Chitosan complex in the technology of feeding broiler chickens

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Abstract. The aim of the study was to study the effectiveness of using a domestic feed additive based on chitosan (chitosan complex KX-1). The three control houses had 118,000 chicks at the start of the experiment, and the three experimental houses had 117,906 chicks. Broilers of experienced poultry houses were injected with a chitosan complex at the rate of 70 g per 1 ton of compound feed during the entire growing period (38-40 days). In the control poultry houses, broilers received feed with nutritional value according to the VNITIP standards. It was found that the gross production of broilers for slaughter in live weight in three control poultry houses was 254,120 kg, in three experimental ones - 255,830 kg, and the production of poultry meat in slaughter weight - 193,950 kg and 197,957 kg, respectively. In poultry houses where the chitosan complex was used in feed for broiler chickens, 4007 kg (2.02%) more meat was obtained than in the control. This was achieved due to the higher viability and safety of broiler chickens in all experimental poultry houses - 93.14%, and in control - 91.83%. The superiority in feed conversion of broilers grown in experimental poultry houses in comparison with the control ones was established. The fat content in the pectoral and leg muscles of the control and experimental broilers was low - 1.42-1.12% and 3.84-3.42%, respectively. At the same time, in the pectoral and femoral muscles of the experimental broilers, the fat content was 0.30% ($P<0.05$) and 0.42% ($P<0.05$) less compared to the control ones, which indicates an increase in the dietary properties of meat with use of the chitosan complex in poultry feeding.

1 Introduction

The ever-growing demand for meat and eggs, animal protein has made the poultry industry a priority for the development of agricultural production, especially industrial-type poultry enterprises, modern highly mechanized poultry farms. World trends in poultry production take into account the welfare of the bird and the quality of the final product. It should be noted that during intensive rearing, broiler chickens are often exposed to the negative impact of a complex of man-made and other factors, leading to a deterioration in the well-being of the bird, a significant decrease in its productive qualities, safety and resistance.

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This problem is especially relevant in the industrial technology of keeping broiler chickens [1-5].

The problem of domestic poultry farming is the high dependence on the import of genetic material, equipment, feed additives and veterinary preparations. The most important factor in the maximum realization of the genetic potential of productivity of modern highly productive crosses of broiler chickens is the feeding of the bird. Optimization of feeding of broiler chickens with the use of feed and biologically active additives and assessment of their physiological status and safety is the most important element of poultry meat production technology [6-9].

Chitosan is the second most common natural biopolymer, which is obtained from chitin, the main source of which is the shell of crustaceans and shrimp. Chitosan is effectively used in medicine, cosmetics, food and light industries, veterinary medicine and animal husbandry due to the fact that it actively exhibits a growth-stimulating effect, antiviral, antibacterial, antifungal action, and immunomodulatory properties [10-12].

The analysis of publications confirms the importance and prospects of expanding exploratory research aimed at the use of chitosan and its derivatives in industrial poultry farming, in particular, when growing broiler chickens. Therefore, comprehensive studies aimed at studying the effectiveness of the use of the chitosan complex in the industrial cultivation of broiler chickens are relevant. In this regard, the goal was to study the effectiveness of the use of a domestic feed additive based on chitosan (chitosan complex KX - 1; manufacturer Agrohitin LLC ") in the technology of broiler meat production.

2 Materials and methods

Experimental studies were carried out under the production conditions of LLC "Production Association of the Closed Cycle Svezhenka" (LLC "POZTs Svezhenka") according to the scheme presented in Table 1. Feeding conditions, technological parameters of outdoor poultry keeping, microclimate in experimental poultry houses corresponded to the recommendations of the Federal Scientific Center "VNITIP" of the Russian Academy of Sciences and recommendations of the company "Aviagen" for working with the cross "Ross-308". A 4-phase feeding of broiler chickens with complete mixed feed was used: starter feed in the period - 0-10 days, growth - 11-24 days, fiish - 1 - 25-33 and finish - 2 - 34 days and until slaughter. The nutritional value and content of crude protein in the feed of the start, growth and finish periods are shown in Table 2.

The three control houses had 118,000 chicks at the start of the experiment, and the three experimental houses had 117,906 chicks.

When conducting research on broiler chickens, generally accepted production and zootechnical indicators were taken into account.

Table 1. Scheme of research and production experience.

Poultry house (item no.)	Accepted for cultivation, goal.	Growing period, days	Planting density, birds/m^2	Features of feeding
14-control	39280	38	23.5	Basic diet balanced for all nutrients in accordance with the VNITIP standards, 2019 (OR)
15- control	39280	39	23.5	OR
16 - control	39440	40	23.6	OR
11- experienced	39280	38	23.5	Basic diet + CH (chitosan complex) at the rate of 70 g / t (OR + CH)
12- experienced	39280	39	23.5	OR + CH
13- experienced	39346	40	23.5	OR + CH

Table 2. Nutritional value and content of crude protein in feed for broiler chickens.

Feeding period	Metabolic energy, kcal/100 g	Metabolic energy + enzyme, kcal/100 g	Crude protein, %
Starting	293	303	22.8
Growth	298	308	22.0
Finish -1	308	318	20.0
Finish-2	310	320	19.5

3 Results. Zootechnical indicators of growing broiler chickens. Meat quality indicators

As a result of the research, it was found that broiler chickens grown in experimental poultry houses, in terms of live weight at 7 days of age, exceeded analogues from control poultry houses by 6.2 - 12.6% (Table 3). At the age of 14 days, this difference was 8.5-10.7% in favor of chickens kept in experimental poultry houses. At 21 days of age, the live weight of chickens in 12 experimental poultry houses was 1.8-7.0% higher than in the control. At the same time, it should be noted that the body weight of chickens in all control houses did not differ much from the weight of chickens in 11 and 13 experimental houses. In subsequent age periods (28-40 days), there were no significant differences in live weight of chickens raised in control and experimental poultry houses.

Table 3. Live weight of broiler chickens in different age periods, g.

Age, days	Poultry houses					
	14-c	15-c	16-c	11- exp.	12- exp.	13- exp.
1	40.0	40.0	40.0	39.0	40.0	39.0
7	143	146	146	161	155	156
14	411	417	401	435	442	444
21	882	855	929	946	905	923
28	1491	1461	1536	1479	1563	1508
38	2260	-	-	2263	-	-
39	-	2364	-	-	2361	-
40	-	-	2416	-	-	2421

It should be noted that in the first 3 weeks of life, the liver and heart of chickens increase 9 times, the spleen - 18 times, the stomach - 5-6 times, the intestines - 7 times. By 5-6 weeks of life, the skeleton of chickens is 70% formed. During this period, it is necessary to provide chickens with easily digestible proteins, energy sources, vitamins, minerals, starter feeds are balanced by a complex of nutrients, minerals and biologically active substances. A bird over the age of 3 weeks is able to maximize the genetic potential of productivity and effectively use the nutrients in the feed. In our opinion, the dose of the chitosan complex, which in the production experience in all age periods is 70 g / t, as well as the scheme for using the drug, need to be adjusted. It is advisable to increase the dose of chitosan complex administration up to 100 g/t in the final period of feeding broiler chickens, starting from 25 days of age and up to slaughter. However, this assumption needs experimental and economic substantiation, which indicates the need for further exploratory research to develop a rational scheme for the use of the drug in the technology of growing broiler chickens.

In terms of absolute and average daily live weight gain, broiler chickens in experimental poultry houses in the first two weeks of life surpassed broilers kept in control poultry houses. Thus, the difference in terms of absolute and average daily body weight gain at 7 days of age between the experiment and control was 8.5-18.4%, at 14 days of age - 5.0-12.2% in favor of chickens raised in experienced poultry houses (Table 4). In subsequent

age periods (21-40 days), there were no significant differences in these indicators between the broilers of the control and experimental poultry houses.

Table 4. Absolute and average daily gain in live weight of broiler chickens, g.

Age, days	Poultry houses					
	14-c	**15-c**	**16-c**	**11- exp.**	**12- exp.**	**13- exp.**
7 days						
Absolute growth, g	103.0	106.0	106.0	122.0	115.0	117.0
Average daily gain, g	14.7	15.1	15.1	17.4	16.4	16.7
14 days						
Absolute growth, g	371.0	377.0	361.0	396.0	402.0	405.0
Average daily gain, g	26.5	26.9	25.8	28.3	28.7	28.9
21 days						
Absolute growth, g	842.0	815.0	889.0	907.0	865.0	884.0
Average daily gain, g	40.1	38.8	42.3	43.2	41.2	42.1
28 days						
Absolute growth, g	1451.0	1421.0	1496.0	1440.0	1523.0	1469.0
Average daily gain, g	51.8	50.8	53.4	51.4	54.4	52.5
38 days						
Absolute growth, g	2220.0	-	-	2224.0	-	-
Average daily gain, g	58.4	-	-	58.5	-	-
39 days						
Absolute growth, g	-	2324.0	-	-	2321.0	-
Average daily gain, g	-	59.6	-	-	59.5	-
40 days						
Absolute growth, g	-		2376.0	-	-	2382.0
Average daily gain, g	-		59.4	-	-	59.6

The safety of broiler chickens at the end of rearing in all experimental poultry houses when using the chitosan complex was higher by 2.9% - when grown up to 38 days of age, by 1.7% - when grown up to 39 days of age and by 0.9% - when growing up to 40 days of age compared with control poultry houses (Table 5).

Table 5. Safety of broiler chickens, %.

Age, days	Poultry houses					
	14-c	**15-c**	**16-c**	**11- exp.**	**12- exp.**	**13- exp.**
7	99.0	99.0	99.2	98.8	98.9	98.9
14	97.9	98.4	98.8	98.4	98.5	98.5
21	95.9	97.1	98.2	97.1	97.4	97.8
28	93.9	95.9	96.8	96.1	96.2	96.7
38	90.2			93.1		
39		91.8			93.5	
40			93.4			94.3

Among the indicators that have a significant impact on the technological and economic efficiency of poultry production, an important role is played by feed costs, which account for up to 70-75% of all costs in the cost structure of broiler meat production. It was found that in 11, 12 and 13 experimental poultry houses, feed costs per 1 kg of live weight gain of broiler chickens, taking into account the duration of cultivation, were 1.3%, 3.1% and 1.2% lower than in 14, 15 and 16 control houses respectively (Table 6).

Table 6. Feed costs when growing broiler chickens, kg.

Index	Poultry houses					
	14-c	**15-c**	**16-c**	**11- exp.**	**12- exp.**	**13- exp.**
Feed consumption, total, kg	122 910	134 990	141 940	125 750	127 900	141 320
Feed consumption per head, kg	3.47	3.74	3.85	3.44	3.54	3.81
Feed costs per 1 kg of live weight gain, kg	1.57	1.61	1.62	1.55	1.56	1.60

Based on the data obtained in the scientific and production experience on the study of the effectiveness of the use of the chitosan complex in feed for broiler chickens, in order to comprehensively assess the productive qualities of broiler chickens, the European efficiency index was calculated (Figure 1). This indicator in 11, 12 and 13 experimental poultry houses was 4.7%, 4.6% and 2.6% higher than in 14, 15 and 16 control poultry houses, respectively.

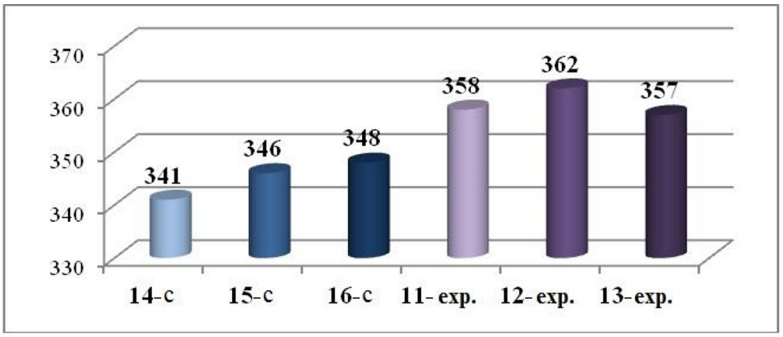

Fig. 1. European efficiency index, units.

The zootechnical indicators of growing broiler chickens of the Ross-308 cross, obtained as a result of studies carried out directly in production conditions, are presented in Table 7.

Table 7. Production and zootechnical indicators of growing broiler chickens.

Index	Poultry houses					
	14-c	**15-c**	**16-c**	**11- exp.**	**12- exp.**	**13- exp.**
Growing time, days	38	39	40	38	39	40
Accepted for cultivation, goal.	39280	39280	39440	39280	39280	39346
Stocking density of broilers, birds/m²	23.5	23.5	23.6	23.5	23.5	23.5
Average live weight 1 goal. at the end of cultivation, g	2 260	2 364	2 416	2 263	2 361	2 421
Average daily live weight gain, g	58.4	59.6	59.4	58.5	59.5	59.6
Livestock at the end of rearing, heads	35438	36069	36849	36566	36609	37098
Safety of broilers, %	90.2	91.8	93.4	93.1	93.2	94.3
Feed consumption per 1 kg of live weight gain, kg	1.57	1.61	1.62	1.55	1.56	1.60
European efficiency index, units	341	346	348	358	362	357
Live weight yield from 1 m² of floor, kg	47.6	51.0	53.2	49.3	51.6	53.6
Broilers produced for slaughter in live weight, kg	79650	85390	89080	82510	86415	89800
Meat produced in slaughter weight, kg	60012	65334	68604	62807	65762	69388
Slaughter yield of meat, %	75.3	76.5	77.0	76.1	76.1	77.3

The total production of broiler chickens for slaughter in live weight in three control poultry houses was 254,120 kg, in three experimental ones - 258,725 kg, and the production of poultry meat in slaughter weight - 193,950 kg and 197,957 kg, respectively. Thus, in poultry houses where the chitosan complex was used in feed for broiler chickens, 4007 kg (2.02%) more meat was obtained than in the control. This was achieved as a result of the fact that the safety of broiler chickens in all experimental houses at the end of rearing was 93.53%, and in the control - 91.83%.

Thus, the results of scientific and production experience prove the prospects for further study of the effectiveness of the use of chitosan complexes in the technology of production of livestock and poultry products.

The results of the anatomical cutting of broiler carcasses, presented in table 8, did not reveal significant differences in the meat qualities of carcasses of control and experimental chickens. At the same time, it should be noted that the content of internal (abdominal) fat in carcasses was at a low level (1.20 - 1.59%), and when using the chitosan complex in the feed for broiler chickens in experimental poultry houses, it was 0.39%. lower than in control.

Table 8. The results of the anatomical cutting of carcasses of broiler chickens (age - 39 days; n=6).

Index	**Poultry houses**			
	control		**experience**	
	weight of carcass parts, g	**% of carcass weight**	**weight of carcass parts, g**	**% of carcass weight**
Weight of gutted carcass, g	1712.37±28. 7	-	1741.54±32.6	-
Breast				
Muscles	526.73	30.76	549.80	31.57
Leather	50.17	2.93	51.20	2.94
Bones	56.68	3.31	57.47	3.30
Total	633.58	37.00	658.48	37.81
Hip				
Muscles	199.66	11.66	202.54	11.63
Leather	44.35	2.59	44.76	2.57
Bones	38.01	2.22	38.66	2.22
Total	282.03	16.47	285.96	16.42
Shin				
Muscles	148.63	8.68	150.64	8.65
Leather	23.97	1.40	24.03	1.38
Bones	39.04	2.28	39.36	2.26
Total	211.65	12.36	214.04	12.29
Wing				
Muscles	94.69	5.53	95.44	5.48
Leather	35.96	2.10	34.83	2.00
Bones	58.22	3.40	57.82	3.32
Total	188.87	11.03	188.09	10.80
Frame				
Muscles	160.11	9.35	162.66	9.34
Leather	69.69	4.07	70.71	4.06
Bones	137.67	8.04	139.32	8.00
Total	367.47	21.46	372.69	21.40
Carcass as a whole				
internal fat	27.23	1.59	20.90	1.20
Process waste	1.54	0.09	1.39	0.08
Edible parts, total	1381.20	80.66	1407.51	80.82
including muscles	1129.82	65.98	1161.08	66.67
leather	224.15	13.09	225.53	12.95
Inedible parts, total	331.17	19.34	334.03	19.18
including bones	329.63	19.25	332.63	19.10
The ratio of edible to inedible parts	4.17	-	4.21	-

For a comprehensive assessment of the effect of the chitosan complex in feed for broiler chickens on the meat productivity of poultry, an analysis of the chemical composition of muscle tissue was carried out, the results of which are presented in Table 9. It was established that there were no statistically significant differences in the content of protein in

the chest (21.57 - 22.36%) and femoral muscles (18.05 - 18.96%) of control and experimental chickens.

Table 9. The chemical composition of the muscles of broiler chickens, % (age - 39 days; M±m; n=6).

Index	Poultry houses	
	control	experience
	Pectoral muscles	
Water	74.68±0.60	74.10±0.71
Protein	21.57±0.34	22.36±0.43
Fat	1.42±0.08	1.12±0.07*
Ash	1.02±0.05	1.13±0.06
	Thigh muscles	
Water	76.20±0.59	75.80±0.41
Protein	18.05±0.37	18.96±0.41
Fat	3.84±0.11	3.42±0.10*
Ash	0.99±0.05	1.10±0.07

Note: * P<0.05

The fat content in the pectoral and leg muscles of the control and experimental broiler chickens was low - 1.42-1.12% and 3.84-3.42%, respectively. At the same time, in the pectoral and femoral muscles of the experimental broilers, the fat content was 0.30% (P<0.05) and 0.42% (P<0.05) less compared to the control ones, which indicates an increase in the dietary properties of meat with use of the chitosan complex in poultry feeding.

When organoleptically assessing the taste qualities of poultry meat, tasting of the broth and boiled meat was carried out according to individual taste indicators on a five-point scale (VNITIP, 2015).

Table 10. Organoleptic evaluation of the quality of the broth and boiled meat of broiler chickens, points (M±m; n=6).

Index	Poultry houses	
	control	experience
Bouillon		
Smell (aroma)	4.3±0.25	4.5±0.31
Taste	4.7±0.30	4.8±0.28
Transparency and color	4.5±0.17	4.5±0.23
Fortress (richness)	4.8±0.23	4.7±0.27
average rating	4.58±0.11	4.63±0.10
Pectoral muscles		
Smell (aroma)	4.4±0.20	4.7±0. 19
Taste	4.6±0.18	4.6±0.23
Transparency and color	4.6±0.32	4.6±0.27
Fortress (richness)	4.7±0.18	4.5±0.19
average rating	4.58 ±0.13	4.60±0.14
Thigh muscles		
Smell (aroma)	4.4±0.31	4.5±0.28
Taste	4.6±0.24	4.7±0.18
Transparency and color	4.8±0.27	4.8±0.30
Fortress (richness)	5.0±0.19	4.9±0.17
average rating	4.68±0.11	4.73±0.09

From the data in Table 10, it follows that there were no statistically significant differences in the quality of meat broth between the experimental (average score 4.63 points) and control (average score 4.58 points) portions. A similar trend was noted in the tasting assessment of broiler meat, while the average score of the pectoral and femoral muscles in the control group was 4.58 and 4.68 points, and in the experimental group - 4.60 and 4.73 points, respectively.

4 Discussion

Information on the use of various forms of chitosan in poultry farming is scarce and contradictory. Data on the positive effect of chitosan on the productive qualities of broiler chickens are given [13-18]. A number of studies report the absence of a positive effect of chitosan on the growth and development of chickens and ducklings [19-20].

It has been proven that the enrichment of the diet with chitosan provided the maximum indicators of the live weight of broiler chickens. So, in the experimental group, an increase in live weight was observed, exceeding the control by 5.7%. In the experimental group, digestibility indicators were higher: organic matter - by 3.7%, protein - by 0.4%, fat - 0.1%, and carbohydrates - 3.8% relative to the control [21].

It has been established that chitosan complexes are valuable additives for poultry. The inclusion of chitosan complexes "KX-1" and "KXM" with the addition of copper in the form of nanoparticles in the amount of 100 g / t, as well as the feeding of the chitosan complex "KXM-aqua" at the rate of 1 ml / l of water throughout the entire period of growing chickens, and the use of the chitosan complex "KXM-aqua" enriched with copper nanoparticles in the amount of 1 ml/l of water from 1 to 5 days; from 11 to 13 days and from 24 to 28 days, and from 6 to 10 days; from 14 to 23 and from 29 to 35 days - watering of the chitosan complex "KX-aqua" allows, with the exclusion of feed antibiotic from feed antibiotics, to obtain a high safety of broilers with an increase in live weight and a decrease in feed costs per 1 kg of live weight gain by increasing the digestibility of the main nutrients feed substances [22]. The cecal bacterial community was analyzed using next generation molecular sequencing (NGS). The results of NGS showed that the effect of chitosan complexes on the regulation of the microbiome composition of the caecum of broilers was predominantly positive. The content of representatives of normal flora, bacteria of the Lactobacillaceae family, increased up to 4.4 times. The number of bacteria of the genus Helicobacter, among which pathogens are often found, in the experimental groups was 2.6-33.3 times lower than in the group receiving antibiotics [23].

In another experiment [24], it was determined that selenium nanoparticles in combination with chitosan improve the morphology of the tibia, histomorphometric characteristics of the pectoral muscle, and some quality characteristics of meat in broiler chickens, and also contribute to the retention of minerals in tissues.

Studies have confirmed that chitosan can be used as an effective feed additive to support growth, liver function, meat quality, muscle glycolysis metabolism, and oxidative status in broiler chickens under heat stress conditions [25].

Thus, the results of our studies are comparable with the results of other authors and confirm the importance and prospects of expanding exploratory studies aimed at the use of chitosan and its derivatives in industrial poultry farming. It is necessary to conduct scientific and economic experiments to develop a biologically, technologically and economically sound scheme for the use of chitosan complexes in the technology of growing broiler chickens.

5 Conclusion

As a result of the research, it was found that the gross production of broilers for slaughter in live weight in three control poultry houses was 254,120 kg, in three experimental ones - 255,830 kg, and the production of poultry meat in slaughter weight - 193,950 kg and 197,957 kg, respectively. In poultry houses where the chitosan complex was used in feed for broiler chickens, 4007 kg (2.02%) more meat was obtained than in the control. This was achieved due to the higher viability and safety of broiler chickens in all experimental poultry houses - 93.14%, and in control - 91.83%. The superiority in feed conversion of

broilers grown in all experimental poultry houses compared to control ones was also revealed. The fat content in the pectoral and leg muscles of the control and experimental broilers was low - 1.42-1.12% and 3.84-3.42%, respectively. At the same time, in the pectoral and femoral muscles of the experimental broilers, the fat content was 0.30% ($P<0.05$) and 0.42% ($P<0.05$) less compared to the control ones, which indicates an increase in the dietary properties of meat with use of the chitosan complex in poultry feeding.

The data of the conducted studies are the basis for further study of the effectiveness of the use of chitosan complexes in the technology of production of livestock and poultry products. Chitosan complexes can be used in poultry farms, livestock farms and complexes to improve existing and create new technologies for the production of livestock products in various forms of management, ensuring the fullest possible realization of the genetic potential of animals and poultry, increasing production and economic performance and contributing to the production of high-quality and environmentally safe products . In the future, it is possible to conduct research to study the effect of chitosan complexes on the physiological state, productivity and quality of turkey, duck, geese and quail meat.

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