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Using additives to improve the effectiveness of rations in quail farming for meat

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Abstract. The aim of this study was to develop a method for modernizing quail meat production. Complex enzyme additives and lyophilized spore-forming bacteria *Bacillus subtilis* (strain DSMz 17299) were used to investigate the formation of quail meat. To assess the effects of additives, four groups were formed: a control group fed only the regular farm main ration, the 1st group with *Bacillus subtilis* added to the main ration, the 2nd group with an added fermentative complex based on endo-1,4-β-xylanase and endo-1,3(4)-β-glucanase, and the 3rd group fed a combination of these additives. During the study, quails were weighed weekly and slaughtered at 70 days of age, followed by evaluating the meat quality according to established control parameters. It was determined that in the control group, the total weight gain was 223.24%, in the 1st group—237.61%, in the 2nd group—227.29%, and in the 3rd group—244.35%. The survival rates in the 1st, 2nd, 3rd, and control groups were 91.32%, 89.66%, 95.02%, and 87.77%, respectively. When evaluating indicators such as live weight, dressed carcass weight, slaughter yield, muscle tissue weight, protein content, energy value, and meat quality index, the highest values were observed in the 3rd group and lowest in the control group. When using mono-additives, the *Bacillus subtilis* preparation (1st group) performed best compared to the fermentative complex. The levels of microbial and toxic element contamination were within normal limits. The sensory evaluation established higher organoleptic characteristics for the meat in the 3rd group compared to other groups and the control. This indicates the high efficacy of applying a complex additive on the mass and quality of meat production in quail farming.

1 Introduction

Quail farming is a promising direction in poultry farming. It is gaining momentum every year in terms of egg and high-quality meat production. One of the main advantages of quails is that their industrial breeding enables the production of high-quality dietary products with economically justified feed costs. This rationale makes this industry attractive for studying by the scientific community and practitioners.

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Environmental conditions are an important factor influencing the breeding of agricultural animals and the quality of the resulting meat [1-2]. The level of elements in feed and water directly and indirectly affect the birds' health. This problem can be solved by supplementing main rations with carefully selected additives [3-7]. The Voronezh Region is one of the leaders in quail meat and egg production in Russia, requiring a continuous search for solutions by zootechnical specialists and veterinarians to maintain positive production dynamics. Successful industrial quail farming is impossible without using modern technological, genetic, pharmacological, and other innovative approaches. This issue can be addressed by developing and using biologically active components in the rations capable of regulating biochemical homeostasis mechanisms, maintaining productive bird health, and providing their bodies with the necessary nutrients and energy for efficient production operations [8-9]. Therefore, the identification and investigation of the most effective feed components used in quail meat production is extremely relevant today [10-13].

The currently implemented state program for developing agriculture and regulating the agricultural product market in Russia envisages solving various essential tasks in the agro-industrial sector. On the one hand, this involves increasing livestock production by maximizing the genetic potential of agricultural animals and birds, developing tech-nologies, and using innovative approaches and solutions, including in the veterinary field [5]. On the other hand, such active intensification of the agricultural sector poses the risk of negative influences on organisms, both exogenous and endogenous, which may lead to reduced overall organism resistance, increased incidence of diseases of various etiolo-gies, decreased productivity and livestock survival rates, deterioration in the qualitative characteristics of livestock products and their safety, and reduced economic efficiency of production [14-15].

Further study of ways to supply quail organisms with the necessary nutrients, primarily through natural, do-mestic, competitive feeds and feed additives, is a promising direction requiring continuous scientific research [16-17].

2 Materials and methods

This study was performed in accordance with the 2020–2021 plan of scientific research of the Department of Veterinary Sanitary Expertise, Epizootology, and Parasitology of the Faculty of Veterinary Medicine and Animal Husbandry Technology of the Federal State Budget Educational Institution of Higher Education "Voronezh State Agrarian University named after Emperor Peter I," Voronezh, Russia. The experimental part of the work was performed at the quail farm of the individual entrepreneur, head of farm household Zhdanov Kirill Aleksandrovich in the Novopodkletnoe Village, Ramonsky District, Voronezh Region, Russia. Laboratory analysis was performed at the Voronezh Regional Veterinary Laboratory (Voronezh, Voronezh Region, Russia) and the Lipetsk Regional Veterinary Laboratory (Lipetsk, Lipetsk Region, Russia).

The evaluation of the feed additive based on probiotics and enzyme preparations was performed on Pharaoh quails according to the methodology of the All-Russian Research and Technological Institute of Poultry Farming (VNITIP) (Sergiev Posad, Moscow Region, Russia). Using the group–analog method, four groups of quails were formed (100 birds per group), as follows.

Control group: The birds were fed only the main complete compound feed used at the farm, as recommended by the VNITIP.

Experimental group 1: Throughout the entire rearing period, in addition to the main ration, the birds were given a preparation containing lyophilized spore-forming bacteria *Bacillus subtilis* (strain DSMz 17299) at a dose of 200 g per ton of feed.

Experimental group 2: A fermentative complex based on endo-1,4-β-xylanase and endo-1,3(4)-β-glucanase was added to the compound feed at a dose of 200 g per ton of feed.

Experimental group 3: The quails received compound feed containing a complex of enzymatic components (100 g/ton of feed) and live bacterial culture *Bacillus subtilis* (200 g/ton of feed).

The experimental scheme is presented in Table 1.

Table 1. Scheme of the scientific–economic experiment.

Group	Number of birds	Feeding conditions
Control	100	Main ration
1st	100	Main ration + *Bacillus subtilis*
2nd	100	Main ration + enzyme supplement
3rd	100	Main ration + *Bacillus subtilis* + enzyme supplement

The birds were kept in cages at the farm. Cage tiers consisted of three sections, each designed for 30 birds (Figures 2–3). A nipple-type watering system was employed, with the birds having constant free access to it. Feeding was mechanized. During the first week, the quails received feed three times a day and then twice a day for the remainder of the study. The humidity, temperature, and lighting in the premises were maintained according to the requirements of VNITIP. During the experimental period, quails consumed compound feed that was balanced in terms of basic nutritional and energy indicators in accordance with age norms. The duration of the experiment was 41 days, and the experimental feed composition for quails was provided from day 30 to day 70 of age.

The dynamics of quail live weight in each group was determined by weekly individual weighing. The live weight gain was determined for the entire rearing period (from day 30 to day 70 of age). The absolute average daily weight gain was calculated using the formula:

$$P_{abs} = (M_e - M_b) / D \quad (1)$$

Where P_{abs} is the absolute average daily weight gain, g; M_e is the live weight of the individual at the end of the experiment period, g; M_b is the live weight of the individual at the beginning of the experiment period, g; and D is number of days of the experiment.

Health and mortality monitoring of the flock was performed daily. The survival rate was calculated as a percentage of the initial flock size for individual rearing periods and for the entire period. The daily consumption of feed and feed additives by the birds in each group was calculated from the first day and throughout the experiment. The feed costs per bird and 1 kg of live weight gain of the birds (conversion) were calculated based on the obtained data,

To study the meat productivity at 70 days of age, a control slaughter and anatomical dissection of birds from each group were conducted. Quails were fasted for 12 hours before slaughter. The following parameters were recorded: live weight of the bird before slaughter, dressed carcass weight, weight of breast and thigh muscles, and weight of internal organs.

The meat's veterinary–sanitary indicators were determined in accordance with the Technical Regulation of the Customs Union 021/2011 "On Food Safety." The sensory evaluation of the quail meat was conducted according to the recommendations of the VNITIP.

3 Results and Discussion

The results of the influence of different schemes of using biologically active components in the rations on the economic indicators of quails are presented in Tables 2 and 3. When analyzing the data presented in these tables, at the beginning of the study, the average weight of the birds in all four groups was the same (any differences observed were statistically insignificant). During the fattening period, the control group of quails showed an increase in weight from 106.83 ± 1.91 to 238.49 ± 2.20 g, with a total weight gain of 131.66 g or 223.24% for the reporting period. The average daily weight gain was 3.21 g, with a flock survival rate of 87.77%. These results were the lowest among all groups involved in the experiment. In the 1st experimental group, the increase in live weight during the experiment period was 145.25 g (from 105.55 ± 2.01 to 250.80 ± 2.03 g) or 237.61%, with an average daily gain of 3.54 g and a flock survival rate of 91.32%.

Quails in the 2nd experimental group showed an increase in weight from the initial 107.44 ± 1.90 to 244.21 ± 2.20 g (a gain of 136.77 g from day 30 to day 70), which amounted to 227.29%. The daily gain during this period was 3.33 g, with a survival rate of 89.66%. The group where a combination of biologically active components was used demonstrated a weight increase of 153.32 g (from 106.21 ± 2.04 to 259.53 ± 1.01 g, 244.35%), providing an average daily weight gain of 3.73 g, with a bird survival rate of 95.02%. All indicators for this group were the highest compared to the control values in the 1st and 2nd experimental groups.

Table 2. Dynamics of quail live weight (n = 100).

Age of the bird, days	Groups			
	Control	1st	2nd	3rd
	Live weight, g			
30	106.83 ± 1.91	105.55 ± 2.01	107.44 ± 1.90	106.21 ± 2.04
40	143.65 ± 1.01	152.28 ± 0.97	149.47 ± 1.05	152.51 ± 1.07
50	188.53 ± 2.19	199.94 ± 2.11	194.12 ± 2.22	200.39 ± 2.26
60	212.29 ± 2.51	230.49 ± 2.76	223.75 ± 2.68	237.86 ± 2.78
70	238.49 ± 2.20	250.80 ± 2.03	244.21 ± 2.20	259.53 ± 1.01*

* $P < 0.05$ with respect to the control values

Table 3. The main economic indicators of quails (n = 100).

Indicator	Groups			
	Control	1st	2nd	3rd
Live weight gain				
Daily average, g	3.21 ± 0.14	3.54 ± 0.12	3.33 ± 0.19	3.73 ± 0.08*
Survival rate				
Total, %	87.77	91.32	89.66	95.02

* $P < 0.05$ with respect to the control values

The final difference in live bird weight was higher in the 3rd experimental group by 8.11% compared to the control group, by 3.37% compared to the 1st experimental group, and by 5.91% compared to the 2nd experimental group.

The average daily weight gain of the birds was also higher in the group where the probiotic was combined with the enzyme component, amounting to 13.95% compared to the control group, 5.09% compared to the 1st experimental group, and 10.73% compared to the 2nd experimental group. The survival rate of quails, depending on the schemes of additive use, demonstrated an advantage of the 3rd experimental group over the control group by 7.25%, over the 1st experimental group by 3.70%, and over the 2nd experimental group by 5.36%.

The evaluation of poultry meat productivity is presented in Table 4. It is observed that the identified trends in quail live weight were maintained even after slaughter. Thus, the dressed carcass weight was 176.84 ± 1.30 g in the control group. The dressed carcass weight was 10.50% higher in the 1st experimental group at 195.42 ± 1.64 g and 4.58% higher in the 2nd experimental group at 184.94 ± 0.95 g compared to the control group. In the 3rd experimental group, the dressed carcass weight was 205.18 ± 1.15 g, which was is 16.02% higher than the dressed carcass weight in the control group and 4.99% and 10.94% higher compared to the 1st and 2nd experimental groups, respectively.

Table 4. Meat productivity of quails.

Indicator	Groups			
	Control	1st	2nd	3rd
Live weight before slaughter, g	238.49 ± 2.20	250.80 ± 2.03	244.21 ± 2.20	259.53 ± 1.01*
Dressed carcass weight, g	176.84 ± 1.30	195.42 ± 1.64	184.94 ± 0.95	205.18 ± 1.15**
Slaughter yield, %	74.15	77.92	75.73	79.06
Muscle tissue weight, g	91.07 ± 2.41	101.81 ± 1.86	95.42 ± 2.09	107.71 ± 1.50*
Weight of internal organs, g	24.31 ± 1.07	26.55 ± 0.25	27.26 ± 1.01	26.37 ± 0.99

* $P < 0.05$ with respect to the control values; ** $P < 0.01$ with respect to the control values

The slaughter yield was also minimal in the control group of quails at 74.15%, while in the experimental groups, it ranged from 75.73% to 79.06%. The maximum value was recorded in the 3rd experimental group. Addition-ally, the proportion of muscle tissue in the dressed carcass weight was determined. In the control birds, the total muscle tissue weight was 91.07 ± 2.41 g or 51.5% of the carcass weight. In 1st experimental group, this indicator was 101.81 ± 1.86 g, or 52.1% of the carcass weight. In the 2nd experimental group, this indicator was 95.42 ± 2.09 g, equivalent to 51.6% of the total dressed carcass weight of birds. In the 3rd experimental group, the percentage of muscle tissue was 52.5%, corresponding to a weight of 107.71 ± 1.50 g.

The fluctuations in the weight of internal organs of the quails involved in the experiment ranged from 24.31 ± 1.07 to 27.26 ± 1.01 g. However, these fluctuations were not statistically significant, and the existing trend indicated a minimal weight of internal organs in the control group, which may be related to the overall lower weight of the birds compared to those in the experimental groups.

Thus, according to the economic indicators of quail rearing, the most effective scheme of use was the com-bined application of live bacterial culture and a complex enzyme compound, compared to their monovariants and in relation to the control values.

The quality of quail meat in the control and experimental groups was evaluated based on the parameters of the chemical and energy composition of the muscles. The meat quality index of the test birds was calculated as the ratio of protein to fat obtained in the chemical analysis. The research results presented in Table 5 showed that the highest meat quality index of 7.58 was in the 3rd experimental group. This result was achieved owing to the high percentage of dry matter (27.39%) and a balanced ratio of protein and fat in it (23.51 ± 0.41% and 3.10 ± 0.1%, respectively). The meat quality index in the 1st experimental group decreased to 6.63, with a quantitative level of dry matter equal to 26.91% and its composition containing 22.70 ± 0.15% of protein, 3.42 ± 0.09% of fat, and 0.79 ± 0.01% of ash. In the 2nd experimental group, the meat quality index was even lower (6.57) owing to a decrease in the amount of dry matter in the meat (26.57%) and a lower amount of protein (22.48 ± 0.64%). The lowest desired index was in the meat of the control birds, only 5.64. This value was obtained owing to the low amount of dry matter (25.79%) and a low protein content (21.29 ± 0.74%). The energy value of quail meat in the experimental groups that received various variants of biologically active additives was higher than that in the control group (i.e., by 0.82%, 1.45%, and 3.28% for the 1st, 2nd, and 3rd groups, respectively).

Table 5. Biochemical parameters of quail meat.

Indicator	**Groups**			
	Control	**1st**	**2nd**	**3rd**
Moisture, %	74.21 ± 1.05	73.09 ± 1.32	73.43 ± 1.25	72.61 ± 1.73
Protein, %	21.29 ± 0.74	22.70 ± 0.15	22.48 ± 0.64	23.51 ± 0.41
Fat, %	3.77 ± 0.07	3.42 ± 0.09	3.42 ± 0.12	3.10 ± 0.1
Ash, %	0.73 ± 0.01	0.79 ± 0.01	0.67 ± 0.01	0.78 ± 0.01
Energy value, kJ	6907.31± 68.54	7007.39± 50.07	6964.18± 47.20	7133.90± 49.32
Meat quality index	5.64	6.63	6.57	7.58

The results of the veterinary–sanitary examination showed that there were no changes in the structure of the organs and tissues of the birds. Quails in all groups had an anatomically correct arrangement of internal organs. There was no fluid in the pleural and abdominal cavities. The lumen of the respiratory system organs (trachea and bronchi) was clear, and the lung tissue had a pale pink color. The mucous membrane of the gastrointestinal tract had a grey–pink color, with no erosions, ulcers, hemorrhages, or other visible abnormalities noted. Subsequently, organoleptic indicators of the meat quality of quails in all groups were studied according to GOST R 51944-2002 and GOST R 54673-2011 (Russian state standards). The assessment of the plumpness of the quail carcasses in the control and experimental groups showed that all birds had well-developed muscles, a round chest shape, and moderate fat deposition in the abdominal and chest areas. Overall, in terms of plumpness, according to GOST R 54673-2011, the quail carcasses in all groups were classified as belonging to the 1st category.

One day after slaughter, a "drying crust" was observed on the surface of the bird carcasses in all studied groups, which had a whitish–yellow color with a pinkish hue. Upon palpation, the muscle tissue was firm and dense, and any dents quickly returned to their original state. When cutting the muscles, slight moisture could be observed, which was detected not only visually but also on blotting paper. The color of the muscles was characteristic of this type of poultry: breast muscles were white–pink, and leg muscles were reddish. The meat had a specific odor typical of freshness. When conducting a boiling test, the broth prepared directly from the meat of quails in the control and exper-imental groups had a pleasant aroma, was transparent, and did not exhibit any foreign odors.

Laboratory safety testing of quail meat included the determination of residual amounts of antibiotics, toxic el-ements, pesticides, and microbiological control (Tables 6–7). Chloramphenicol, bacitracin, and antibiotics of the tetra-cycline group were not detected in the examined samples of all four groups. Toxic elements analysis confirmed compli-ance with the maximum allowable concentration values. For cadmium, the recorded levels were below the normative value of no more than 0.05 mg/kg in all groups. Arsenic content did not exceed the required 0.1 mg/kg. Mercury was present in quantities less than 0.03 mg/kg. Lead was registered in amounts not exceeding 0.5 mg/kg.

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Table 6. Safety indicators of quail meat.

Indicator	Groups			
	Control	**1st**	**2nd**	**3rd**
Antibiotics, mg/kg				
Chloramphenicol	not detected	not detected	not detected	not detected
Bacitracin	not detected	not detected	not detected	not detected
Tetracycline group	not detected	not detected	not detected	not detected
Toxic elements, mg/kg				
Cadmium	0.01	0.01	0.01	0.01
Arsenic	0.04	0.05	0.03	0.04
Mercury	0.0041	0.0038	0.0040	0.0040
Lead	0.11	0.13	0.15	0.14
Pesticides, mg/kg				
Hexachlorocyclohexane (HCH) and isomers	Less than 0.005	Less than 0.005	Less than 0.005	Less than 0.005
Dichlorodiphenyltrichloroethane (DDT) and metabolites	Less than 0.005	Less than 0.005	Less than 0.005	Less than 0.005

The results of microbiological analysis of quail meat samples indicated a high level of bacteriological purity of the animal product (Table 7). *Listeria monocytogenes*, *Salmonella*, or other pathogenic microorganisms were not found in the meat. Additionally, coliform bacteria were not detected, and the value of the most probable number of aerobic mesophilic bacteria did not exceed the allowable level of 1×10^5 CFU/g.

Table 7. Microbiological parameters of quail meat.

Indicator	Groups			
	Control	**1st**	**2nd**	**3rd**
Listeria monocytogenes, g	not detected in 25.0 g	not detected in 25.0 g	not detected in 25.0 g	not detected in 25.0 g
Coliform bacteria, g	not detected	not detected	not detected	not detected
Total aerobic mesophilic count, CFU/g	3.7 × 103	3.6 × 103	3.6 × 103	3.7 × 103
Pathogenic microorganisms, including Salmonella	not detected in 25.0 g	not detected in 25.0 g	not detected in 25.0 g	not detected in 25.0 g

The final stage of our research involved sensory evaluation of the meat. Muscles from the breast, thighs, and legs, as well as broth, were subjected to organoleptic analysis (Table 8). The results showed that the quality of the broth and the quail meat from the 3rd experimental group was 2.25–3.98% higher than that of the control, 1st, and 2nd groups. The broth was clear, had a pleasant taste and aroma, and had slight droplets of fat on its surface. According to sensory evaluation, the meat in all studied groups had a pleasant taste and aroma. The muscle tissue was tender and moderately juicy. No off-flavors or aftertastes were detected.

Table 8. Tasting evaluation of quail meat.

Indicator	Groups			
	Control	**1st**	**2nd**	**3rd**
Organoleptic assessment, points				
Pectoral muscles	4.80 ± 0.16	4.80 ± 0.10	4.82 ± 0.13	4.91 ± 0.11
Shin	4.80 ± 0.14	4.80 ± 0.12	4.80 ± 0.15	4.90 ± 0.18
Femoral muscles	4.64 ± 0.15	4.68 ± 0.16	4.69 ± 0.10	4.77 ± 0.13
Broth	4.52 ± 0.10	4.55 ± 0.12	4.55 ± 0.12	4.70 ± 0.10

4 Conclusion

The experiments were conducted at an industrial quail farm to study the efficacy of using lyophilized spore-forming bacteria *Bacillus subtilis* (strain DSMz 17299) and an enzyme complex based on endo-1,4-β-xylanase and endo-1,3(4)-β-glucanase as mono-additives to the main rations and in combination. During the feeding period, in the control group of quails, the total weight gain was 223.24%. The average daily weight gain was 3.21 g, with a flock survival rate of 87.77%. In the 1st experimental group, the live weight gain was 237.61%, with an average daily gain of 3.54 g and a flock survival rate of 91.32%. Quails in the 2nd experimental group showed a weight gain of 227.29%. The daily gain during this period was 3.33 g, with a survival rate of 89.66%. The group where the combination of bioactive components was used demonstrated a weight gain of 244.35%, resulting in an average daily weight gain of 3.73 g and a flock survival rate of 95.02%. The final difference in live bird weight was higher in the 3rd experimental group by 8.11% compared to the control, by 3.37% compared to the 1st experimental group, and by 5.91% compared to the 2nd experimental group. The average daily weight gain of the birds was also higher in the group where the probiotic was combined with the enzyme component, amounting to 13.95% compared to the control group, 5.09% compared to the 1st experimental group, and 10.73% compared to the 2nd experimental group. Depending on the scheme of supplement use, quail survival rates were 7.25% higher for the 3rd experimental group compared to the control, 3.70% higher compared to the 1st experimental group, and 5.36% higher compared to the 2nd experimental group. The quail meat productivity in the 3rd experimental group was 16.02% higher than that in the control group, and 4.99% and 10.94% higher compared to the 1st and 2nd experimental groups, respectively. The slaughter yield was the smallest in the control group of quails, i.e., 74.15%. In the experimental groups, it ranged from 75.73% to 79.06%. The total muscle tissue weight of quails in the control group was 91.07 ± 2.41 g or 51.5% of the carcass weight. For the 1st experimental group, this indicator was 101.81 ± 1.86 g or 52.1% of the carcass weight. For the 2nd experimental group, this indicator was 95.42 ± 2.09 g, which was 51.6% of the total dressed carcass weight of birds. In the 3rd experimental group, the percentage of muscle tissue was 52.5%, which in terms of weight corresponded to 107.71 ± 1.50 g. Fluctuations in the weight of the internal organs of the quails ranged from 24.31 ± 1.07 to 27.26 ± 1.01 g. The highest meat quality index (7.58) was observed in the 3rd experimental group owing to the high percentage of dry matter (27.39%) and a balanced ratio of protein and fat in it (23.51 ± 0.41% and 3.10 ± 0.1%, respectively). The meat quality index in the 1st experimental group decreased to 6.63, with a quantitative level of dry matter equal to 26.91% and its composition containing 22.70 ± 0.15% of protein, 3.42 ± 0.09 of fat, and 0.79 ± 0.01 of ash. In the 2nd experimental group, the meat quality index was 6.57 owing to the reduction in the amount of dry matter in the meat (26.57%) and a low amount of protein (22.48 ± 0.64%). The lowest index (5.64) was recorded for quail meat in the control group. The energy value of quail meat in the 1st, 2nd, and 3rd groups, which received various variants of biologically active additives, was higher than that in the control group by 0.82%, 1.45%, and 3.28%, respectively. The results of the veterinary–sanitary examination showed no changes in the structure of the organs and tissues of the birds. Chloramphenicol, bacitracin, or antibiotics of the tetracycline group were not detected in the examined samples of all four groups. For cadmium, the recorded values were below the regulatory value of no more than 0.05 mg/kg in all groups. The arsenic content did not exceed the required 0.1 mg/kg. The mercury values were below 0.03 mg/kg. The lead content did not exceed 0.5 mg/kg. The results of microbiological studies of quail meat samples indicate the absence of *Listeria monocytogenes*, *Salmonella*, and other pathogenic microorganisms in the meat. Additionally, *Escherichia coli* was not detected in the samples, and the total aerobic mesophilic count did not exceed the allowable level of 1×10^5 CFU/g. The quality of the broth and the quail meat from the 3rd experimental group was 2.25–3.98% higher than that of the control, 1st, and 2nd experimental groups.

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