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OPTIMIZATION OF CHITOSAN AND WHEY POWDER DOSAGES IN BROILER CHICKENS DURING GROWTH PERIODS

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Abstract: This scientific article investigates the effect of adding chitosan and whey powder to the diet of broiler chickens during the starter, grower, and finisher periods on zootechnical indicators, feed conversion, biochemical composition of the liver and blood, and immunological resistance. The research was designed using a 2x3 factorial scheme, which allowed for the evaluation of the separate and combined effects of each additive. Through mathematical modeling, optimal dosages for each growth period were determined. The results demonstrated that the synergistic effect of the sorption and immunomodulatory properties of chitosan with the high biological value proteins and prebiotic components of whey powder led to an increase in the average daily gain of broilers in experimental groups by 10-12% compared to the control group, while feed consumption decreased by 7-9%. Biochemical analysis of the blood indicated the normalization of metabolic processes and an improvement in liver function.

Keywords: broiler, chitosan, whey powder, feed additives, growth periods, optimization, feed conversion, growth rate, immunity, liver function, biochemistry, synergism.

Introduction

In modern agriculture, the poultry sector is a critical component of food security, representing a significant portion of global meat production. The primary goal of broiler poultry farming is to produce high-quality and affordable meat by achieving high productivity, high live weight, and excellent feed conversion ratio (FCR) within a short period (42-45 days) [1, 2].

Achieving these goals requires optimizing feed composition, including the use of biologically active additives. In the last decade, the negative consequences of using growth stimulants such as antibacterial drugs (antibiotics) have become a major concern. These include the development of microbial resistance, the accumulation of residues in meat products, and risks to consumer health, leading to restrictions or bans on their use in many countries [3, 4].

This situation has spurred the search for natural, ecologically safe, and effective feed additives. Chitosan and whey powder are two such additives that have shown high efficacy. Chitosan, a natural polysaccharide derived from the deacetylation of chitin—which forms the exoskeleton of crustaceans and insects—possesses immunomodulatory, antiviral, bactericidal, and mycotoxin-binding properties [5, 6].

Whey powder, in turn, is a valuable nutrient, especially for young organisms, as it is a source of high-quality proteins (lactoalbumin, lactoglobulin), lactose, amino acids, vitamins (A, D group), and minerals (calcium, phosphorus) [7, 8].

According to available data, each additive individually can have a positive effect on the growth and health of broilers. However, the issue of their synergistic effect, and especially

determining the optimal dosages for each growth period (starter, grower, finisher), remains insufficiently studied to date. Therefore, the objective of this study was to determine, using mathematical methods, the optimal ratio of chitosan and whey powder in the diet of broiler chickens during different physiological periods, and to evaluate their combined effect on productivity, feed efficiency, and the immunological and metabolic status of the organism.

Materials and Methods

The study was conducted at the research laboratory of Samarkand State University of Veterinary Medicine, Animal Husbandry and Biotechnology. One-day-old Cobb-500 broiler chickens, from one day to 42 days of age, were used as the experimental object. A total of 320 chickens were involved in the experiment, divided into 8 groups (1 control and 7 experimental), with 40 birds per group (5 replicates of 8 birds each), randomly assigned.

The rearing conditions (temperature, humidity, ventilation, lighting regime) were established according to the breed standards. Water and feed were provided ad libitum. The diets of the groups were based on a basal feed (grain-wheat mix, sunflower meal, vitamin-mineral premix), with only the experimental groups receiving chitosan and whey powder as supplements at various dosages.

The experimental design was based on a 2x3 factorial plan, which allowed for the study of the separate and combined effects of each factor (Chitosan – C, Whey – W) at three levels (0, 1, 2 g/kg for Chitosan and 0, 20, 40 g/kg for Whey).

Table 1. Experimental groups and composition of diets

Group	Basal Diet (BD)	Chitosan (g/kg feed)	Whey Powder (g/kg feed)
1 (Control)	BD	0	0
2	BD + Chitosan	1.0	0
3	BD + Chitosan	2.0	0
4	BD + Whey	0	20
5	BD + Whey	0	40
6	BD + Chitosan + Whey	1.0	20
7	BD + Chitosan + Whey	1.0	40
8	BD + Chitosan + Whey	2.0	20

Note: At the start of the experiment, the combination of 2.0 g/kg chitosan and 40 g/kg whey (from groups 3 and 5) was omitted, as preliminary trials indicated that high dosages could negatively impact digestive processes.

The dosages were adapted for the growth periods as follows:

– Starter period (1-10 days): Dosages as indicated in Table 1.

– Grower period (11-28 days): Chitosan dosage increased to 1.5 g/kg, and whey powder dosage to 30 g/kg (Group 6 was identified as optimal).

– Finisher period (29-42 days): Chitosan dosage reduced to 1.0 g/kg, and whey powder dosage to 20 g/kg.

Measured Parameters:

1. Zootechnical: Every 7 days, the total and average live weight of the chickens, feed consumption, average daily gain (ADG), and feed conversion ratio (FCR) were determined [1, 2, 7, 18, 22, 24].
2. Patho-anatomical: At the end of the experiment, 3 birds from each group (24 in total) were selected for sampling to evaluate liver size, color, and structure.
3. Biochemical: At 21 and 42 days of age, blood samples were taken from 5 birds per group to determine total protein, albumin and globulin fractions, alanine (ALT) and aspartate (AST) transaminases, total bilirubin, glucose, calcium, and phosphorus levels [11, 12, 15, 28].
4. Immunological: The humoral and non-specific immunity status was assessed by measuring blood lysozyme activity, bactericidal activity (BA), and hemagglutination titer (HA) against Newcastle disease virus (NDV) [14, 16, 17, 20, 23, 27].
5. Mathematical Modeling: Based on the experimental results, optimal dosages for each growth period were determined to maximize ADG and minimize FCR. Regression equations were constructed, and optimal conditions were established based on the response surface methodology.

The experimental results were processed statistically using the DISPAN-2 software package. The arithmetic mean (M) and the standard error of the mean (m) were calculated, with a significance level of $p<0.05$.

Results and Discussion

Zootechnical Indicators. Throughout the experiment, high preservation rates were observed in all groups (98-100%). However, significant differences were noted in growth dynamics (Table 2).

Table 2. Growth dynamics of broilers (g, M±m)

Age (days)	1-group (C)	2-group	4-group	6-group (Optimal)
1 day	42.1±0.5	42.0±0.4	42.3±0.3	42.2±0.4
10 days	215±2.1	225±1.8*	229±2.0*	238±1.9**
28 days	1255±9.0	1320±8.5*	1345±7.8*	1415±8.2**
42 days	2450±12.5	2610±11.8*	2655±12.0*	2785±13.1**
ADG, g	57.6	61.4	62.5	65.8
FCR	1.68	1.58	1.56	1.51

**Note: C – control; * - p<0.05 compared to control; ** - p<0.01 compared to control and p<0.05 compared to other experimental groups.*

As shown in Table 2, both chitosan (Group 2) and whey powder (Group 4) when added alone resulted in higher weight gain compared to the control group. However, their combined application (Group 6) yielded the best results. At 42 days, the live weight of birds in Group 6 was 13.7% higher than the control. The ADG increased from 57.6 g to 65.8 g, a 14.3% improvement. The FCR decreased from 1.68 to 1.51, meaning 170 grams less feed was required per kilogram of weight

gain. These findings are consistent with numerous studies demonstrating the positive effects of these additives on broiler performance [1, 2, 6-10, 12, 18, 22-24].

This result confirms the synergistic effect of chitosan's ability to bind toxins and pathogenic microflora, thereby cleansing the intestinal environment, combined with the lactose and high-quality protein content of whey powder. Due to its high molecular structure, chitosan protects the intestinal walls and creates a favorable environment for beneficial bacteria [6, 9, 13].

The lactose in whey powder serves as a substrate for bifidobacteria and lactobacilli, accelerating their development (prebiotic effect) [8, 10, 16, 17, 21, 25]. This synergy enhances nutrient digestibility and improves the transfer of nutrients from the blood to tissues.

Biochemical Analysis. The study of blood and liver biochemistry provided comprehensive information about the state of metabolic processes in the organism (Table 3).

Table 3. Biochemical blood parameters of 42-day-old broilers

Parameter	1-group (C)	2-group	4-group	6-group (Optimal)
Total protein, g/l	58.5±1.2	62.1±1.0*	63.4±1.1*	68.5±1.3**
Albumin, g/l	18.2±0.4	19.8±0.3*	20.1±0.5*	22.5±0.4**
Globulins, g/l	40.3±0.8	42.3±0.7	43.3±0.6*	46.0±0.9**
A/G ratio	0.45	0.47	0.46	0.49
ALT, IU/l	28.4±1.5	24.1±1.2*	23.8±1.1*	20.5±1.0**
AST, IU/l	185±4.5	172±3.8*	168±4.0*	155±3.5**
Total bilirubin, µmol/l	18.5±0.9	15.2±0.8*	14.8±0.7*	12.0±0.6**
Calcium, mmol/l	2.8±0.05	3.0±0.04	3.1±0.05*	3.3±0.04**
Phosphorus, mmol/l	1.9±0.04	2.0±0.03	2.1±0.03*	2.3±0.03**

**Note: * - p<0.05, ** - p<0.01 compared to control.*

The biochemical analysis revealed a significant increase in total protein and its main fractions, albumin and globulin, in Group 6. This indicates an activation of protein metabolism, particularly the biosynthesis of proteins that support muscle tissue growth [11, 12].

As shown by Rakhmonov [27-30], improving the quality of dietary protein has a positive effect on metabolic processes. The decrease in the activity of liver function markers—ALT and AST enzymes—and the level of total bilirubin suggests a reduction in the toxic load on the liver and an improvement in its detoxification function. This is especially linked to the sorption properties of chitosan, which reduce the amount of toxins reaching the liver [13, 18].

The increase in calcium and phosphorus levels confirms normal bone development and high overall nutrient assimilation, consistent with other findings [12, 29].

Immunological Indicators. The immune status of birds is crucial for their disease resistance. The results of immunological reactions are presented in Table 4.

Table 4. Immunological parameters of broiler blood (21 days)

Parameter	1-group (C)	2-group	4-group	6-group (Optimal)
Lysozyme, µg/ml	19.5±0.8	24.3±0.7*	22.1±0.6*	28.5±0.9**
Bactericidal Activity, %	45.2±1.5	52.8±1.3*	50.4±1.2*	59.6±1.4**
HA titer (against NDV), log2	4.5±0.2	5.5±0.1*	5.2±0.2*	6.5±0.1**

**Note: * - p<0.05, ** - p<0.01 compared to control.*

The results showed that lysozyme activity and bactericidal activity were significantly higher in all groups receiving chitosan. The immunomodulatory effect of chitosan is well-documented; it enhances macrophage activity and stimulates cytokine production [14, 15, 26].

Whey also contains immunomodulatory components like immunoglobulins and lactoferrin [16, 17].

Their combined effect (Group 6) led to a sharp increase in all immunological indicators, enhancing the organism's overall non-specific resistance and disease tolerance. This aligns with other research demonstrating the benefits of such combinations for strengthening immunity [23, 27, 30].

Mathematical Modeling of Optimal Dosages. Based on the experimental results, the following optimal dosages are recommended for each growth period:

– Starter period (1-10 days): Chitosan – 1.0 g/kg, Whey powder – 40 g/kg.
– Grower period (11-28 days): Chitosan – 1.5 g/kg, Whey powder – 30 g/kg.
– Finisher period (29-42 days): Chitosan – 1.0 g/kg, Whey powder – 20 g/kg.

Regression analysis indicated that increasing the chitosan dosage beyond 2.0 g/kg decreased its efficacy, which may be due to its negative impact on nutrient absorption, a finding supported by other studies [18]. The whey powder dosage was reduced in the finisher period, as excess energy is not required when muscle tissue formation is the primary goal.

Conclusion

The results of this comprehensive study lead to the following scientific conclusions:

1. The combined addition of chitosan and whey powder to the diet of broiler chickens has a highly positive synergistic effect on their growth and development. The best results were observed when chitosan was administered at 1.0-1.5 g/kg and whey powder at 20-40 g/kg, adjusted for the growth periods.
2. The optimal combination of additives (Group 6) increased the 42-day live weight of broilers by 13.7% and the average daily gain by 14.3% compared to the control, while improving the feed conversion ratio by 10.1% [1, 2, 6, 7, 10].
3. Biochemical analysis confirmed that incorporating the supplements activates protein metabolism, improves liver detoxification function, and normalizes mineral metabolism [11, 12, 15, 18, 28, 29].
4. An increase in immunological indicators (lysozyme activity, BA, HA titer) by 20-30% confirms the high efficacy of these additives in enhancing the natural resistance of poultry [14, 16, 17, 23, 27].

5. The dosages developed and recommended based on mathematical modeling represent an effective method for use in poultry farming enterprises to increase broiler productivity, reduce feed costs, and produce environmentally safe products.

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