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Synthesis of boron chelates and their usage in broiler feeding

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Abstract

Synthesis conditions are established and boron chelate compounds are synthesized with general formulas $[(H_3BO_3)x \cdot gl] \cdot nH_2O$, (where x=1-3; gl-glutamine acid, n=1;2) (I) and $[(H_3BO_3)x \cdot Mt] \cdot 2H_2O$ (II) (where x = 1; 2; Mt-methionine). The composition, individuality, and qualitative solubility in different solvents of the synthesized compounds are determined. Thermal analysis determines the nature of the thermal decomposition of the compounds. The degree of dissociation of chelates and the dissociation constants are determined based on the conductometric study. An experiment was conducted on a broiler to study biological activity. Dynamics of broiler live mass, absolute live weight gain, daily weight gain, fowl keeping, feeding expenditure for a one-kilogram weight gain, broiler growth efficiency. It has been established that the usage of chelate boron in broiler feeding had a positive effect on all of the abovementioned parameters and the optimal dose of chelate is 100 mcg. per one kilogram of food.

Keywords: Boron; Chelate; Broiler; Feeding cost; Weight gain

1. Introduction

Georgia has a rich agricultural potential, yet not even a third of it is fully exploited. Therefore, providing the population with cheap, high-quality, ecologically safe livestock and poultry products is a topical issue today. One of the main reasons for these products' low quantity and quality is the lack of micronutrients in animals and poultry, as they are involved in all vital processes. However, it is established that the micronutrients necessary for life in the living organism perform their functions in the form of chelate compounds, so among the measures that must solve this problem, the most important condition is their provision with the optimal composition, quantity, and ratio of micronutrients; This can be achieved by creating premixes in the form of chelates containing essential micronutrients, as evidenced by the research of scientists working in this field [1-9], and the results of our experiment over the years [10-16], according to which chelate form has significant advantages over non-chelate when it comes to replenishing the deficit of micronutrients. This is because trace elements in the chelate form have low toxicity, high absorption capacity, and, consequently, an increased degree of efficiency when used in small doses, which in turn leads to the ecological safety of using trace elements in this form. Inorganic salts are characterized by high toxicity, a low degree of absorption, and efficiency, leading to poorly soluble and difficult-to-assimilate compounds in the gastrointestinal tract of livestock and poultry. According to the detailed norms of animal nutrition, the premixes currently contain the following trace elements Mn, Zn, Fe, Co, Cu, I, and Se. Herein, there is a large number of vital (essential) micronutrients that cannot be replaced by other micronutrients, and in the total absence or deficit of which the body cannot grow normally, consequently ending the life cycle. Among these trace elements, our focus has been set on boron. Boron is involved in regulating the action of the central nervous system, affecting the function of the genitals and thyroid glands. It plays an important role in the

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formation of bone tissue, promotes its strength, and prevents the development of osteoporosis. **Boron** is believed to improve the absorption of calcium by bone tissue. There is data on Boron's positive effects on life expectancy and growth. It is well known that boron, in the form of boric acid and its compounds, has long been used as an antimicrobial and antiseptic agent [17-25]. Georgia is an endemic source of boron deficiency, however, it is not currently included in premixes and is used in fertilizers in the form of inorganic salts; This is because as a trace element in the composition of anions, it is characterized by a lower tendency to form compounds in the form of chelate. According to the modern view of the ability to form complex microelements, which implies the use of a base nature chelate agent the aim of our work is the synthesis of boron-containing chelate compounds, physical-chemical research, and to determine its impact on fowl growth and development, productivity and physiological condition.

2. Material and methods

- Microelement analysis - to determine the composition of boron chelate compounds.
- Determination of melting temperature and diffractogram study - To determine the individuality of the chelates.
- Determination of solubility - to study the qualitative solubility of chelate compounds in different solvents.
- Conductometric research - determination of dissociation constant and dissociation quality of solutions containing solutions of chelate compounds.
- Thermographic analysis - to study the thermal stability of chelate compounds and the study of the sequence of the thermolysis process.
- Weighing method - to determine the weight gain of the broiler.
- Accounting method of food consumption - to determine the conversion of food and consumed nutrients (protein, energy).

3. Results and discussion

To obtain boron chelate compounds with general formulas $[(H_3BO_3)x{\cdot}gl]{\cdot}nH_2O$, (where x=1-3; gl-glutamine acid, n=1; 2) (I) and $[(H_3BO_3)\,x{\cdot}Mt]{\cdot}2H_2O$ (Where x=1; 2; Mt-methionine). (II). In the case of (I) boric acid and glutamine acid are taken separately with 1:1; 1:2 and 1:3 molar ratios, and in the case of (II), also separate boric acid and methionine are taken with 1:1 or 1:2 molar ratios. Each dissolves in a minimum volume of water under intense stirring and heating conditions. To the solutions of glutamine acid and methionine is added ammonia up to a weak alkaline range (pH=8). solutions of boric acid and glutamine acid, as well as boric acid and methionine, are mixed together in the above-mentioned sequence, filtered, and each of the three is kept at room temperature. After a few days, the obtained compounds are filtered, washed with water, ether, and dried at room temperature.

The composition and individuality of the obtained compounds are determined. The melting point is defined by the device melting point /SMP10 (Table 1), And it ranges from 180-240 ^{0}C temperature range.

Table 1 Some Physical Characteristics of the chelate compounds of Boric Acid

#	The formula of the Compound	Mol Mass	Melting t ^{0}c	Solubility				Conductometric Survey Results		
				Water	Alcohol	Acetone	Dmf*	α Average	R^2	K
1	$[H_3BO_3{\cdot}gl]{\cdot}H_2O$	226.98	235	+	+ t	+ t	+	0.8711	0.9864	$9.4522{\cdot}10^{-6}$
2	$[(H_3BO_3)_2{\cdot}gl]{\cdot}H_2O$	288.81	180	+	+ t	+	+	0.8569	0.8864	0.0692
3	$[(H_3BO_3)_3{\cdot}gl]{\cdot}2H_2O$	268.61	240	+	+ t	+ t	+	0.8911	0.9536	0.0549
4	$H_3BO_3{\cdot}Mt{\cdot}2H_2O$	247.08	215	+	+ t	+	+ t	0.4387	0.9433	0.0697
5	$(H_3BO_3)_2{\cdot}Mt{\cdot}2H_2O$	308.91	225	+	+ t	+ t	+	0.5865	0.8446	0.0472

Dmf* - Dimethyl formamide; + It is soluble; +t Soluble by heating.

The qualitative solubility of compounds in different solvents is determined, according to which they are characterized by good solubility in water and dimethyl formamide and relatively poor solubility in alcohol and acetone.

To determine the degree of dissociation and dissociation constant of boron chelate compounds, a conductometric study was performed on the device pH and Conductivity Sensor LE703. For compounds for this purpose: $[H_3BO_3{\cdot}gl]{\cdot}H_2O$, $[(H_3BO_3)_2{\cdot}gl]{\cdot}H_2O$, $[(H_3BO_3)_3{\cdot}gl]{\cdot}2H_2O$, $[H_3BO_3{\cdot}Mt]{\cdot}2H_2O$ and $[(H_3BO_3)_2{\cdot}Mt]{\cdot}2H_2O$ solutions were prepared in the concentration range from 0.025N to 0.0006503N N. The experiment was conducted on a thermostat at 25 ^{0}C. The results of the experiment are presented in Table 1. **R^2 -** (Determination coefficient), is called the approximation reliability coefficient, which shows how close the experimental data is to the corresponding function of the graph. As can be seen from the table it is quite high and ranges from 0.8446-0.9864. The degree of dissociation, which is variable, increases with dissolution. As for the values of the dissociation constant, it does not depend on the dissolution of the solution, is the constant value, as shown in the table, is quite low and ranges from $0.0472\text{-}9.4522{\cdot}10^{-6}$.

To study the sequence of thermal stability and thermolysis process of the synthesized boron chelates $[H_3BO_3{\cdot}gl]{\cdot}H_2O$, $[(H_3BO_3)_2{\cdot}gl]{\cdot}H_2O$, $[H_3BO_3{\cdot}Mt]{\cdot}2H_2O$ and $[(H_3BO_3)_2{\cdot}Mt]{\cdot}2H_2O$ a thermographic study was performed on the device: NETZSCH STA2500 in the atmosphere. The compounds were studied under the following conditions: TG = 100 mg., T = 700 ^{0}C, DTA = DTG = 1/5 heating rate of samples at 5 degrees/min. As can be seen from the thermographic study, all thermograms are characterized by several endo and exogenous effects and corresponding effects on the curve (Table 2).

Table 2 Results of a thermographic study of boron chelate compounds

#	Formula	T^0 C	Mass loss,%		Broken-off Molecule, Mol	Solid Product of Decomposition
			Practical	Theoretical		
1	$[H_3BO_3{\cdot}gl]{\cdot}H_2O$	80	4.23	3.97	$0.5H_2O$	$H_3BO_3{\cdot}gl{\cdot}0.5H_2O$
		100	3.89	4.13	$0.5H_2O$	$H_3BO_3{\cdot}gl$
		255	34.95	35.21	0.5 gl	$H_3BO_3{\cdot}gl_{0.5}$
		360	54.10	54.34	0.5 gl	H_3BO_3
		540	43.47	43.70	1.5 H_2O	0.5 B_2O_3
2	$[(H_3BO_3)_2{\cdot}gl]{\cdot}H_2O$	120	6.11	6.24	H_2O	$H_3BO_3{\cdot}gl$
		240	27.78	27.17	0.5 gl	$H_3BO_3{\cdot}gl_{0.5}$
		265	37.14	37.30	0.5 gl	H_3BO_3
		550	44.03	43.7	$3H_2O$	B_2O_3
3	$[H_3BO_3{\cdot}Mt]{\cdot}2H_2O$	85	11	7.29	H_2O	$H_3BO_3{\cdot}Mt{\cdot}H_2O$
		110	7.24	7.86	H_2O	$H_3BO_3{\cdot}Mt$
		250	35.78	35.35	0.5 Mt	$H_3BO_3{\cdot}Mt_{0.5}$
		270	55.13	54.68		H_3BO_3
		545	43.21	43.70		B_2O_3
4	$[(H_3BO_3)_2{\cdot}Mt]{\cdot}2H_2O$	110	6.03	5.83	H_2O	$(H_3BO_3)_2{\cdot}Mt\ H_2O$
		125	6.43	6.21	H_2O	$(H_3BO_3)_2{\cdot}Mt$
		245	27.12	27.43	0.5 Mt	$(H_3BO_3)_2{\cdot}Mt_{0.5}$
		310	37.54	37.80	0.5 Mt	$2H_3BO_3$
		540	43.92	44.02	$3H_2O$	B_2O_3

Thermogravimetric analysis of the chelate compound $[H_3BO_3{\cdot}gl]{\cdot}H_2O$ shows that I endo effect (80 ^{0}C) corresponds to a 0.5 mol H_2O breaking off (mass loss: practical 4.23%, theoretical 3.97%), at next endo effect (100 ^{0}C) the remaining

0.5Mol H_2O is broken off (mass loss: practical 3.89%, theoretical 4.13%). As the analysis shows, at the next endo effect (255 ^{0}C) there is an oxidation of 0.5 mol glutamine acid (mass loss: practical 34.95.0%, theoretical 35.21%). Oxidation of glutamine acid ends at 360 ^{0}C (mass loss: practical 54.10%, theoretical 54.34%). The thermal decomposition of boric acid corresponds to a strong exogenous effect at 540 ^{0}C (mass loss: practical 43.47%, theoretical 43.70%), and the final product of thermolysis is boric oxide B_2O_3, which was confirmed by qualitative and quantitative analysis of thermolysis residue.

The compound $[(H_3BO_3)_2{\cdot}gl]{\cdot}H_2O$ on the thermogravimetric graph shows three endo and one strong exogenous effect. The first endo effect at 120 ^{0}C corresponds to the break-off of 1 mol of water (mass loss: practical 6.11%, theoretical 6.24%), at the next endo effect (240 ^{0}C) oxidation of 0.5 mol glutamine acid takes place (mass loss: practical 27.78%, theoretical 27.17%), at the third endo effect (265 ^{0}C) oxidation of 0.5 mol glutamine acid takes place (mass loss: practical 37.14%, theoretical 37.30%). Thermolysis ends with a strong exogenous effect (550 ^{0}C) with the thermal decomposition of boric acid (mass loss: practical 44.03%, theoretical 43.71%) and the formation of boric oxide B_2O_3. The obtained result was confirmed by qualitative and quantitative analysis of the residue.

The thermogravimetric graph of the compound $[H_3BO_3{\cdot}Mt]{\cdot}2H_2O$ is characterized by several endos and one strong exogenous effect, indicating that it is decomposing in stages. In particular, the first endo effect at 85 ^{0}C corresponds to the breaking-off of 1 mole of water (mass loss: practical 7.11%, theoretical 7.29%). At the second endo effect at 110 ^{0}C, there is a break-off in the remaining second water molecule (mass loss: practical 7.24%, theoretical 7.86%). The third endo effect at 250 ^{0}C corresponds to an oxidation of 0.5 mol **Mt** (mass loss: practical 35.78%, theoretical 35.35%). At the next endo effect at 270 ^{0}C, methionine oxidation ends (mass loss: practical 55.13%, theoretical 54.68%). The thermal decomposition of boric acid corresponds to a strong exogenous effect at 545 ^{0}C and the final product of thermolysis is boric oxide. The obtained result was confirmed by qualitative and quantitative analysis of the thermal residue.

Thermal decomposition of the compound $[(H_3BO_3)_2{\cdot}Mt]{\cdot}2H_2O$ begins with the break-off of 1 mole of water at 110 ^{0}C (mass loss: practical 6.03%, theoretical 5.83%). At the next endo effect (125 ^{0}C) the remaining 1 mole of water is broken off (mass loss: practical 6.43%, theoretical 6.21%). At 245^{0}C the endo effect corresponds to the oxidation of 0.5 mol of methionine (break-off at 110 ^{0}C (mass loss: practical 27.12%, theoretical 27.43%). At the next endo effect (310 ^{0}C) the full oxidation of the remaining 0.5 mol methionine (mass loss: practical 37.54%, theoretical 37.80%). As in all other cases, the thermal decomposition ends with the decomposition of boric acid at 540 ^{0}C and the formation of boric oxide (mass loss: practical 43.92%, theoretical 44.02%). The obtained result was confirmed by qualitative and quantitative analysis of the residue.

To determine the biological activity of the boron chelate compound containing glutamine acid, the effect of chelate on broiler productivity was studied. The experiment was conducted according to the following scheme:

Table 3 Test scheme

Groups	Number of Fowls	Rearing Period	Boron Dose per 1 Wing (mcg)
I Control	100	35	-
II Experimental	100	35	50
III Experimental	100	35	100
IV Experimental	100	35	150

Table 4 Broiler live weight dynamic

Groups	Age, Dey			
	1	14	28	35
I Control	40.1	483.4	1439.1	1909.2
II Experimental	39.9	493.8	1487.0	2025.0
III Experimental	40.5	508.9	1473.2	2007.3
IV Experimental	40.0	495.5	1480.0	2000.1

During the experiment, we studied the growth and development of broilers, live weight dynamics, with weighing - at the age of 1; 14; 28; 36 days. We studied absolute gain during different periods of growth, and daily gain during rearing. We also studied: poultry keeping, feed expenditure per wing and one kilogram of weight gain, productivity index, meat quality, and some biochemical and morphological indicators of blood.

At the beginning of the experiment, the live weight of all four groups of broilers is almost identical and amounted to 39.9-40.5 grams. Which indicates their high homogeneity. At 14 days of age, the group III broiler had the highest live weight - 508.9 grams, which is 5.30% higher than in the control group. ($P \geq 0.001$) Group II and IV broilers had a higher live weight compared to the control group (by 2.50%, although the difference is not reliable).

At 28 days of age, the highest live weight was in group II broilers -1487.0 grams, which is 3.30% higher than the control group. ($P \geq 0.95$)

The live weight at this age of group III and IV broilers is 2.50-2.80% higher compared to the control group, although the difference is not reliable.

The broiler was slaughtered at the age of 35 days. The highest live weight for this period was 2025 grams from a Group II broiler and it weighed 6.1% more than the control group. ($P \geq 0.01$)

At the age of 35 days, group III and IV fowls also had a higher live weight compared to the control group (by 4.80-5.10%, $P \geq 0.01$).

Thus, the usage of boron in a chelate form had a positive effect on the growth and development of the broiler.

Table 5 Absolute weight dynamic

Groups	Absolute Gain, g			
	0-14 days	14-28 days	28-35 days	0-35 days
I Control	443.3	955.6	470.4	1869.3
II Experimental	453.9	993.2	538.0	1985.1
III Experimental	468.4	964.1	534.0	1966.5
IV Experimental	455.5	984.5	520.5	196.5

During the 0-14 days period, the highest absolute live weight gain was observed in group III, which was 468.4 grams, and the lowest in the control group - 443.3 grams.

The highest results are observed in group II in the period of 14-28 days, however, compared to the control group, the absolute gains of group III and IV broilers are also high.

During the 0-35 day period, the absolute growth of fowls in all three experimental groups is 4.8-6.2% higher compared to the control group's.

Figure 1 Broiler fowl groups

During the rearing period of 0-35 days, the daily increase in the experimental groups was 56.01-56.72 grams, while in the control group, it was 53.41 grams. Which is 4.8-6.2% lower than in the experimental group (Figure 1).

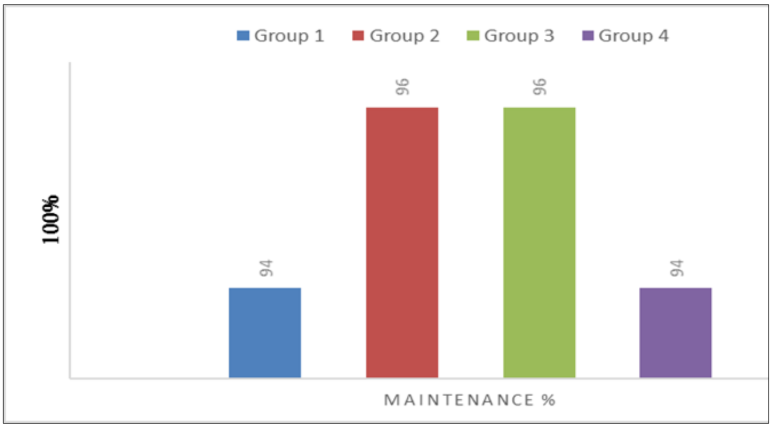

Figure 2 Broiler fowl groups

Broiler maintenance showed that maintenance in the 35 days was quite high in all groups, ranging from 94.0-96.0%.

94% in the control and IV groups, and 96% in the II and III experimental groups.

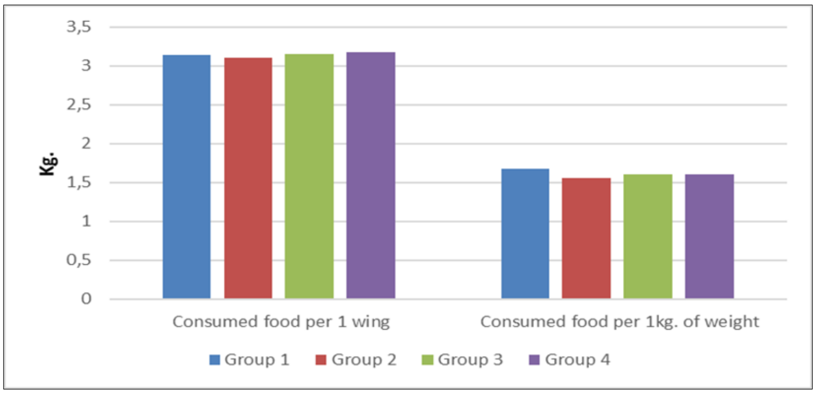

Figure 3 Broiler fowl groups

Feed consumption during the rearing period is almost the same for all four groups for one wing at 3.1-3.18 kg.

At one kilogram of body weight gain, feed consumption was the lowest in the II experimental group - 1.56 kg. Which is 7.2% lower than the control group. Also, food consumption per kilogram of body weight gain is 3.6-4.8% lower compared to the control group in experimental groups III and IV (Figure 3).

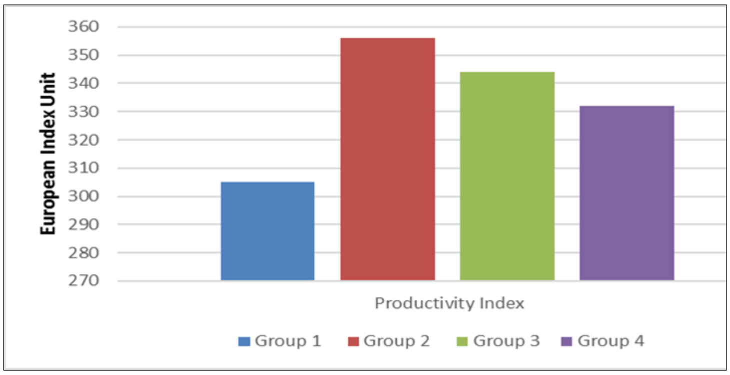

Figure 4 Broiler fowl groups

The efficiency of broiler rearing is shown by the European Productivity Index, which is calculated by the ratio of 4 indicators during the rearing of the broiler

$$\text{Productivity Index} = \frac{.live\ weight * maintenance}{feed\ conversion * slaughtering\ period}$$

This indicator is presented by the highest number in group II fowl - 356 units, and the lowest in the control group - 305.2.

The efficiency index in the III and IV experimental groups was 332-344 units, which is 27-39 units higher than in the control group.

Table 6 Slaughter results

Slaughter Results	I Control	II Group	III Group	IV Group
Number of slaughtered fowls, wing	88	90	90	88
Live weight of the slaughtered fowl, kg	167	181	180	176
Live weight of 1 wing	1900	2010	2000	2000
Half-gutted slaughtered fowl's weight	135	148	147	143
Slaughter output %	80.8	81.8	81.6	81.3
Weight of the half-gutted 1 wing	1534	1644	1633	1625
Poultry Category				
First category wing	68	74	72	71
First category %	77.3	82.2	80.0	80.6
Second category wing	17	14	16	14
The second category %	19.3	15.6	17.8	15.9
Non-standard wing	3	2	2	3
Non-standard %	3.4	2.2	2.2	3.5

The birds were slaughtered at 35 days of age. Slaughter results showed that the semi-gutted slaughtered fowl output was 80.8% in the control group and 81.3-8.6% in the experimental groups (Table 5).

The first category of meat was 77.3% in the control group and 82.2% in the second group, which is 4.9% higher. Slaughtered fowl output in III and IV experimental groups is 1.8-1.5% higher than the control group's (Table 3).

The chemical composition of meat (water, crude protein, fat) is almost the same in all four groups and the difference in these indicators is almost none between the groups (18.0-18.2% crude protein).

4. Conclusion

Based on the studies conducted, the following conclusions can be made:

- Synthesis conditions are established and glutamine and methionine-containing boron chelate compounds are synthesized.
- The individuality of the synthesized compounds is determined by measuring the melting temperature and dif fractographic method.
- Chelates are characterized by good solubility in water and dimethyl formamide and poor solubility in alcohol and acetone.

- The degree of dissociation of compounds and the dissociation constants are determined by the method of conductometric research.
- Thermal analysis has established that the thermal decomposition of compounds takes place in stages at the temperature range of 80-550 ^{0}C in the following sequence: I- break-off of water molecules; II-oxidizing-glutamine (methionine) molecule; III- Boric acid decomposes and in all cases, the final product of decomposition is a boric oxide.
- The use of chelate boron in broiler feeding had a positive effect on broiler live weight dynamic, absolute live weight gain, daily weight gain, and on fowl keeping.
- Consumption of feed was reduced per one kilogram of weight gain and broiler rearing efficiency was increased. The optimal dose of chelate is 100 mcg. per one kilogram of feed.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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