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NUTRITION METHOD OF ACTIVATING OSTEOGENESIS IN THE ORGANISM OF FARM ANIMALS AND POULTRY

Abstract

Minerals take part in all metabolic processes of the body of farm animals and poultry, are catalysts of metabolism; enzyme and hormonal systems, take part in the implementation of the immune response, development and integrity of tissues and bones, protection from oxidative stress, growth and division of cells, plumage, appetite formation, etc. The efficiency of mineral metabolism depends on the productivity of farm animals and poultry, the quality and safety of livestock and poultry products, profitability and profitability of industries. The problem of ensuring bone mineralization for young modern highly productive animals and poultry, providing calcium for laying hens, dairy cows, in which the course of metabolic processes, the functions of individual systems and organs are carried out on the border of norm and pathology, is urgent. It is substantiated that due to a number of problems, the correction of mineral metabolism during the maintenance process is ineffective, the development of nutritional methods for managing mineralization processes in the body of farm animals and poultry is promising. To maintain the metabolism of macroelements, osteobiotic components are appropriate, since the most frequent problem of mineral supply is not a deficiency in feed, but the problem of metabolism and endogenous losses in the body. To activate osteogenesis, the choice of isoflavones is justified, since the wide spectrum of biological action of polyphenols allows for a systemic corrective effect on organs and systems, significantly increasing the nonspecific resistance of the body to endo- and exogenous factors. Using the developed technology, a feed additive of soy isoflavones EXSO was obtained, its effect on the main indicators of mineral metabolism in the body of laboratory animals was determined, and the prospects for its use as a component of compound feed products to ensure osteobiotic action were outlined. It has been established that the chemical composition of EXO is represented by a wide range of water-soluble substances: peptides, amino acids (32-38%), sugars 42-46% (raffinose and stachyose, etc.), vitamins, macro- and microelements, isoflavones genistein and daidzein. A significant number of proteolysis inhibitors in the preparation, which have anti-inflammatory properties, prebiotics (raffinose and stachyose), which eliminate the phenomenon of dysbiosis and allow using the potential of normobiota to enhance osteobiotic action. In vivo it was established: the introduction of the feed additive of soy isoflavones EXSO into the body increases the activity of alkaline phosphatase (a biochemical marker of osteoblasts) in the blood serum: starting from the 8th day of use, at a dose of 300 mg/kg, as well as from the 24th day at a dose of 150 mg/kg, and by the end of the observation, the activity level is significantly higher than the corresponding indicators in the control group. The introduction of EXSO reduces the calcium content in the blood on the 14th day at a dose of 300 mg/kg and on the 34th day at a dose of 150 mg/kg, which indicates an intensive course of mineralization processes in the body. Daily administration of EXSO significantly shortened the period of bone densification: at a dose of 150 mg/kg - 30 days earlier, and 300 mg/kg - 40 days earlier than in the control group. It is advisable to use the feed preparation of soy isoflavones EXSO in the production of compound feed products, not increasing the calcium content in the feed, but normalizing metabolic processes in the body, which will allow avoiding diseases and pathologies caused by excessive intake the calcium.

Keywords: mineral metabolism, poultry, soy, isoflavones, osteobiotics, bone tissue, feed.

Introduction

The problem of adjusting mineral metabolism in the body remains relevant today [1-3], on the PubMed platform on this topic over the past 10 years the number of works has increased more than 3 times and exceeds two thousand.

Mineral substances take part in all metabolic processes of the body, are catalysts of metabolism, enzyme and hormonal systems, take part in the implementation of the immune response, development and integrity of tissues and bones, protection against oxidative stress, cell growth and division, plumage, appetite formation, etc. [1-4].

As a result, the efficiency of mineral metabolism

depends on the productivity, quality and safety of livestock and poultry products, the profitability and profitability of industries [4, 8], the effective use of resources (feed, energy, human, etc.) and the formation of food resource parameters to ensure food security of mankind.

Despite the accumulated extensive data on the metabolism of macroelements [7], the existing long-term experience of application in feed production [3, 5, 6, 8], this knowledge is currently insufficient to address the issue of ensuring the needs of livestock and poultry.

The physiological characteristics of modern high-yielding animal breeds and poultry crosses are significantly different from those previously identified and for which recommendations have been developed, the pecu-



liarities of digestion processes and ensuring the availability of nutrients and biologically active substances have been studied [5, 6, 8].

Intensive selection to increase growth rate, without taking into account the regularities of the formation of all systems and organs, genetic maximums of productivity, cause vital activity, the course of metabolic processes, the functions of individual systems and organs on the border of norm and pathology [9].

The problem of ensuring the mineralization of bone tissue in young pigs, poultry, and providing calcium to laying hens and dairy cows remains relevant. In the first 10 days of growth of young poultry, there should be a daily increase in bone density of 0.7%. A laying hen spends 2.2 g of calcium on the formation of an egg [1, 2, 5, 6].

The development of various types of mineral supplements has allowed to increase their bioavailability [5, 6], but the issue of providing the body with macroelements has not been resolved. In practice, different effectiveness of the same supplements is obtained when changing feed, conditions of detention, etc. In the case of mineral metabolism, this is a particularly acute issue, which is the cause of significant losses in livestock and poultry farming. Fluctuations in the degree of absorption of mineral supplements do not allow to comply with physiologically justified norms. Excessive mineralization of tissues leads to significant violations of all vital systems of the body [7, 9].

The most significant manifestations of impaired absorption of macroelements in the body of farm animals and poultry:

- arthritis, inflammatory processes in the joints (aggravating factors: genetic predisposition, congestion, lack of exercise, etc.) (pain, decreased appetite, decreased productivity, long before the appearance of symptoms);
- osteoporosis, cellular paralysis, joint weakness (systemic skeletal disease, decreased bone mass, fractures, losses of 3-6% per month of operation);
- Laminitis, lameness, hoof damage (sow culling, piglet mortality, stillbirth, decreased milk yield, etc.);
- eggshell fragility, egg fighting (egg waste in the EU, USA 1-10% sometimes up to 15%);
- decreased milk production, egg production;
- decreased resistance to viral and infectious diseases (risk group for African and classical swine fever, gastroenteritis, etc.);
- hypercalcemia, excess calcium (deposits in soft tissues: lungs, brain, kidneys, gastrointestinal tract, etc.) [2, 4, 8, 9].

The problems of correcting mineral metabolism in the process of keeping animals and poultry are related to the fact that clinical manifestations of the disorder appear after a long time, during which growth, development, productivity are not ensured [2, 7, 8], but it is impossible to establish the causes and carry out therapeutic and preventive actions.

However, even establishing the fact of the disease does not mean the effectiveness of further solutions, which is due to: a short growing cycle; unprofitable further maintenance, since irreversible changes in systems and organs will not ensure full restoration of productivi-

ty; livestock and poultry products will not meet the requirements of quality and safety due to the use of drugs [4, 8].

Very often, cases of partial violation of mineral metabolism are widespread [7], it is impossible to diagnose the causes and carry out corrective actions (for the manifestation of clinical symptoms of diseases, lesions are insufficient, but there are violations of the functions and systems of the body, the formation of a shell in the oviduct, decreased productivity, etc.) [2, 8, 9].

It is impossible to carry out preventive control for a number of reasons, there are no effective indicators, the cardiovascular, lymphatic, urinary systems of poultry are almost inaccessible for research, only blood analysis and even that has its own problems due to the amount of sample [9].

Thus, the only acceptable option is to change approaches to mineral metabolism from control during the maintenance process to management during the creation of compound feed products based on soybeans [10, 17, 18], which contain active components of broad biological action. It is known that soy isoflavones [10-16], possessing a wide spectrum of biological effects of polyphenols, allow for a systemic corrective effect on organs and systems, significantly increasing the body's nonspecific resistance to endo- and exogenous factors.

The purpose of the work: to determine the effect of the developed feed additive of soy isoflavones (EXSO) on the main indicators of mineral metabolism in the body of laboratory animals and to outline the prospects for its use as a component of compound feed products with osteobiotic action.

Materials and methods of the study

The object of the study is the feed additive soy isoflavones (EXSO). The subject of the study is the study of the chemical composition of the feed additive soy isoflavones (EXSO) and its effect on the main indicators of mineral metabolism in the body of laboratory animals.

The chemical composition of the samples was determined by standard methods recommended by AOAC (Association of Official Analytical Chemists) [19].

The amino acid content was determined after preliminary acid hydrolysis of feed additive samples with 6 M HCl at a temperature of +110 °C for 22-24 hours in hermetically sealed flasks. After neutralization of the hydrolysate, quantitative determination of amino acids was carried out by high-performance liquid chromatography (HPLC) with preliminary derivatization with o-phthalaldehyde and spectrophotometric detection. The content of short-chain peptides was determined without complete hydrolysis by HPLC, which allows estimating the total content of peptide fractions. The methods met the requirements of AOAC and ISO 13903:2005. Animal feeding stuffs - Determination of amino acids.

The content of total sugars was determined by the photometric method after acid hydrolysis by reaction with phenol and concentrated sulfuric acid. The color intensity was measured at a wavelength of 490 nm. Monosaccharides (glucose, fructose, sucrose) were determined by HPLC with a refractometric detector after aqueous extraction of the sample.

The mineral composition of the feed additive (Ca,



P, K, Mg, Na, S, Fe, Mn, Zn, Cu) was determined after preliminary wet mineralization of samples in a mixture of concentrated acids ($\text{HNO}_3/\text{H}_2\text{O}_2$). Quantitative determination of elements was carried out by atomic absorption spectrometry (AAS). The methods complied with the standards AOAC, ISO 6869:2000. Animal feeding stuffs — Determination of calcium, copper, iron, magnesium, manganese, potassium, sodium and zinc and ISO 11885:2007. Water quality — Determination of selected elements by ICP-OES.

The content of vitamins of the water-soluble (B_1 , B_2 , B_3 , B_5 , B_6 , H, B_{12}) groups was determined by HPLC after appropriate sample preparation (extraction with organic solvents or aqueous buffer systems). Detection was carried out by UV or fluorimetric detector depending on the nature of the vitamin. Quantitative determination was carried out by comparison with calibration standards. The methods complied with the requirements of AOAC Official Methods, ISO 20633, ISO 6866.

The biological efficacy of EXSO was tested on female Wistar rats of herd breeding. During the experiment, 180 animals aged 33-39 days (average age 36 days) were used, which were divided into three groups: control and two experimental. Every day, the rats were intragastrically administered:

- saline solution (control),
- aqueous suspension of EXSO at a dose of 150 mg/kg (I-a - experimental group);
- aqueous suspension of EXSO at a dose of 300 mg/kg (II-a - experimental group).

On the 3rd, 8th, 14th, 24th, 34th, 44th and 54th days of drug administration, rats underwent complete cardiac exsanguination under light ether anesthesia. Blood serum was collected, femurs and jaws were isolated.

The work used biological research methods [20]. In the blood serum, which was obtained by centrifugation of whole blood at 3000 min^{-1} for 10 min, the level of calcium, phosphorus and alkaline phosphatase (ALP) activity were determined [21]. Biochemical parameters were determined by spectrophotometric methods using standard commercial reagent sets in accordance with international recommendations [20].

The concentration of total calcium in blood serum was determined by the colorimetric method with o-cresolphthalein complex. The method is based on the formation of a colored complex of calcium ions with o-cresolphthalein complex in an alkaline medium, the intensity of the color of which is directly proportional to the concentration of calcium in the sample. The optical density was measured at a wavelength of 570-580 nm relative to the calibration standard. The methodology was in accordance with ISO 15189:2022 (Medical laboratories - Requirements for quality and competence) and IFCC recommendations for the determination of total calcium in serum.

The content of inorganic phosphorus was determined by the photometric molybdate method. In the presence of phosphate ions in an acidic medium, a reaction occurs with ammonium molybdate to form a phosphomolybdate complex, the color intensity of which is proportional to the phosphorus concentration. The optical density was measured at a wavelength of 620-660 nm.

The determination was carried out in accordance with ISO 15189:2022 and generally accepted photometric methods of clinical biochemistry, harmonized with IFCC recommendations.

The activity of alkaline phosphatase in serum was determined by a kinetic colorimetric method using p-nitrophenyl phosphate. The principle of the method is based on the enzymatic hydrolysis of p-nitrophenyl phosphate in an alkaline medium with the formation of p-nitrophenol, the rate of accumulation of which was determined spectrophotometrically at a wavelength of 405 nm. The fermentation activity was calculated from the rate of change in optical density and expressed in international units (U/dm^3) at a temperature of $+37 \text{ }^\circ\text{C}$. The method met the recommendations of the IFCC (International Federation of Clinical Chemistry and Laboratory Medicine) and the requirements of ISO 15189:2022.

The ash content of the femur was determined by the gravimetric method after dry ashing as an additional indicator of the mineral saturation of bone tissue. The femur (jaw), previously dried according to ISO 6496:1999 (Animal feeding stuffs — Determination of moisture and other volatile matter content (preparation of samples for drying)) to a constant mass, was crushed and placed in porcelain crucibles. Ashing was carried out in a muffle furnace at a temperature of $+550 \pm 25^\circ\text{C}$ until light gray or white ash with a constant mass was obtained. After cooling in a desiccator, the crucibles with ash were weighed on an analytical balance. The ash content (bone ash) was calculated as a percentage of the mass of dry bone according to the formula:

$$\text{Ash content} = (m_{\text{ash}} / m_{\text{dry bone}}) \times 100, \% \quad (1)$$

where m_{ash} - the mass of the mineral residue after ashing, g;

$m_{\text{dry bone}}$ - mass of the femur after drying, g.

The obtained indicator directly reflects the content of mineral components (mainly calcium and phosphate salts) in bone tissue and is widely used to assess the effectiveness of mineral nutrition of poultry in accordance with IFCC Recommendations on biochemical markers of bone and mineral metabolism.

The combined determination of femur density and its ash content (bone ash) allows you to objectively assess the degree of bone tissue mineralization [22], the intensity of osteogenesis and the efficiency of calcium and phosphorus absorption, which is especially informative when studying the effect of rations and nutraceutical supplements in poultry.

The density of the femur was determined in order to assess the degree of bone tissue mineralization. The method is based on determining the mass of mineral components of the bone relative to its volume or area, which is an integral indicator of the mineral saturation of bone tissue. The density of the femur was determined by the gravimetric method by weighing the dried bone with subsequent determination of its volume by the liquid displacement method. The gravimetric method of determining bone density is simple, reproducible and suitable for experimental studies; for this, after preparation of the scapula, the femur (jaw) was cleaned of soft tissues, washed with distilled water and dried to constant mass at a temperature of $+105 \pm 2^\circ\text{C}$ in accordance with ISO 6496:1999. The mass of the bone was determined by



analytical balances with an accuracy of at least 0.001 g. The volume of the bone was determined by the liquid displacement method (Archimedes' principle) by immersing the sample in a measuring cylinder with distilled water and recording the change in volume.

Bone density (g/cm³) was calculated using the formula:

$$\rho = m/V, \quad (2)$$

where m - is the mass of dried bone, g;

V - is the volume of bone, cm³.

The method was in accordance with AOAC International (Official Methods of Analysis, methods for determining bone ash and gravimetric evaluation of mineral content); ISO 5725. Accuracy (trueness and precision) measurement methods and results and IFCC (Recommendations on biochemical markers of bone metabolism (for interpreting the results of bone mineralization).

The density of the femur is an informative indicator of the state of mineral metabolism, the intensity of osteogenesis and the efficiency of calcium and phosphorus absorption. Changes in this indicator reflect the level of bone mineralization and can be used to assess the impact of diet, nutraceutical supplements or technological factors in keeping animals and poultry; it allows for a comprehensive assessment of the efficiency of mineral absorption depending on the composition of the diet and the physiological state of the animals.

Research results and discussion

In laboratory conditions, experimental samples of the feed additive soy isoflavones (EXSO) were produced using the developed technology by selective extraction from soybeans and the nutritional and biological value was determined (Table 1). It was found that the chemical composition is represented by a wide range water-soluble substances: peptides, amino acids (32-38%), sugars 42-46% (raffinose and stachyose, etc.), vitamins, phenolic compounds, macro- and microelements, isoflavones genistein and daidzein.

A significant amount of proteolysis inhibitors in the preparation, which have anti-inflammatory properties, prebiotics (raffinose and stachyose), which eliminate

Table 1 – Chemical composition of the feed additive soy isoflavones (EXSO)

No	Name	Contents
1	Amino acids and peptides, %	28-32
2	Sugar, %	42-46
3	Potassium, g/kg	78-83
4	Phosphorus, g/kg	27-31
5	Calcium, g/kg	17-19
6	Magnesium, g/kg	11-14
7	Sulfur, g/kg	11-13
8	Sodium, g/kg	2-3
9	Iron, mg/kg	250-280
10	Manganese, mg/kg	100-118
11	Zinc, mg/kg	77-85
12	Copper, mg/kg	18-22
13	Vitamin B ₁ (thiamine), mg/kg	35-40
14	Vitamin B ₂ (riboflavone), mg/kg	10-12
15	Vitamin B ₃ (pantothenic acid), mg/kg	85-93
16	Vitamin B ₅ (nicotinamide), mg/kg	115-118
17	Vitamin B ₆ (pyridoxine), mg/kg	35-40
18	Biotin, mg/kg	1,8-2,1
19	Folic acid, mg/kg	6-7

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the phenomenon of dysbiosis and allow you to use the potential of normobiota to enhance osteobiotic action.

Among the macroelements, it should be noted the high content of potassium, calcium, magnesium and phosphorus. The microelement composition of the feed preparation EXSO is represented by almost all the elements necessary for life, among which iron, manganese, zinc and copper are contained in the largest quantities.

The biological value of EXSO is largely due to the presence of phenolic compounds (bioflavonoids, other polyphenols [10], aromatic acids) in its composition, which give the drug antioxidant, anti-inflammatory, and adaptogenic properties [16].

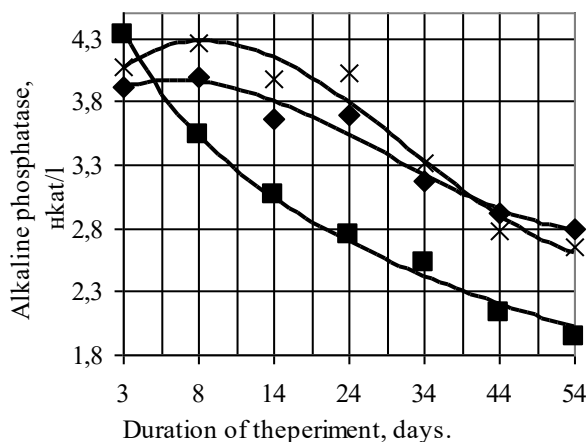


Fig. 1 - Change phosphatase content in rat serum

- control
- ◆ I research group (150 mg/kg) EXSO
- × II research group (300 mg/kg) EXSO

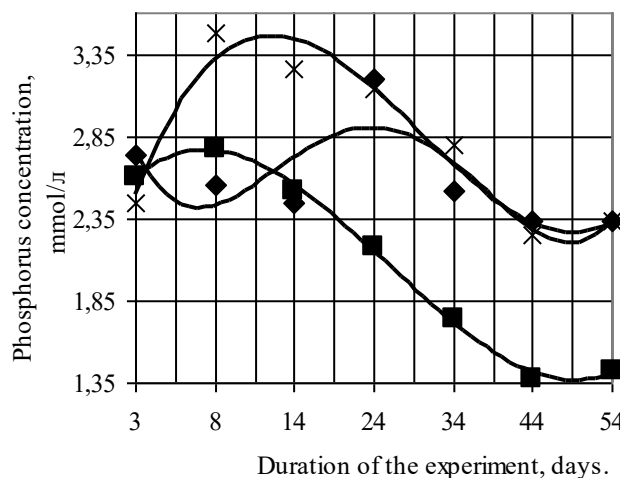


Fig. 2 - Change phosphorus in rat serum

- control
- ◆ I research group (150 mg/kg) EXSO
- × II research group (300 mg/kg) EXSO

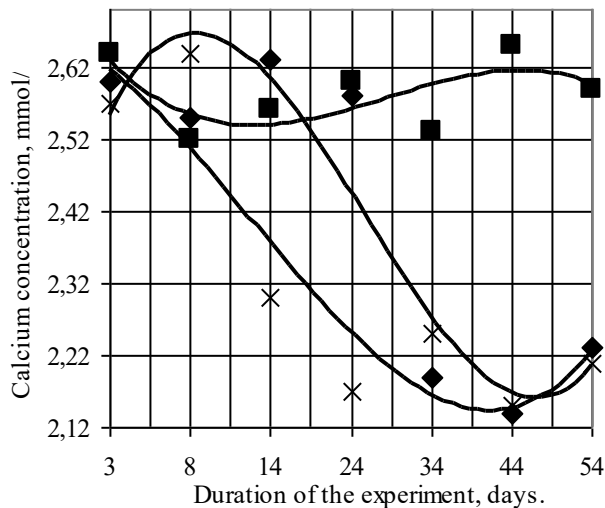


Рис. 3 - Change calcium in rats serum

- control
- ◆ I research group (150mg/kg EXSO)
- × II research group (300 mg/kg EXSO)

The effect of EXSO supplements on mineral metabolism in the blood serum of rats was determined in the selected samples (Fig. 1-3).

As can be seen from Figure 1, the activity of alkaline phosphatase (ALP) in the blood serum of 39-day-old intact rats is quite high - 4.32 ± 0.34 nkat/l. As a rule, the increased activity of this enzyme reflects processes associated with or osteoblast proliferation, or with the phenomenon of cholestasis.

Since the latter is excluded, this age of rats can be considered a period of intensive mineralization of bone tissue. In the process of further ontogenesis, the activity of LF decreases by 1.6 times at 60 days of age and by 2.2 times at 90 days of age.

Against the background of the introduction of the feed preparation of soy isoflavones EXSO, the activity of this enzyme also continues to fall, but starting from the 8th day of application, at a dose of 300 mg/g (II experimental group) and also from the 24th day of administration at a dose of 150 mg/kg (I experimental group) and until the end of observation, the level of serum LF activity is significantly higher than the corresponding indicators in the control group, that is, the drug inhibits the decrease in the activity of the enzyme responsible for the processes of bone mineralization.

Similar to the activity of LF, there is a decrease in the content of phosphorus in the blood serum (Fig. 2) during the growth and development of young rats, the level of which during the observation period falls in the control group by 1.8 times, and against the background of the introduction of 150 mg/kg of EXSO it decreases slightly. The dose of the drug 300 mg/kg maintains the concentration of serum phosphorus at a high level from 39 to 90 days of age of rats.

Thus, due to the varying degrees of reduction, the phosphorus level is significantly higher than the control values from the 24th day of administration of 150 mg/kg and from the 8th day of administration of 300 mg/kg of EXSO. A significant difference between the control and experimental values of phosphorus content is observed

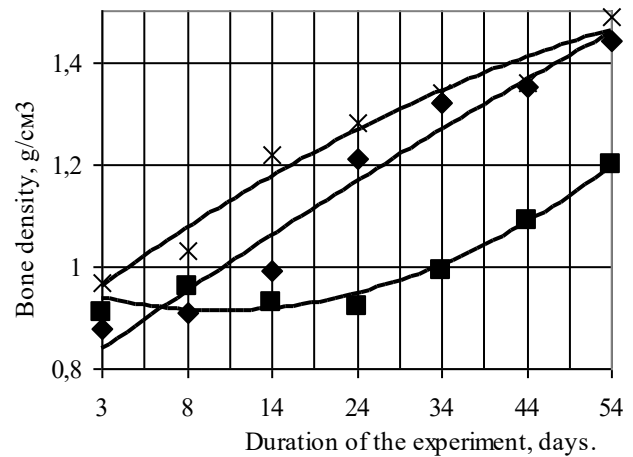


Рис. 4 - Dynamics of change density thigh bone rats

- control
- ◆ I research group (150mg/kg EXSO)
- × II research group (300 mg/kg EXSO)

until the end of the experiment.

The serum calcium level (Fig. 3) was stable and did not change during the study period in the control group of animals. The introduction of EXSO reduces the calcium content in the blood on the 14th day at a dose of 300 mg/kg and on the 34th day at a dose of 150 mg/kg. The above indicates an intensive course of mineralization processes in the body of growing rats, which are enhanced under the influence of EXSO.

Bone tissue is approximately 35% composed of an organic matrix, represented by 90% collagen, the basis for mineralization.

Healthy bone tissue is a dynamic system that is constantly updated due to remodeling - interdependent and clearly coordinated processes of bone resorption and formation. In pathology, there is a predominance of one of the processes, most often resorption, which leads to significant loss of bone mass. The initial stage in bone remodeling is the moment when osteoclasts secrete lysosomal enzymes (acid phosphatase and acid proteases), citrate, H^+ , and collagenase-type proteases. Acid phosphatases dissolve hydroxyapatite, and proteases destroy the organic matrix of bone tissue [23].

The osteotropic effect of the drug EXSO is confirmed by the study of femoral bone density in rats during their puberty (Fig. 4).

As can be seen from the data obtained, during the experiment in the control group, the density of the femur increases from 0.91 ± 0.07 to 1.20 ± 0.08 g/cm³, which indicates the superiority of mineralization over bone tissue resorption during this period of ontogenesis of rats.

Under the influence of daily administration of EXO, bone density increases significantly earlier than in the control group of animals, in particular: in the I experimental group on the 24th day this indicator is significantly higher than in the control group and on the 14th day of the experiment in the II experimental group.

Thus, receiving 150 mg/kg of EXSO daily, the bones of rats are densified 30 days earlier, and 300 mg/kg of EXO - 40 days earlier than in the control group.



Considering the mechanism of osteotropic action of the drug EXSO, first of all, it is necessary to pay attention to the presence of isoflavones genistein and daidzein, as well as their glycosides in the drug.

The obtained data are fully consistent with the results of other scientists. Studies (Williams, J.P. et. al., 1998) established the inhibitory effect of genistein on the activity of protein tyrosine kinase - an activator of bone osteoclasts [24].

By suppressing the processes of bone tissue reabsorption in this way, genistein EXSO activates the activity of osteoblasts and the formation of the main bone material hydroxyapatite. As a result, in the serum of rats receiving EXSO, LF activity increased and the level of phosphorus increased. At the same time, the simultaneous decrease in serum calcium is most likely associated with its increased entry into bone tissue for the formation of hydroxyapatite crystals.

Thus, the acute problem of ensuring the intensity of bone tissue mineralization processes for the critical period of young poultry in the first 10 days of growth, when bone density should increase by almost 30%, the egg-laying period of laying hens, young pigs, and the productive period of animals, can be solved by the alimentary method, using osteobiotics, in particular: the feed additive of soy isoflavones EXSO in the production of compound feed products.

Conclusions

1. It is impossible to ensure the zootechnical efficiency of compound feed products, the efficiency and

profitability of the livestock and poultry industries without the formation of adequate conditions for the occurrence of mineral metabolism.

2. It has been established that the most significant problem of mineral supply of farm animals and poultry is not a deficiency in feed, but a problem of metabolism and endogenous losses in the body, which necessitates the need to manage the specified parameters.

3. Development of nutritional approaches to manage mineralization processes in the body of farm animals and poultry will allow to ensure physiological needs for macronutrients and avoid cases of excessive intake and the occurrence of subsequent pathologies and diseases.

4. The feasibility of using soy isoflavones (EXSO) feed additive in feed production to activate osteogenesis has been established. Daily administration of EXSO significantly shortened the period of bone densification in rats, in particular: at a dose of 150 mg/kg - 30 days earlier, and 300 mg/kg - 40 days earlier than in the control group.

5. Further research is needed on the use of the feed additive soy isoflavones (EXSO) in feed production, taking into account the characteristics of different species, age groups, direction of use, conditions of keeping farm animals and poultry, and technological factors of production (composition and properties of feed components, features of the processes of preparation and manufacturing of products).

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АЛІМЕНТАРНИЙ СПОСІБ АКТИВІЗАЦІЇ ОСТЕОГЕНЕЗУ В ОРГАНІЗМІ СІЛЬСЬКОГОСПОДАРСЬКИХ ТВАРИН ТА ПТИЦІ

Анотація

Мінеральні речовини приймають участь в усіх обмінних процесах організму сільськогосподарських тварин та птиці, є каталізаторами метаболізму; ферментних і гормональних систем, приймають участь в реалізації імунної відповіді, розвитку і цілісності тканин і кісток, захисті від окисного стресу, рості і діленні клітин, оперенні, формуванні апетиту та ін. Від ефективності мінерального обміну залежить продуктивність сільськогосподарських тварин та птиці, якість та безпечність продукції тваринництва і птахівництва, рентабельність та прибутковість галузей. Актуальною є проблема забезпечення мінералізації кісткової тканини для молодняка сучасних високопродуктивних тварин та птиці, забезпечення кальцієм курей-несучок, дійних корів, в яких протікають обмінні процеси, функції окремих систем і органів здійснюються на межі норми й патології. Обґрунтовано, що через низку проблем, корегування мінерального обміну в процесі утримання неефективне, перспективною є розробка аліментарних способів управління процесами мінералізації в організмі сільськогосподарських тварин та птиці. Для підтримання метаболізму макроелементів доцільними є компоненти остеобіотики, оскільки найчастішою проблемою мінерального забезпечення є не дефіцит у кормі а проблема обміну та ендогенні втрати в організмі. Для активізації остеогенезу обґрунтовано вибір ізофлавонів, оскільки широкий спектр біологічної дії поліфенолів дозволяє здійснювати системний коригуючий вплив на органи і системи, істотно підвищуючи неспецифічну резистентність організму до ендо- і екзогенних факторів. За розробленою технологією отримано кормову добавку соєвих ізофлавонів ЕКСО, визначено її вплив на основні показники мінерального обміну в організмі лабораторних тварин та окреслено перспективи її використання як компоненту комбікормової продукції для забезпечення остеобіотичної дії. Встановлено, що хімічний склад ЕКСО представлений широким спектром водорозчинних речовин: пептиди, амінокислоти (32-38%), цукри 42-46% (рафіноза, стахіоза та ін.), вітаміни, макро- і мікроелементи, ізофлавонони геністеїн і дайдзеїн. Значна кількість в препараті інгібіторів протеолізу, які володіють антизапальними властивостями, пребіотики (рафіноза і стахіоза), які усувають явище дисбіозу і дозволяють використати потенціал нормобіоти для посилення остеобіотичної дії. In vivo встановлено: введення в організм кормової добавки соєвих ізофлавонів ЕКСО збільшує в сироватці крові активність лужної фосфатази (біохімічний маркер остеобластів): починаючи з 8-го дня застосування, в дозі 300 мг/г, а також з 24-го дня в дозі 150 мг/кг, і до кінця спостереження рівень активності вірогідно вище відповідних показників у контрольній групі. Введення ЕКСО знижує вміст кальцію в крові на 14-й день у дозі 300 мг/кг і на 34-й день у дозі 150 мг/кг, що свідчить про інтенсивний хід процесів мінералізації в організмі. Щоденне введення ЕКСО значно скоротило термін ущільнення кісток: у дозі 150 мг/кг – на 30 днів раніше, і 300 мг/кг – на 40 днів раніше, ніж у контрольній групі. Доцільно застосовувати при виробництві комбікормової продукції кормовий препарат соєвих



ізофлавонів ЕКСО, не підвищуючи вміст в кормі кальцію, а нормалізуючи обмінні процеси в організмі, що дозволить уникнути захворювань і патологій, зумовлених надлишковим надходженням кальцію.

Ключові слова: мінеральний обмін, сільськогосподарська птиця, соя, ізофлавоони, остеобіотики, кісткова тканина, комбікорм.

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INNOVATIVE DESIGN SOLUTIONS FOR IMPROVING THE ENERGY EFFICIENCY OF SCRAPER CONVEYORS

Abstract

The article examines the issue of improving the energy efficiency of scraper conveyors in transport, logistics and transshipment systems of flexible automated production facilities. The relevance of the work is determined by current trends in industrial development within the framework of Industry 4.0, which involves the introduction of digitalisation, automation and intelligent management technologies for the stable operation of production processes. One of the key tasks in this direction is to minimise energy consumption and increase equipment reliability while ensuring flexibility and efficiency of material flows. The advantages and disadvantages of traditional belt and scraper conveyors are analysed, with an emphasis on the operational limitations of the latter – increased energy consumption, cargo fragmentation, wear and tear of components, etc. The feasibility of using continuous action machines (CAM) as a key element in cargo handling systems is substantiated. A new design of a scraper conveyor with a movable trough bottom is proposed, which eliminates relative friction between the cargo and the bottom of the transport surface, as well as between individual cargo particles in the scraper zone. This design solution makes it possible to reduce energy consumption by more than 70% compared to traditional systems, as well as significantly increase the durability of the equipment and ensure careful transportation of fragile and solid materials. The paper presents a mathematical model for determining the coefficient of resistance to cargo movement, taking into account the reduced contact area, and develops formulas for determining the traction force and drive power. A theoretical justification for the reduction in energy consumption has been provided, confirmed by relevant calculations. The modified design eliminates a number of operational shortcomings of traditional scraper systems. The results obtained are of practical importance for engineers and designers of modern automated transport systems.

Keywords: continuous machines; scraper conveyor; belt conveyor; innovative design; mechanization, cargo flows; digital production; wear; ergonomics; safety; transportation; modernization, transport equipment.

Introduction

In transport-handling and transport-storage systems of flexible automated production, it is expedient and promising to use continuous-action machines (CAM) as key elements for moving cargo flows. CMMs increase the efficiency of transportation in flexible production facilities and contribute to the achievement of Industry 4.0 goals – digitalisation, automation and optimisation of all stages of the production process, including the following areas:

- continuity and stability of transportation – MBDs ensure uniform and continuous movement of goods, which is especially important for automated systems where maintaining the rhythm of production processes is critical.

- compatibility with automated logistics schemes – MBDs are easily integrated into cargo flow management systems, including robotic warehouses, automated sorting centres and digitally controlled lines;

- increased productivity thanks to continuous operation and minimal delays between MBD cycles;
- flexibility of layout in technological lines (flows);
- improved ergonomics and safety.

Among continuous-action machines, belt and scraper conveyors are the most widely used due to their relative simplicity of design, reliability and wide range of applications. At the same time, when each type of these conveyors is used separately, along with their advantages – in particular, high productivity, the ability to transport goods over long distances and ease of maintenance – there are also significant operational disadvantages. For belt conveyors, these limitations include the inability to transport bulk cargo with high moisture content, lumpy and abrasive cargo, as well as the risk of material spillage.

Scraper conveyors are characterised by the movement of cargo along a chute, flat deck or bedding