time; morphological and physical-chemical indicators of eggs were assessed under methodological recommendations of the All-Russian Research and Technological Poultry Institute (ARRTPI); results of hatching were studied according to manual for biological control of poultry eggs hatching (ARRTPI, 2014); egg embryonation (%) – ratio of embryonated eggs to hatching eggs; hatched birds (%) – ratio of hatched certified birds to hatching eggs; content of carotenoid and vitamins in the yolk – by using standard methods of Skurikhin and Shabaev (1996). The morphological composition of blood was analyzed by conventional methods of Sukhanova and Azaubayeva (2017), digestibility and feed nutrient utilization (%) by conducting digestible trials following ARRTPI methodology. Laboratory tests were performed in analytic laboratories of Bashkir State Agrarian University and Bashkir Research Institute of Agriculture.

A cost-effectiveness analysis of sapropel application in goose farming was based on the results of research and production studies, actual prices for the period of studies.

2.4. Data analysis

The data under research, received during the studies, have been processed using a variation statistics method on a PC using Microsoft Excel software. Statistical significance of differences was calculated using Student's t-test with three confidence levels: $p<0.05$; $p<0.01$; $p<0.001$.

3. RESULTS AND DISCUSSION:

One of the factors determining the poultry's genetically determined productivity is the usefulness of feeding. Numerous studies have proved that including various feed additives and biologically active substances in diets favorably affects the poultry productivity and poultry product quality, helps to enhance the body's resistance to adverse environmental factors.

According to many authors, sapropel is a good source of diet enrichment with the necessary components for breeding and keeping poultry (Rumyantsev *et al.,* 2017; Shtin, 2005). As a substrate rich in minerals and vitamins, sapropel is an environmentally friendly mineral-and-vitamin feed for poultry (Stankevica *et al.,* 2016).

The data received in this paper shows the results of a comprehensive scientific analysis of the effects of sapropel in a dose of 3.0, 6.0, and 9.0% of the feed weight on reproductive and productive qualities of the parent flock geese. The methodological basis for the study was previous works by foreign and domestic researchers on this topic.

Sapropel in mixed feed of the goose parent flock in the amount of 6.0% per the combined feed weight has been found to raise the survival rate of poultry by 2.0% ($p<0.05$), which is equal to 96%. Bailey et al. (2006) also found in their studies that the use of montmorillonite clay as NovaSil PLUS additive allowed protecting broiler chickens from aflatoxicosis and increasing the livestock preservation.

When keeping geese of experimental groups, no adverse effect of sapropel on the goose live weight parameters has been recorded. However, at the end of the productive period, a slight decrease in live weight was observed in all groups, both in males and females. A relatively higher reduction of live weight was observed in females of the 2nd experimental group in June (by 1.3%) at the confidence level of $p<0.05$, due to high rates of their egg production. This phenomenon indicates a correlation between the live weight and egg productivity.

The results of the research by Mikulioniene and Balezentiene (2012) also show that the use of sapropel as a feed additive had a positive effect on the live weight, the digestive tract development, the digestibility of nutrients, and the quality of gosling and duckling meat. Thus, the ducklings' diet added with 6% of sapropel and the goslings' food without the same (the control group, CG) provided for the most effective feed conversion (3.62 and 3.83, respectively). The diet based on feed added with 9% of sapropel ensured the most significant body weight: 1.931 g and 2.704 g for ducklings aged 40 and 50 days; 1.766 g and 3.772 g for goslings aged 20 and 60 days, respectively. Adding sapropel increased the body weight by 9% in 50-day ducklings and 60-day goslings by 5% and 9%, respectively. The ducklings' diet added with 9% of sapropel improved the feed digestibility along with the highest meat output (66.7%), increasing the CG weight by 1.6%. Also, there was an increased content of fat and duck meat fat by 1.7% and 1.1%, respectively. However, the gosling meat quality parameters were better in the CG than in the 4th experimental group added with 9% of sapropel; it was probably due to their higher body weight and nutritional needs, as compared to ducklings. Besides, the presence of essential amino acids in sapropel is confirmed in the amount of 47% to 60% of their total number. The availability of a large number of nutrients allows for the use of sapropel as a natural, environmentally friendly mineral-and-vitamin feed supplement of natural origin.

Bayurov (2018), in his research, established the beneficial effects of liquid sapropel extract (ES-2) on broiler chickens. According to this author, adding sapropel in the poultry diet increased the chicken growth rate, enhanced the body resistance, and livestock preservation.

Researchers Ezhkova *et al.* (2018) also found the positive effect of sapropel on broiler chicken's body. Thus, for their study, they formed seven groups of 10-day chickens, 120 birds in each. The birds in the control group I received complete mixed feed (OP). The birds in the experimental group II received OP + feed sapropel at the dose of 3.0% to the dry matter of the diet. The birds in the experimental groups III, IV, V, VI, and VII, received 3.0; 2.4; 1.8; 1.2, and 0.6% of nanostructured sapropel added to their diet, respectively. The additive was given for 30 days – until the technological slaughter of chickens for meat. According to the research results, it was found that the relative increase in the poultry weight was more considerable in the experimental groups than in the control group (2,190.0 g) by 1.1...8.2%; the weight of the whole bird without giblets, by 14.5...175.1 g. The slaughter yield of experimental broilers was 1.7...2.1% higher than in the control group (70.5%), except for the group III, where it was 0.5% lower. The meat of experimental broilers had an increased content of essential amino acids by 1.7...8.7%, nonessential amino acids, by 2.4...12.5%, with the same values in the control group equal to 27.68 and 31.67 g/kg, respectively. The ratio of essential and non-essential amino acids in the poultry meat of the experimental groups was 1.15...1.18; in the control group, 1.14; the protein quality indicator was 4.56...4.64; in the control group, 4.51, respectively. The economic efficiency per 1 ruble of costs amounted to when using sapropel in the dose of 3.0% – 2.1 rubles, nanostructured sapropel in the treatments of 3.0; 2.8; 1.8; 1.2 and 0.6% – 1.1; 2.4; 3.5; 3.8, and 4.2 rubles, respectively (Ezhkova *et al.,* 2018).

The impact of sapropel on body weight was also studied in pigs on feed. Thus, according to Mikulioniene and Balezentiene (2009) addition of 200-400 g of sapropel in the diet (treatment group) allowed increasing the total body weight of pigs by 12% and decreasing their food consumption by 12% compared to pigs of the control group.

There is a positive effect of sapropel on the egg productivity and the goose hatching eggs quality. The data on the egg-laying capacity by months are shown in Figure 1. As follows from Figure 1, adding sapropel in the feed for parent flock poultry had a positive effect on poultry egg productivity in all experimental groups in the first month of use compared to their peers in the control group. In the first month of egg-laying (February) noted an increase in egg-laying by 15.2–24.2% ($p<0.001$) among poultry in the experimental groups, where the birds received mixed feed added with sapropel within the range of 3% to 9%, as compared to the control group.

The total goose egg productivity in the experimental groups met the breed standard, and, based on the productivity records, it was within the range of 49.2 to 51.6 pcs. It should be noted that increasing the content of sapropel added up to 9% (the 3rd experimental group) did not contribute to further increase in poultry production and, to some extent, it resulted in its decrease. Goose egg production in the 3rd experimental group decreased during the last two months of productivity, as compared to peers in the control group, by 4.2 ($p<0.05$) and 9.5% ($p<0.01$), respectively. When adding sapropel in the amount of 6% of the combined feed weight (the 2nd experimental group), goose egg productivity per average layer was, in general, 51.6 pcs., which is higher by 3.6 pcs. Or 7.5% ($p<0.01$), as compared to the control group.

The hatching process effectiveness is greatly affected by the morphological composition of eggs and their biological value; therefore, the assessment was made according to these criteria. As it was expected, adding sapropel to the poultry's diet had no significant effect on the main morphological parameters of eggs. However, there was a slight increase of the egg weight in the experimental groups by 0.96–1.12%, due to higher specific weight of the yolk by 1.83 – 2.48% and that of the shell by 4.45–5.38%.

When assessing the biological value of hatching eggs, adding sapropel into the goose mixed feed in the amount of 6.0% of its weight confidently increased the content in vitamin A in eggs by 8.5% ($p<0.01$); vitamin B2, by 6.3% ($p<0.01$), and carotenoids, by 11.9% ($p<0.01$), which indicates the advisability of using sapropel in this dose.

Producing sound and high-quality hatching eggs is an essential factor in goose breeding. Accounting of the hatching egg production showed that its highest level was recorded in the 2nd experimental group; the difference with the control group was 2.0% ($p<0.05$). For the first and third experimental groups, it was 0.2% and 0.7%, in favor of the experimental groups.

The use of sapropel positively affected the egg fertilization, which increased to 4.8% ($p<0.01$) in the second experimental group, and by 1.1% and 1.9% ($p<0.05$) in the first and third experimental groups, respectively. This fact confirms the favorable effect of sapropel on the egg-laying capacity. In turn, better egg-laying capacity favorably affected the hatching results. Thus, goslings output increased in the experimental groups by 0.38–5.43% ($p<0.05$), and hatchability, by 1.49–1.91%. The best hatching results were recorded in the 2nd experimental group, where the content of the sapropel added was 6% of the mixed feed weight. Along with sapropel, the researchers' attention has long been attracted by such natural clay minerals as bentonite and kaolinite due to their environmental friendliness and low cost (Adamis *et al.,* 2005; Almquist *et al.,* 1967; Erwin *et al.,* 1957).

Experiments held on hens, when adding bentonite and kaolinite into their diet, showed that poultry significantly increased their body weight, egg size, and lifetime. However, they consumed fewer calories than in the control group (Quisenberry, 1968). At the same time, the use of kaolin increased the feed caloric value even slightly better than bentonite; however, without a visible effect on the growth and the carcass quality. Effective kaolins are estimated at two calories of metabolizable energy per gram. However, according to the above author, the main positive effect is probably due to a decreased rate of feed passage through the bird's intestinal tract.

Researchers Pasha *et al.* (2008) also determined the effect of diets containing various doses of sodium bentonite on broiler chickens' productivity. Their study involved 280 one-day chickens, which were randomly divided into 7 experimental groups: A (control); B, and C (0.5% and 1.0% of sodium bentonite, respectively); D and E (0.5% and 1.0% of sodium bentonite + 0.5% and 1.0% of gentian (respectively); F and G (0.5% and 1.0% of sodium bentonite + 0.5% and 1.0% of acetic acid, respectively). According to the research results, it was found that birds who received the diet with sodium bentonite treated with 0.5% or 1.0% acetic acid significantly increased their live weight gain (P <0.05), reduced feed consumption per unit of product, and increased the protein digestibility ratio, as compared to the control and other experimental groups.

As known, feed is a significant part of the total cost of growing and keeping poultry, which accounts on average for more than 70% of all costs and, accordingly, the feed utilization by the poultry body affects the entire production performance. Accounting of the feed costs per unit of products showed that the poultry in the 1st and 2nd experimental groups consumed 0.4–1.6 kg or 2.5–10.1% less feed (p<0.05) to produce ten eggs. The use of feed components was determined based on the digestibility and utilization of feed nutrients by carrying out balance experiments. Based on the data obtained, it should be noted that the use of sapropel as a feed additive in the goose diet increased the digestibility and utilization of the primary feed nutrients (Table 1).

The use of sapropel as a feed additive in the goose diet has been found to increase the digestibility and utilization of the main feed nutrients. Thus, the digestibility of protein increased by 0.4–4.9% (p<0.001), fat, by 0.2–1.6% (p<0.01), and fiber, by 0.4–2.6% (p<0.01). In terms of nitrogen, calcium, and phosphorus utilization, we noted the same tendency in the experimental groups. Thus, adding sapropel in the goose diet increased the use of nitrogen to 6.2% (p<0.001), calcium, to 8.7% (p<0.001), and phosphorus, to 1.6% (p<0.05).

Among the experimental groups, the best results in terms of digestibility and utilization of feed components were that of geese in the 2nd experimental group, where the level of sapropel added was 6.0% of the mixed feed weight. It should be noted that increasing the level of sapropel added to 9.0% of the mixed feed weight did not provide any further improvement in the utilization of feed components.

Gous (2010) also stated the opportunities to improve the use of feed nutrients. Thus, according to this researcher, over the past 50 years, genetics has shown success in improving potential bird growth indicators, and, probably, further genetic progress is possible in the future. However, to maximize the potential growth of fast-growing crosses, nutritionists will need to change their feeding method. It is assumed that, with some manipulation of the nutrient content in the feed, nutritionists will be able to support these genetic changes. In the future, feed restrictions may occur immediately after hatching, when the intestinal volume does not allow consuming a sufficient amount of the usual starting feed, but so that a chicken could fully grow, revealing its full potential.

Blood, ensuring the constancy of the body's internal environment and the connection between its parts, plays an essential role in metabolism. The general health status of a bird can be assessed through blood counts. Therefore, we studied the morphological composition of the goose blood when consuming mixed feeds with different levels of sapropel, the results of which are presented in Table 2.

It was demonstrated that goose hematological parameters in all groups were within the physiological standards and corresponded to clinically healthy poultry. At the same time, these parameters were slightly higher in the experimental groups than in the control group, which indicates a positive effect of sapropel on hematopoiesis in their body. Thus, the level of hemoglobin in the goose blood in the experimental groups increased by 2.9–9.1% (p<0.05); the number of red blood cells increased by 0.7–1.7%; white blood cells, by 1.9–6.3%, as compared to the control group, whereas the best indicators were recorded in the experimental group -2, making 132.2 g/L, 3.01×10^{12}/L, and 25.84×10^{9}/L, respectively. Therefore, the use of sapropel-enriched diets increased the level of hemoglobin and blood cells, which, in turn, has a favorable effect on the redox processes in the goose body.

The positive effect of sapropel on the poultry body was revealed in the research by other authors. Thus, Losyakova *et al.* (2018) studied slaughter indicators of Ross 308 cross broiler chickens, whose diet included sapropel-based feed additives. The control broiler chickens received mixed feed without additives; the 2nd group, mixed feed with the addition of 1% (by weight) sapropel extract into drinking water; the 3rd and 4th groups, mixed feed partially replaced (by weight) with the studied additives: poultry in the 3rd group received 2.5% of frozen sapropel; the 4th group, 10% of additional green feed with sapropel mass. The study lasted 56 days. The most regular results were obtained in young hens, where broiler chickens in the experimental groups exceeded the control group by all studied slaughter indicators. Among the chickens of the experimental groups, the advantage was observed in the 3rd group. With no differentiation by gender, poultry in the experimental groups exceeded the control group by such valuable indicators as the weight of the pectoral and femoral muscles, the weight of the heart, and gizzard stomach.

Along with using sapropel as a feed additive for farm animals and poultry, it is added to finished products to increase their nutritional value. Thus, Gorelik *et al.* (2017) studied the chemical and mineral composition of a new fermented-milk biological product with sapropel powder. They added sapropel in the form of powder to the fermented milk formulation in the amount of 1.5% of the total weight. According to the results of their investigation, the researchers found that the protein content in the new fermented-milk biological product was significantly higher (20.95%) than in the control sample (18.40%) with a decrease in moisture content to 76.0–76.3% against 79.50% in the control group. At the same time, the nutritional value of the final product increased to 15.3 kcal or 16.4% due to the high protein and fat content (Gorelik *et al.,* 2017, Chernitskiy *et al.,* 2019).

A high ability of sapropel to biogenic stimulation and its protective properties was indicated. Thus, Kurzo (2005) and Makarov *et al.* (2017) argue that the use of sapropel promotes tissue repair processes; it has an anti-inflammatory effect in case of burns and corneal diseases, stimulates respiration, and inhibits free radical activity. Therefore, sapropel preparations as biological stimulants are becoming perspective in different branches of the economy, including healthcare, agriculture, and veterinary medicine (Stankevica *et al.,* 2019, Vorobyev *et al.,* 2019).

Along with assessing the sapropel effects on the manifestation of economically useful traits and biological parameters in the parent flock of geese, it is also important to evaluate its economic efficiency in this age and gender group. For this purpose, an industrial validation of the sapropel effectiveness in the parent flock diets of Hungarian white geese was conducted on the premises of the Bashkirskaya Ptitsa, LLC, located in the Blagovar District, the Republic of Bashkortostan. The results are presented in Table 3.

The study was conducted on two groups of geese with different types of feeding. There were 1,000 birds in each group with 3 hens per 1 male. Geese of the first group received mixed feed without sapropel; birds in the second group got feed with sapropel in the amount of 6.0% of the feed weight. The poultry of both studied groups had the same keeping and feeding conditions consistent with the recommendations of the All-Russian Research and Technological Institute of Poultry Breeding (Sergiev Posad), except for the studied factor.

The results of the industrial validation confirmed the positive effect of sapropel on the reproductive qualities of the goose parent flock. Thus, geese fed with sapropel showed a higher egg productivity per average layer, i.e., 49.1 eggs, which is higher by 7.2% ($p<0.01$) compared to the group that did not receive sapropel. This has resulted in higher gross egg production and the total yield of hatching eggs by 9.8% ($p<0.01$) and 2.3% ($p<0.05$), respectively. Better productive parameters, that increased the number of standard-quality goslings by 3,850 birds or 17.46% ($p<0.01$), had a positive impact on the economic indicators of geese raising. Thus, the cost of one-day goslings reduced by 7.1%; the revenue and profit from their selling increased by 17.5% and 153,439.3 rubles, respectively, whereas the sector’s profitability grew by 9.8%.

4. CONCLUSIONS:

The results of the conducted research prove that adding sapropel in the diet of the parent flock of geese promoted a complete satisfaction of the body’s needs for nutrients and improved metabolic processes, as evidenced by the poultry’s highly productive and reproductive qualities. The optimal rate of sapropel in the goose diet was found to be 6.0% of the mixed feed weight. It enhances a survival rate of poultry by 2.0%, egg production by 7.5%, the number of goslings hatched by 5.4%, improved the morphological composition of blood and the diet nutrients utilization. The production rate of one-day goslings was found to be higher by 17.5% while reducing the cost of feed per unit of products. This ultimately increased the sector's profitability by 9.8%.

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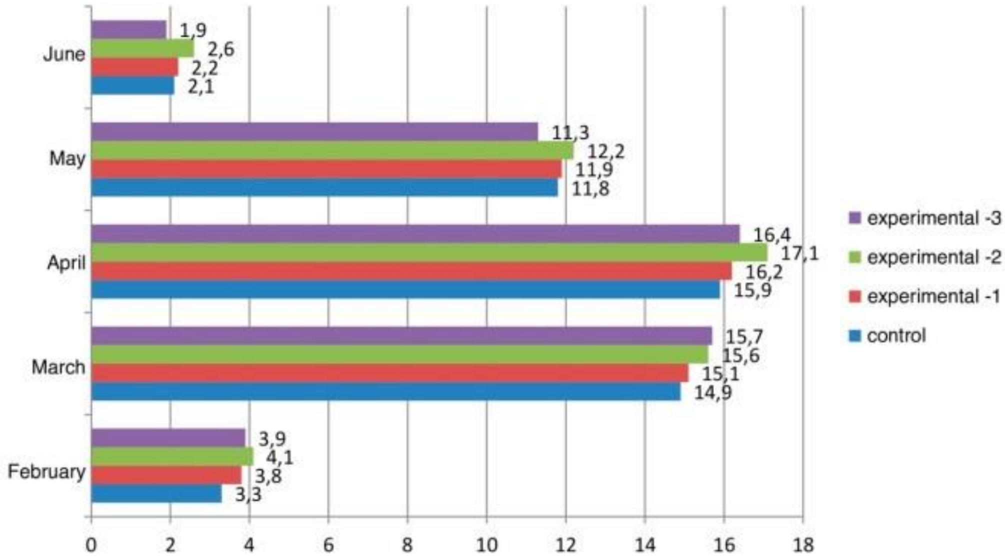

Figure 1. *Goose egg productivity per average layer, pcs.*

Table 1. *Generalized utilization indicators of the mixed feed nutrients*

Group	Digestibility, %			Utilization, %		
	protein	fat	fiber	nitrogen	calcium	phosphorus
control	78.3±0.38	55.8±0.18	53.1±0.16	46.9±0.41	41.6±0.52	38.3±0.18
experimental -1	78.6±0.42	55.9±0.19	53.3±0.23	47.2±0.35	42.3±0.19	38.4±0.15
experimental -2	82.1±0.46***	56.7±0.21**	54.5±0.26**	49.8±0.39***	45.2±0.47***	38.9±0.13*
experimental -3	79.7±0.48*	56.1±0.08	53.7±0.24	48.3±0.46*	42.8±0.38	38.6±0.12

*Confident differences with control: * – p<0.05; ** – p<0.01; *** – p<0.001*

Table 2. *Morphological composition of goose blood at the peak of productivity (in April)*

Group	Hemoglobin, g/L	Red blood cells, ×10^{12}/L	White blood cells, ×10^{9}/L
Control	121.2±1.39	2.96±0.19	24.31±1.98
Experimental -1	124.8±1.31	2.98±0.21	24.79±2.06
Experimental -2	132.2±1.44*	3.01±0.26	25.84±2.11
Experimental -3	128.6±1.34*	2.98±0.24	25.81±2.04

** – p<0.05*

Table 3. *Results of the industrial use of sapropel in the husbandry of the parent flock geese*

Indicator	**Diet type**	
	Basic diet without sapropel	**Basic diet added with sapropel in the amount of 6.0% by weight of feed**
Total goose stock, birds.	1,000	1,000
including females, birds	750	750
males, birds	250	250
Egg production by average layer, pieces	45.8±0.56	49.1±0.53***
Gross egg production – total, pieces	32,564	35,757
Hatching egg output, %	94.8	97.1
Goslings hatched, %	67.71	72.43
Number of one-day goslings, birds	22,049	25,899
Feed consumption – total, kg	81,121	83,903
Feed cost – total, rubles	42,1829.2	43,6295.6
Sapropel cost, rubles	0	5,191.68
Cost of a one-day gosling, rubles	51.7	48.0
Egg production cost – total, rubles	1,138,938.8	1,243,442.5
Revenue – total, rubles	1,477,280.0	1,735,223.0
Profit, rubles	338,341.2	491,780.5
Profitability, %	29.7	39.5

*** – *p<0.001*