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USE OF DRY GARLIC POWDER (*ALLIUM SATIVUM*) IN YOUNG MEAT QUAILS FEEDING

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Abstract

The effect of enriching the diets of young quails in the direction of meat productivity with dry garlic powder in different concentrations was studied. For this purpose, four groups of one-day-old quails of the Pharaoh breed were formed, each consisting of 100 birds. The experiment lasted 35 days and was divided into two periods (1–21 days and 22–35 days). During the experiment, quails were kept in single-tier cage batteries and fed a complete feed mixture that met the recommended standards according to the age of the quails. The diet differed only in the content of garlic powder. In particular, young birds of group I (control) received only a complete feed, while 0.3% dry garlic powder was added to the diet of quails of group II, group III – 0.6% and group IV – 0.9%. It was found that the introduction of dry garlic powder into the diet of young meat quails at a concentration of 0.6% provides higher growth rate by 1.1% ($p < 0.05$) and live weight by 5.4% ($p < 0.001$) without reducing the survival of the population. The quality of quail meat has also improved, namely increased in pre-slaughter live weight by 5.1% ($p < 0.05$), the weight of unguilted, semi-gutted and gutted carcasses by 5.4–5.8% ($p < 0.05$), as well as the weight of pectoral muscles by 5.0% ($p < 0.05$), leg muscles by 5.1% ($p < 0.001$), skin by 9.3% ($p < 0.05$), internal fat by 20.0% ($p < 0.001$) and liver by 0.4 g or 7.1% ($p < 0.05$), with an increase in the yield of edible parts by 3.1% ($p < 0.05$) and a decrease in bone density by 3.1% ($p < 0.05$). Correlation analysis confirmed that increasing the concentration of garlic powder in the quail diet is associated with improving their meat productivity and slaughter qualities. Therefore, the most effective concentration of introducing dry garlic powder into the diet of young meat quails is 0.6%.

Keywords: quail, garlic, body weight, average daily live weight gain, growth rate, meat productivity, carcass weight, slaughter yield, yield of edible parts, meatiness

INTRODUCTION

The continuous growth of the human population and its projected increase to over 10 billion individuals by 2050 (Jalal *et al.*, 2023) poses significant challenges, especially in the field of food production. Poultry farming has become an important factor in meeting the growing demand for food, providing consumers worldwide with high-quality animal protein (Asghar *et al.*, 2022). Japanese quail (*Coturnix coturnix japonica*) is of considerable interest in the egg and meat production industry due to its growth rate and cost-effective management (Salas *et al.*, 2025). Notably, in a free-range system, quail can reach a live weight of 100–160 g, while quail raised in industrial conditions can reach 200 g in just 4 weeks after hatching (Arunrao *et al.*, 2023). Attractive biological characteristics, growth rate, and dietary properties of meat have made quail a desirable choice among poultry producers. Although intensification of poultry production has traditionally been associated with the use of antibiotics to reduce morbidity and mortality (Akram *et al.*, 2021), consumer concerns about

antimicrobial resistance have led to the search for alternatives. Recent developments in food production have increased interest in natural preservatives that can maintain meat quality and safety (Akram *et al*., 2019). Although the fatty acid profile of poultry meat makes it susceptible to oxidation (Domínguez *et al*., 2019), modern processing and storage methods have largely mitigated these problems in industrial settings. However, strategies to improve meat stability remain relevant (Jiang and Xiong, 2016).

Antibiotic growth promoters are antimicrobial agents used at subtherapeutic doses to improve growth and performance by modulating the gut microbiota (Rushton, 2015). In addition to the beneficial effects of antibiotics, antimicrobial resistance in the gut microbiota has also been reported when they are used as growth promoters (Luiken *et al*., 2019; Driesen *et al.,* 2024). Antibiotic resistance is the inability of antimicrobial drugs to eliminate or attenuate the proliferation of specific bacterial populations (Uddin *et al.*, 2021; Farrukh *et al.*, 2025). Antibiotics lead to the destruction of sensitive bacterial populations, which in turn contributes to the spread of resistant strains (Bava *et al.*, 2024). These risk factors and public concerns have led to active research into non-antibiotic strategies that could promote poultry growth and mitigate the spread of pathogens (Abreu *et al.*, 2023), highlighting the urgent need for effective alternatives that could maintain poultry health, promote normal intestinal physiology for efficient nutrient utilization, ensure welfare, and enhance performance without the side effects associated with antibiotics (Aminullah *et al.*, 2025). In this context, phytobiotics have emerged as a promising alternative to antibiotics, offering significant potential for improving gut function, health, and performance. Phytobiotics are feed additives derived from plant materials that include natural compounds, herbal and plant extracts, and biologically active compounds that have the potential to improve animal health, increase productivity, and product quality (Wang *et al.*, 2024; Abdel-Latif *et al.*, 2025).

One of the promising phytogenic additives in poultry feeding is garlic products (Hidayatik *et al.,* 2024). Garlic is added to poultry diets as powder, aqueous extract, essential oil, and other commercial products in feed or drinking water (Abd El-Ghany, 2024). It is known that the addition of garlic products to poultry diets contributes to increased growth rate, improved intestinal morphometry, productivity and reduced production costs (Makwana *et al.,* 2015; Elbaz *et al.,* 2021; Tanti *et al.,* 2023), modulation of immunity and hematological parameters (Ismail *et al.,* 2021), prevents bacterial and parasitic infections (Bhatwalkar *et al.,* 2021; Abd-ELrahman *et al.,* 2022) and mitigates the effects of heat stress on the body (Elbaz *et al.,* 2022). Adding garlic to poultry feed does not negatively impact since it has no residues, and bird droppings do not pollute the environment. Therefore, poultry products on diets supplemented with garlic are safe for human consumption (Abd El-Ghany, 2024).

Supplementing livestock and poultry diets with garlic products has been shown to improve growth parameters, feed efficiency, and meat quality (Ogbuewu *et al.,* 2019). Garlic products have been widely studied in poultry diets over the past decades (Kothari *et al.,* 2019; Al-Tekreeti and Allaw, 2022). Garlic contains at least 33 sulfur compounds, various enzymes, minerals, vitamins, amino acids, and dietary fiber (Aarti and Khusro, 2020). Allicin, the most studied primary bioactive component, has demonstrated significant antimicrobial, antioxidant, and growth-promoting effects (El-Ghany, 2024). Previous studies have shown that garlic can positively affect poultry growth rate, digestive processes, immune function and carcass quality (Swain *et al.,* 2017; Bhavani *et al.,* 2020; Elbaz *et al.,* 2021). In addition, the antimicrobial properties of garlic have been found to reduce bacterial infections in poultry, reducing the need for antibiotics (Ogbuewu *et al.,* 2019; Alagawany *et al.,* 2021). Ogbuewu *et al.* (2019) suggested that the wide range of beneficial properties of garlic makes it a promising natural alternative to synthetic additives in poultry production. Incorporating garlic into the poultry diet may be a strategy to introduce natural antimicrobial and antioxidant components into their bodies. Garlic bioactive compounds can potentially circulate throughout the body and accumulate in tissues, thereby affecting lipid oxidation and microbial activity (Akram *et al.,* 2021). However, the reported results of using garlic in poultry feeding are quite contradictory, which may be due to the use of different garlic products, their dosage, study duration and other factors. For example, Elbaz *et al.* (2021) and Sangilimadan *et al.* (2019) found that adding garlic to the diet of broilers contributes to an increase in their growth rate. Elbaz *et al.* and Noruzi and Aziz-Aliabadi (2024) described an enhanced immune response in broilers whose diet was enriched with garlic. On the other hand, Toghyani *et al.* (2011) did not find a significant effect of feeding garlic on the immune function of birds. This discrepancy indicates the need for further research and the establishment of clear recommendations regarding the role of garlic in poultry nutrition.

MATERIALS AND METHODS

Ethics

Experiments with experimental animals were performed following the rules of the European Convention for the Protection of Vertebrate Animals (Official Journal of the European Union L276/33, 2010) and the Order of the Ministry of Economy of Ukraine «On approval of the requirements for the welfare of farm animals during their housing»

of February 18, 2021, were organized. The local Commission approved the experimental protocol on Bioethics of the National University of Life and Environmental Sciences of Ukraine.

Experimental Treatment Groups

For the experiment, 400 one-day-old Pharaoh quails were selected. According to the principle of analogy (by age and body weight), one control and three experimental groups of 100 birds each were formed (Tab. I).

I: *Experimental scheme*

Group	Poultry group at the beginning of the experiment, the birds	Age, days	
		1–21	22–35
		Dry garlic powder, %	
G 0	100	-	-
G 0.3	100	0.3	0.3
G 0.6	100	0.6	0.6
G 0.9	100	0.9	0.9

The experiment lasted 35 days and was divided into two periods (days 1–21 and 22–35) and seven sub-periods of 7 days each. During the experiment, quails were kept in single-tier cage batteries. Twenty-five birds were placed in each cage measuring 46 × 40 × 20 cm. Given this, the floor area per bird was 73.6 cm^2. The cage frames provided a tube feeder in front of the cage at least 1.5 cm. Bell drinker were used to water the quails. From the 1st to the 7th day, the quails were heated with artificial heating to a temperature of 33–35 °C, from the 8th to the 21st day - 23–30 °C, from the 22nd to the 35th day the temperature in the room was 20–22 °C. The relative humidity in the room was 65–70%. 24-hour lighting was used for the first 3 weeks after birth. Starting from the 4th week of growth, the duration of the light period was gradually reduced to 17 hours per day. The lighting intensity throughout the growth period was 25–30 lux.

Feeding Characteristics

Experimental quails were given a complete feed mixture. The diet met the recommended standards according to the age of the quails and differed only in the content of garlic powder (Tab. II, III). The birds were fed twice a day (morning and evening). Accurate records of feed data and uneaten residues were kept throughout the experiment.

The survival of quails, their body weight and live weight gains, feed consumption per 1 kg of gain were recorded. The live weight of quails was determined once a week on a Veit BAT1 scale (Veit Electronics, Czech Republic). At the end of the experiment, the experimental birds were slaughtered (6 birds from each group, including 3 females and 3 males), and slaughter indicators were studied. Slaughter was carried out by the decapitation method. The indicators for assessing the slaughter qualities of quails were the following: weight before slaughter – body weight of quails after 12-hour starvation; weight of unguilted carcass – weight of carcass without blood and feathers; weight of semi-gutted carcass – weight of carcass without blood, feathers and intestines; weight of gutted carcass – weight of carcass without blood, feathers, head, legs, wings to the elbow joint, intestines; weight of edible parts – weight of all

II: *Energy and essential nutrient content in 100 g of compound feed*

Parameters	Age, days	
	1–21	22–35
Metabolic energy, MJ	1.214	1.252
Crude protein, g	27.50	20.50
Crude fat, g	5.00	5.00
Crude fiber, g	4.20	4.29
Linolenic acid, g	1.62	1.90
Lysine, g	1.68	1.11
Calcium, g	1.00	1.00
Methionine+cystine, g	1.00	0.75
Threonine, g	1.00	0.75
Phosphorus, g	0.80	0.80
Methionine, g	0.65	0.46
Tryptophan, g	0.33	0.23
Sodium, g	0.25	0.25
Vitamin E, mg	2.00	0.50
Vitamin A, IU	1500.00	700.00
Vitamin D3, IU	300.00	150.00

III: Composition of complete feeds for young quails of meat production, %

Indicator	Age of quails, days	
	1–21	22–35
Soybean caking	29.8	–
Corn	26.4	40.3
Wheat	23.2	27.4
Fish meal	10.0	6.0
Soy meal	5.8	21.5
Sunflower meal	2.6	2.1
Limestone	0.2	0.1
Premix 2%	2.0	–
Premix 2.5%	–	2.5

edible parts of the gutted carcass; weight of internal fat. Edible parts included pectoral muscles, leg muscles, skin with subcutaneous fat, internal fat, liver, lungs, kidneys, muscular stomach, and heart. The weight of slaughter products was determined using VLTK-500 scales. evaluated were weights of carcass parts and percentage of each evaluated of part or organ in relationship with live body weight.

The feed mixtures were used to feed experimental quails. The recipes of the feed mixtures were composed so that their nutritional value was the same. In this regard, the same ingredients were used (wheat, corn, soybean meal, sunflower meal, dried garlic, fish meal, soybean cake, premix, limestone), but in different proportions depending on the age.

Data Analysis

One-way analysis of variance (ANOVA) and Tukey-Kramer multiple comparison testing were used to establish and investigate group differences. The latter instrument was applied in the context of a post-hoc test tool. Information is placed in the Tab. III–VI was presented as M ± SEM (mean ± standard error of the mean), in Tab. VII–VIII as r ± Er (Pearson's correlation coefficient ± error of the correlation coefficient). Assessment of the distribution of sample materials for normality was carried out using the Kolmogorov-Smirnov criterion. In this case, if the data distribution significantly differed from normal, the Mann-Whitney U-test was applied. Thus, the concept of normal differences meant those that reached a value of $p < 0.05$. Microsoft Excel produced statistical analysis data.

RESULTS

Effect of Quail's Diet Enriched With Garlic Powder on Their Viability, Body Weight and Growth Rate

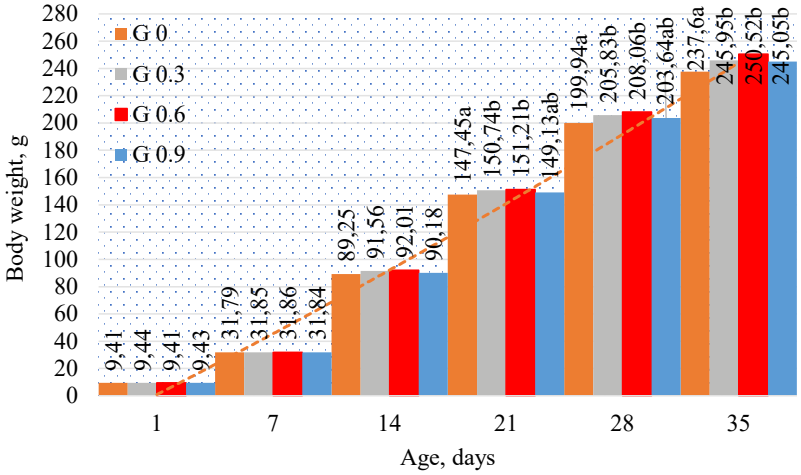
The survival of young quails throughout the entire studied period met the requirements of Ukrainian standards (Departmental standards for technological design in poultry farming, 2005) without any visible influence of the diet's composition (Tab. IV).

It should be noted that at the beginning of the studies, as well as during the first three weeks of feeding, no differences in live weight were observed between the young (Fig. 1). While, starting from the age of 21 days, the young that received

IV: *Quail productivity depending on the level of garlic powder in the diet, M ± SEM, n = 100/group*

Parameters, age period 1–35 days	Quail group			
	G 0	G 0.3	G 0.6	G 0.9
Preservation of poultry stock, %	94.0 ± 2.37^{a}	95.0 ± 2.18^{a}	95.0 ± 2.18^{a}	94.00 ± 2.37^{a}
Body weight, g	237.60 ± 2.540^{a}	245.95 ± 2.675^{b}	250.52 ± 2.864^{b}	245.05 ± 2.642^{bc}
Average daily body weight gain, g	6.52 ± 0.072^{a}	6.76 ± 0.076^{b}	6.89 ± 0.081^{b}	6.73 ± 0.064^{bc}
Relative body weight gain, %	184.3 ± 0.19^{a}	185.0 ± 0.17^{b}	185.4 ± 0.21^{b}	185.0 ± 0.24^{bc}
Feed conversion ratio, kg	2.984 ± 0.014^{a}	2.877 ± 0.021^{b}	2.786 ± 0.028^{b}	2.891 ± 0.026^{bc}

Notes: Different superscript letters indicate significant differences ($p < 0.05$). Values sharing at least one letter do not differ significantly.

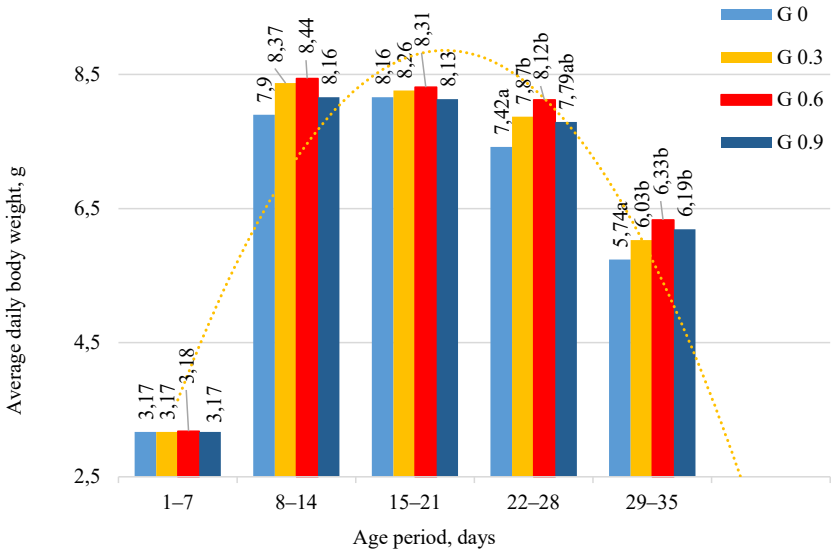


1: *The dynamics of the live weight of quails depend on the level of garlic powder introduced into the diet*
Notes: Different superscript letters indicate significant differences ($p < 0.05$). Values sharing at least one letter do not differ significantly.

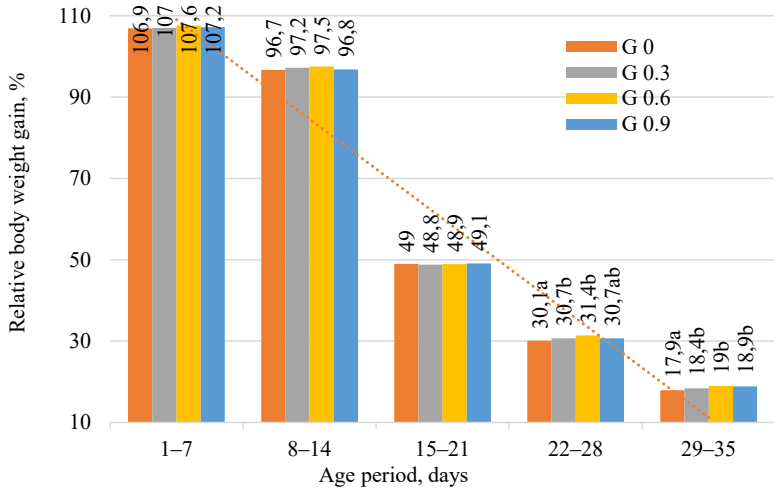
garlic powder were characterized by a higher body weight. In particular, the young of the G 0.3 group at the age of 21 days was characterized by a higher live weight by 2.2% ($p < 0.05$), at the age of 28 days – by 2.9% ($p < 0.05$), which resulted in a higher final body weight at the age of 35 days by 3.5% ($p < 0.05$) compared to the control group, the bird of which received a standard diet.

Young quails of the G 0.6 group were characterized by a higher live weight at 21 days of age by 2.6% ($p < 0.05$), at 28 days of age by 4.1% ($p < 0.05$), which resulted in a higher final body weight at 35 days of age by 5.4% ($p < 0.05$) compared to the control group, whose birds received a standard diet without the addition of garlic products. Interestingly, young quails of the G 0.9 group were not characterized, as might be expected, by the highest body weight parameters. Thus, quails of this group at 21 and 28 days of age did not differ in live weight from birds of the control group. While at the age of 35 days, their live weight leveled off and was 3.1% higher ($p < 0.05$) compared to the control group, whose birds received a standard diet without adding garlic products.

The effect of adding garlic powder to the diet of young quails on their average daily body weight gains was revealed (Fig. 2, 3). In particular, young birds of the G 0.3 group were characterized by higher average daily body weight gains by 6.1% ($p < 0.05$) in the 4th week of growing, and by 5.1% ($p < 0.05$) in the 5th week, which resulted in a higher average daily gain for the entire growing period



2: *The dynamics of average daily body weight of quails depend on the level of garlic powder introduced into the diet*
Notes: Different superscript letters indicate significant differences ($p < 0.05$). Values sharing at least one letter do not differ significantly.



3: *The dynamics of average daily body weight of quails depend on the level of garlic powder introduced into the diet*
Notes: Different superscript letters indicate significant differences ($p < 0.05$). Values sharing at least one letter do not differ significantly.

up to 35 days by 3.7% ($p < 0.05$) compared to the control group, whose birds received a standard diet. Young birds of the G 0.6 group were characterized by higher average daily body weight gains by 9.4% ($p < 0.05$) in the 4th week of growth, and by 10.3% ($p < 0.05$) in the 5th week, which resulted in higher average daily gains for the entire growth period up to 35 days by 5.7% ($p < 0.05$) compared to the control group, whose birds received a standard diet. Young birds G 0.9 were characterized by significantly lower average daily body weight gains, which were higher only in the 5th week of growth by 7.8% ($p < 0.05$). However, this provided a higher average daily gain for the growing period up to 35 days by 3.2% ($p < 0.05$) compared to the control group, whose birds received a standard diet.

As for the intensity of young quails, the effect of adding dry garlic powder to their diet is traced here, too. In particular, young birds of G 0.3 group were characterized by higher relative body weight gains by 0.60% ($p < 0.05$) in the 4th week of growing, and by 0.5% ($p < 0.05$) in the 5th week, which resulted in higher relative gains for the entire growing period up to 35 days by 0.7% ($p < 0.05$) compared to the control group, whose birds received a standard diet. Young birds of the G 0.6 group were characterized by the highest growth performance and in the 4th week of growing had higher relative body weight gains by 1.3% ($p < 0.05$), in the 5th week – by 1.1% ($p < 0.05$), which resulted in higher relative gain for the entire growing period up to 35 days by 1.1% ($p < 0.05$) compared to the control group, whose birds received a standard diet. While the young birds G 0. were characterized by a significantly lower intensity of growth processes, namely, their relative gains were higher in the 4th week of growing by 0.6% ($p < 0.05$), and in the 5th week – by 1.0 ($p < 0.05$), which resulted in a higher relative gain for the entire growing period up to 35 days by 0.7% ($p < 0.05$) compared to the control group, whose birds received a standard diet.

However, despite the same level of feed conversion ratio by quails, different growth performance processes in the bird's body caused differences in the efficiency of its use (Tab. III). Thus, differences in feed conversion ratio were observed already during the first week of growing. In particular, young birds of the G 0.3 group were characterized by lower feed conversion ratio in the 2nd week of growing by 3.1% ($p < 0.05$), in the 3rd – by 3.9% ($p < 0.05$), in the 4th – by 3.0% ($p < 0.05$), which resulted in lower feed conversion ratio for the entire growing period by 107 g/kg of live weight gain or by 3.6% ($p < 0.05$) compared to the control group, whose birds received a standard diet. Young birds of the G 0.6 group were characterized by lower feed conversion ratio from the first week of growing by 2.5% ($p < 0.05$), in the 2nd – by 4.4% ($p < 0.05$), in the 3rd – by 3.0% ($p < 0.05$), in the 4th – by 5.3% ($p < 0.05$), in the 5th – by 6.7% ($p < 0.05$), which resulted in lower feed consumption for the entire growing period by 198 g/kg of live weight gain or by 6.6% ($p < 0.05$) compared to the control group, whose birds received a standard diet. While the young birds of the G 0.9 group were characterized by lower feed conversion ratio only from the 3rd week of growing by 3.1% ($p < 0.05$), in the 4th – by 2.6% ($p < 0.05$), in the 5th – by 6.8% ($p < 0.05$), which resulted in lower feed conversion ratio for the entire growing period by 93 g/kg of live weight gain or by 3.1% ($p < 0.05$) compared to the control group, whose birds received a standard diet.

Enriching the diet of poultry with phytobiotics improves performance parameters, including feeding intake, body weight, live weight gain and feed conversion ratio (Khan *et al*., 2012; Ibatullin *et al*., 2022; Sychov *et al*., 2022; Tanti *et al*., 2022), which was confirmed by this study specifically on young quails. In particular, we found that the most effective concentration of introducing dry garlic powder into the diet of young quails of the meat direction of productivity is 0.6%, which provides a higher live weight of birds at the age of 35 days by 5.4% ($p < 0.05$), with higher average daily body weight gains by 5.7% ($p < 0.05$) and more intensive growth by 1.1% ($p < 0.05$) without reducing the safety of the population. Adding 0.3 and 0.9% dry garlic powder to the diet was less effective regarding growth parameters ($p < 0.05$). The data obtained are consistent with the results of Suriya *et al.* (2012), who found that adding 0.5% garlic into the diet contributes to increased body weight gain in chickens. Sangilimadan *et al.* (2019) also noted the effectiveness of adding fresh garlic paste to the diet at a concentration of 0.25 and 0.50% of the diet, which contributes to an increase in the safety of poultry, body weight gain and conversion rate and does not affect the quality of the carcass. According to Ismail *et al.* (2021), enrichment of the diet with 0.25, 0.50 and 0.75 g/kg of garlic powder provides an increase in body weight and fat content in the carcass, as well as an increase in the length and width of the small intestine. At the same time, Jalal *et al.* (2024) noted the effectiveness of significantly higher concentrations of garlic powder in the diet of quails, namely 1–2%, which demonstrated a growth-stimulating effect and positively affected the quality of meat, including its sensory characteristics. Similar results regarding the effectiveness of increasing concentrations of garlic powder were also obtained by Tanti *et al.* (2022), who noted an increase in body weight gain and final live weight of chickens when adding as much as 3% of a garlic product to their diet. Al-Rabadi *et al.* (2020) studied the effect of adding garlic powder to the diet of broilers at concentrations of 0.5, 1 and 1.5%. They found that feeding garlic powder at a concentration of 1.5% reduces feed intake, while increasing body weight gain and feed conversion ratio. According to Premavalli and Omprakash (2020), who studied

the effect of garlic powder at concentrations of 0.5, 1.0, and 1.5% on quail meat performance, it was the 1.5% level that was most effective in increasing growth rate and body weight gain in birds.

At the same time, our data contradict some studies that did not reveal the effect of enriching diets with garlic products on poultry performance. In particular, Choi *et al.* (2010), who studied the impact of adding garlic to broiler diets in 1, 3 and 5% with enrichment of 200 units of α-tocopherol/kg of feed, did not reveal the effect on performance. Raeesi *et al.* (2010) did not reveal the impact of adding 0.5%, 1.0% and 3% garlic to the diet on poultry performance, but noted a decrease in heart weight. According to Aydogan *et al.* (2020), enriching the diet of poultry with 5 g/kg of garlic, 5 g/kg of black cumin, or their combination does not affect body weight gain, feed consumption and feed conversion ratio. According to Gautam and Nabaraj Shishir (2017), adding fresh garlic paste to the drinking water of chickens at a concentration of 0.2, 0.4, 0.6 and 0.8 %/l does not affect body weight gain and feed conversion ratio, but contributes to an increase in the safety of the poultry population. At the same time, Varmaghany *et al.* (2015) note that adding garlic bulbs to the poultry diet in 5, 10 or 15 g/kg, on the contrary, causes a decrease in body weight, without affecting the feed conversion ratio. However, the data we obtained on the positive effect of enriching the diet with garlic powder on the meat productivity of quails and their slaughter qualities were confirmed by significant correlation coefficients.

Effect of Quail's Diet Enriched With Garlic Powder on Their Meat Productivity and Slaughter Qualities

Adding dry garlic powder to the quail diet significantly affected their meat productivity (Tab. V). In particular, adding the lowest tested concentration of garlic product to the diet – 0.3% – resulted in an increase in pre-slaughter live weight by 3.8% ($p < 0.05$) and eviscerated carcass weight by 4.0% ($p < 0.05$), compared to the control group, whose birds received a standard diet. Young quails of the G 0.6 group characterized by a higher pre-slaughter live weight by 5.1% ($p < 0.05$), and eviscerated carcass weight by 5.4% ($p < 0.05$), compared to the control group, whose birds received a standard diet. While young quails of the G 0.9 group did not differ in meat productivity from the birds of the control group, which received a diet without enrichment with dry garlic powder.

As for the yield of edible parts, the effect of enriching the diet with garlic powder is visible. In particular, the young birds of G 0.3 group were characterized by a greater mass of pectoral muscles by 4.5% ($p < 0.05$) and leg muscles by 3.1% ($p < 0.05$) compared to the control group, whose birds received a standard diet. In turn, young birds of the G 0.6 group were characterized by a greater mass of pectoral muscles by 5.0% ($p < 0.05$), leg muscles by 5.1% ($p < 0.05$), skin by 9.3% ($p < 0.05$), abdominal fat by 20.0% ($p < 0.05$) and liver by 7.1% ($p < 0.05$) compared to the control group, whose birds received a standard diet. While young birds of the G 0.9 group did not differ from those of the control group, which received a diet without enrichment with dry garlic powder.

V: *Slaughter qualities of quails depending on the level of garlic powder introduction into the diet, M ± SEM, n = 6/group*

Parameters, g	Quail group			
	G 0	G 0.3	G 0.6	G 0.9
Weight:				
– pre-slaughter live	231.7 ± 2.12^{a}	240.4 ± 2.19^{b}	243.5 ± 1.93^{b}	232.7 ± 2.32^{a}
– eviscerated carcass	171.1 ± 1.13^{a}	177.9 ± 1.07^{b}	180.4 ± 1.19^{b}	169.7 ± 1.41^{a}
Weight of edible parts:				
– pectoral muscles	40.3 ± 0.69^{a}	42.1 ± 0.40^{b}	42.3 ± 0.37^{b}	40.6 ± 0.63^{a}
– leg muscles	25.7 ± 0.25^{a}	26.5 ± 0.13^{b}	27.0 ± 0.21^{b}	25.3 ± 0.19^{a}
– skin with subcutaneous fat	15.1 ± 0.38^{a}	15.8 ± 0.56^{a}	16.5 ± 0.44^{b}	15.5 ± 0.54^{a}
– abdominal fat	2.0 ± 0.08^{a}	2.3 ± 0.09^{ab}	2.4 ± 0.09^{b}	2.7 ± 0.11^{c}
– liver	5.6 ± 0.10^{a}	5.9 ± 0.04^{ab}	6.0 ± 0.09^{bc}	5.9 ± 0.10^{c}
– lungs	2.0 ± 0.08^{a}	2.1 ± 0.10^{a}	2.2 ± 0.09^{a}	2.0 ± 0.10^{a}
– kidneys	1.1 ± 0.05^{a}	1.1 ± 0.06^{a}	1.1 ± 0.08^{a}	1.1 ± 0.03^{a}
– muscular stomach	4.7 ± 0.12^{a}	4.9 ± 0.17^{a}	4.9 ± 0.11^{a}	4.7 ± 0.07^{a}
– heart	2.0 ± 0.10^{a}	2.1 ± 0.06^{a}	2.1 ± 0.04^{a}	1.9 ± 0.06^{a}

Notes: Different superscript letters indicate significant differences ($p < 0.05$). Values sharing at least one letter do not differ significantly.

It was established that the slaughter qualities of meat quails changed under the influence of enrichment of the bird's diet with dry garlic powder (Tab. VI). In particular, it was found that the addition of 0.3% garlic powder contributed to an increase in the output of leg muscles by 1.0% ($p < 0.05$), the addition of 0.6% garlic powder contributed to an increase in the output of pectoral muscles by 0.6% ($p < 0.05$), leg muscles by 0.8% ($p < 0.05$), and the output of skin with subcutaneous fat by 0.3% ($p < 0.05$). While the young birds of the G 0.9 group did not differ from those of the control group, which received a diet without enrichment with dry garlic powder.

So this is his study found that adding dry garlic powder to the diet of young meat-producing quails helps improve their meat quality. The obtained data are consistent with the results of Saghi and Zarghi (2022), who note that diets with the addition of 1% garlic powder provide the highest carcass yield and reduce undesirable blood metabolites. The effect of diet enrichment on quail meat productivity was confirmed by Ashayerizadeh *et al.* (2009), who found that adding garlic to the diet at 1 kg/ton increased carcass yield and reduced abdominal fat percentage in broiler chickens. Elagib *et al.* (2013) showed that enriching the chickens' diet with garlic powder at a concentration of 3% increased breast muscle yield, while adding 5% caused a decrease in live weight.

Relationship Between Changes in Garlic Powder Concentration in Quail Diets and Their Performance Parameters

The results of the correlation analysis showed that there are relationships of different strengths and directions between the concentration of dry garlic powder in the diet of young quails and their productivity parameters (Tab. VII and VIII). In particular, at the level of 0.71–0.77 units ($p < 0.001$), a strong direct proportional relationship was found between the concentration of garlic powder in the diet of quails and the survival of the population and relative body weight gains. A significant direct proportional relationship, at the level of 0.58–0.65 units ($p < 0.001$), was observed between the concentration of garlic powder in the diet of quails and their body weight, average daily live weight gains and feed consumption. While between the concentration of garlic powder in the quail diet and feed consumption per 1 kg of body weight gain, a noticeable inverse proportional

VI: *Quail slaughter yield depending on the level of garlic powder in the diet, %, M ± SEM, n = 6/group*

Parameters	Quail group			
	G 0	G 0.3	G 0.6	G 0.9
Eviscerated carcass output	73.8 ± 0.33[a]	74.0 ± 0.35[a]	74.1 ± 0.39[a]	72.9 ± 0.34[a]
Edible parts output:				
– pectoral muscles	17.4 ± 0.15[a]	17.5 ± 0.22[a]	18.0 ± 0.22[b]	17.2 ± 0.13[a]
– leg muscles	11.1 ± 0.18[a]	12.1 ± 0.12[b]	11.9 ± 0.14[b]	10.9 ± 0.21[a]
– skin with subcutaneous fat	6.5 ± 0.10[a]	6.6 ± 0.11[a]	6.8 ± 0.09[b]	6.6 ± 0.10[a]
– abdominal fat	0.9 ± 0.02[a]	0.9 ± 0.02[a]	0.9 ± 0.03[a]	1.0 ± 0.04[a]
– liver	2.4 ± 0.03[a]	2.5 ± 0.02[a]	2.4 ± 0.01[a]	2.5 ± 0.02[a]
– lungs	0.9 ± 0.02[a]	0.9 ± 0.03[a]	0.9 ± 0.03[a]	0.9 ± 0.03[a]
– kidneys	0.5 ± 0.02[a]	0.4 ± 0.02[a]	0.4 ± 0.03[a]	0.5 ± 0.01[a]
– muscular stomach	2.0 ± 0.06[a]	2.0 ± 0.05[a]	2.0 ± 0.03[a]	2.0 ± 0.01[a]
– heart	0.9 ± 0.03[a]	0.9 ± 0.01[a]	0.9 ± 0.01[a]	0.8 ± 0.01[a]

Notes: Different superscript letters indicate significant differences ($p < 0.05$). Values sharing at least one letter do not differ significantly.

VII: *Correlation coefficients between the level of introduction of dry garlic powder into the diet and the quail's productivity, r ± Er, n = 400*

Parameters	The level of introduction of dry garlic powder into the diet	Significant value
Preservation of poultry stock	0.77 ± 0.020	p < 0.001
Body weight	0.65 ± 0.029	p < 0.001
Average daily body weight gain	0.64 ± 0.030	p < 0.001
Relative body weight gain	0.71 ± 0.025	p < 0.001
Feed conversion ratio	-0.59 ± 0.033	p < 0.001

VIII: *Correlation coefficients between the level of introduction of dry garlic powder into the diet and slaughter qualities of quails, r ± Er, n = 24*

Parameters, g	The level of introduction of dry garlic powder into the diet	Significant value
Weight:		
– pre-slaughter live	0.62 ± 0.122	p < 0.01
– eviscerated carcass	0.86 ± 0.052	p < 0.001
Weight of edible parts:		
– pectoral muscles	0.91 ± 0.033	p < 0.001
– leg muscles	0.79 ± 0.075	p < 0.001
– skin with subcutaneous fat	0.42 ± 0.165	p < 0.05
– abdominal fat	0.53 ± 0.144	p < 0.05
– liver	0.74 ± 0.088	p < 0.001
– lungs	0.13 ± 0.196	No significant
– kidneys	0.06 ± 0.011	No significant
– muscular stomach	0.19 ± 0.193	No significant
– heart	-0.40 ± 0.286	No significant

relationship of -0.59 units were observed ($p < 0.001$). The obtained data confirm that the enrichment of the quail diet with garlic powder is noticeably and strongly associated with an increase in such economically beneficial traits as the safety of the poultry population, live weight, average daily body weight gain, feed consumption and, at the same time, a decrease in feed conversion ratio.

In addition, a powerful direct proportional relationship was found, at the level of 0.91 units ($p < 0.001$), between the concentration of garlic powder in the diet and the mass of the pectoral muscles, as well as a strong direct proportional relationship, at the level of 0.74–0.86 units ($p < 0.001$), between the mass of semi-gutted and gutted carcasses, the mass of leg muscles and liver. A noticeable direct proportional relationship, at the level of 0.53–0.62 units ($p < 0.05$; $p < 0.01$), was observed between the concentration of garlic powder in the diet and pre-slaughter live weight, ungutted carcass weight, internal fat weight, as well as a moderate direct proportional relationship, at the level of 0.42 units ($p < 0.05$), with skin weight. Thus, increasing the concentration of garlic powder in the diet of quails is associated with improving their slaughter qualities.

The mechanism by which garlic powder can improve the performance parameters of poultry may be related to the presence of several organosulfur compounds, including allicin, alliin, ajoene, dithiin, diallyl sulfide, and S-allylcysteine (Ziarlarimi *et al*., 2011). Ross *et al.* (2001) demonstrated that garlic's antibacterial compound dialkyl polysulfide is pivotal in improving body weight gains in birds. A combined diet containing garlic and turmeric (10 g/kg each) reduced gastrointestinal pH and increased apparent and digestible metabolizable energy in the ileum of broiler chickens (Olukosi and Dono, 2014). Inulin component of garlic decreases the digesta pH of birds and increases the volatile fatty acids production which may help in enhancing the beneficial bacterial colonization (Grajek *et al*., 2005). In addition, garlic can increase the productivity of pancreatic enzymes, which creates a favourable environment for digestion and absorption of nutrients (Ismail *et al*., 2021; Osadcha *et al*., 2023), which was confirmed in our studies and will be highlighted in future publications. The addition of eugenol and garlic tincture could improve the intestinal integrity and enhance the mucin-producing goblet cell numbers as a defensive response to the birds against necrotic enteritis (Kumar *et al*., 2021). Administration of garlic increased the villus height and crypt depth but decreased epithelial thickness and goblet cell numbers in the intestine of poultry (Adibmoradi *et al*., 2006). Furthermore, the highest capacity of crypt and villi of small intestines was detected following dietary addition of garlic in coccidiosis infected chickens (Gotep *et al*., 2016).

Allicin is the most described active ingredient in garlic (Gao *et al.*, 2022). Allicin, a sulfur-containing compound, is a kind of natural compound that can be extracted from garlic. Many studies have demonstrated its beneficial roles in anti-microbial, anti-inflammatory, anti-oxidative, and anti-cancer activities (Guan *et al*., 2018; Salehi *et al*., 2019). In addition, we previously reported that allicin, as an effective organic osmotic substance, plays an important role in regulating cells' adaptation to endoplasmic reticulum stress (Jiang *et al*., 2019). Attributed to the activities in inhibiting cell proliferation (Li *et al.*, 2015), allicin might be effective in cancer treatment (Guo *et al*., 2020).

Besides, allicin attenuates chronic social defeat stress-induced depression which may be attributed to the regulatory roles of allicin in the gut-blood-brain axis (Gao *et al*., 2019). Allicin could enhance the antioxidant capacity, scavenge free radicals, and regulate antioxidant process mediated by different signal pathways (Xu *et al.*, 2022; Yue *et al*., 2022). Importantly, evidence suggests that allicin benefits intestinal development in animals (Huang *et al*., 2020). Allicin reduces serum metabolic disorders and strengthens the intestinal barrier (Gao *et al*., 2025). Allicin can regenerate and improve the physiological structure epithelium layer of the intestine, increase the crypt's depth and villus height, which eventually support the digestive capacity via increasing the nutrients absorption and assimilation (Adibmoradi *et al*., 2006). A longer villi and deeper crypt are considered a sign of a healthy intestine architecture, and consequently a good digestive capacity and the pancreatic enzyme activity (Abd El-Ghany, 2024). However, the specific effects and mechanisms of allicin involved in the intestinal barrier function remain elusive.

Moreover, the antioxidant characteristics of garlic can enhance the overall gut function and improve the nitrogen energy utilization (Halliwell *et al*., 2000). Yang *et al.* (2009) reported that feeding poultry on garlic reduces the pH of digesta which was resulted in an increase in the production of the volatile fatty acid and the proliferation of beneficial bacteria. Dietary addition of 0.5% garlic efficiently reduced the systemic hypertension and the prevalence of ascites, but had no negative influences on poultry performance (Varmaghany *et al.*, 2015).

Thus, the acceleration of poultry growth and improved survival promoted by allicin can be explained by at least three key aspects. First, allicin, with its intense garlic flavor, has a strong stimulating effect on the olfactory system of most aquatic animals, encouraging them to consume more feed (Lee and Gao, 2012; Valenzuela-Gutiérrez *et al*., 2021). Second, allicin enhances gastrointestinal motility and regulates the secretion of various digestive enzymes, thereby improving digestion and nutrient absorption (Chen *et al*., 2021). Finally, allicin can directly inhibit and kill a wide range of pathogenic bacteria (including Streptococcus, Vibrio, and Aeromonas) and enhance the activity of the body's defense system (Chirawithayaboon *et al*., 2020; Muahiddah and Diamahesa, 2023).

CONCLUSION

It was found that the most effective concentration of introducing dry garlic powder into the diet of young quails of the meat production direction is 0.6%, which provides higher growth intensity by 1.1% ($p < 0.05$) and live weight by 5.4% ($p < 0.001$) without reducing the safety of the livestock. The meat quality of quails also improves, namely, there is an increase in pre-slaughter live weight by 5.1% ($p < 0.05$), the weight of eviscerated carcass – by 5.4% ($p < 0.05$), as well as the weight of pectoral muscles – by 5.0% ($p < 0.05$), leg muscles – by 5.1% ($p < 0.001$), skin – by 9.3% ($p < 0.05$), abdominal fat – by 20.0% ($p < 0.05$) and liver – by 0.4 g or 7.1% ($p < 0.05$), with an increase in the yield of edible parts by 3.1% ($p < 0.05$) and a decrease in bone density by 3.1% ($p < 0.05$). Correlation analysis confirmed that increasing the concentration of garlic powder in the quail diet is associated with improving their meat productivity and slaughter qualities.

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