Scientific and technical bulletin of Livestock farming Institute of NAAS of Ukraine, 2026, Is. 138
***ISSN* 3083-7987 print**

DOI 10.32900/3083-7987-2026-138-88-101
UDC 598.261.7:636.084

GROWTH PERFORMANCE OF MEAT-TYPE QUAIL FED DIETS CONTAINING DIFFERENT LEVELS OF HYDROLYZED FEATHER MEAL

Volodymyr OTCHENASHKO, Doctor of Agricultural Sciences, Professor,
Corresponding Member of NAAS of Ukraine
https://orcid.org/0000-0003-0336-9340
Vadym CHERNYSH, PhD student
https://orcid.org/0009-0006-1483-1982
National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine

Received: October 9, 2026
Revised: October 16, 2026
Published: October 30, 2026
This is an Open Access article under the **CC BY-NC-ND 4.0 license**

The use of alternative protein ingredients in compound feeds for meat-type poultry can diversify feed resources while enabling the valorization of poultry-processing by-products. Hydrolyzed feather meal (HFM) is of particular interest because its nutritional value depends on processing conditions and dietary inclusion level. The growth performance of Pharaoh meat-type quail was investigated at the Educational, Research and Practical Laboratory of Poultry Production Technologies, National University of Life and Environmental Sciences of Ukraine. During a 35-day rearing period, birds received compound feeds containing 0, 3, 5, or 7% HFM. At the end of the experiment, mean body weights in the 3 and 5% HFM groups were 241.24 and 242.01 g, respectively, compared with 237.65 g in the control group. At 7% HFM, final body weight was lower than in the control group (226.70 g; $p < 0.05$). Absolute body-weight gain over days 1–35 was 226.10 g in the control group and 229.66, 230.47, and 212.30 g in the 3, 5, and 7% HFM groups, respectively. Corresponding average daily gains were 6.65, 6.75, 6.78, and 6.24 g/day. No statistically significant between-group differences were detected in absolute or average daily gain. Relative body-weight gain over the entire period was 181.38, 181.71, 181.73, and 179.80%, respectively, with no statistically significant difference among diets ($p = 0.5074$). Calculated cumulative feed intake was 683.88 g/bird in the control group and 688.84, 699.49, and 717.02 g/bird in the experimental groups. The corresponding calculated feed conversion ratios were 3.025, 2.999, 3.035, and 3.441 g/g. Survival rates were 93, 97, 95, and 91%, respectively. These findings indicate that HFM can be incorporated at 3–5% in compound feeds for growing meat-type quail without an observed reduction in final body weight relative to the control. Inclusion at 7% was associated with lower final body weight and a higher calculated feed conversion ratio, which should be considered when selecting the dietary inclusion level.

Keywords: meat-type quail, hydrolyzed feather meal, compound feed, body weight, body-weight gain, feed intake, feed conversion ratio.

ISSN 3083-7987 print

ПРОДУКТИВНІСТЬ М'ЯСНИХ ПЕРЕПЕЛІВ ЗА РІЗНИХ РІВНІВ ГІДРОЛІЗОВАНОГО ПІР'ЯНОГО БОРОШНА

Володимир ОТЧЕНАШКО, д. с.-г. н., професор, член – кореспондент НААН, https://orcid.org/0000-0003-0336-9340
Вадим ЧЕРНИШ, аспірант, https://orcid.org/0009-0006-1483-1982
Національний університет біоресурсів і природокористування України, Київ, Україна

Дата надходження до редакції: 09.10.2026 р.
Дата прийняття до друку після рецензування: 16.10.2026 р.
Дата публікації: 30.10.2026 р.
Це стаття відкритого доступу за ліцензією **CC BY-NC-ND 4.0**

Використання нетрадиційних протеїнових компонентів у комбікормах для м'ясної птиці дає змогу розширити сировинну базу годівлі та залучити продукти переробки відходів птахівництва. Особливий інтерес становить гідролізоване пір'яне борошно, поживна цінність якого залежить від особливостей оброблення сировини та рівня введення до раціону. Дослідження продуктивності молодняку перепелів породи Фараон проведено на базі навчально-науково-практичної лабораторії технологій виробництва продукції птахівництва НУБіП України. Протягом 35-добового періоду вирощування птиці згодовували комбікорми з рівнями включення гідролізованого пір'яного борошна 0, 3, 5 та 7 %. Наприкінці дослідного періоду середня жива маса птиці за введення 3 і 5 % цього кормового компонента становила відповідно 241,24 і 242,01 г, тоді як у контрольній групі — 237,65 г. За вмісту 7 % показник дорівнював 226,70 г і був нижчим від контрольного ($p < 0,05$). Абсолютний приріст живої маси за 1–35 діб у контролі становив 226,10 г, а в групах із 3, 5 і 7 % пір'яного борошна — відповідно 229,66; 230,47 і 212,30 г. Середньодобові прирости в цих групах дорівнювали 6,65; 6,75; 6,78 і 6,24 г. Для абсолютних та середньодобових приростів статистично значущих міжгрупових відмінностей не встановлено. Відносний приріст за весь період становив відповідно 181,38; 181,71; 181,73 і 179,80 % без статистично значущої різниці між раціонами ($p = 0,5074$). Розрахункове споживання корму за період вирощування становило 683,88 г на голову в контролі та 688,84; 699,49 і 717,02 г на голову в дослідних групах. Відповідні розрахункові витрати корму на одиницю приросту середньої живої маси становили 3,025; 2,999; 3,035 і 3,441 г/г. Збереженість поголів'я дорівнювала 93, 97, 95 і 91 % відповідно. Отримані результати свідчать про можливість використання 3–5 % гідролізованого пір'яного борошна у складі комбікормів для молодняку м'ясних перепелів без зафіксованого зниження кінцевої живої маси порівняно з контролем. За введення 7 % спостерігалися нижча жива маса та вищі розрахункові витрати корму, що слід враховувати під час добору рівня цього компонента в раціонах.

Ключові слова: м'ясні перепели, гідролізоване пір'яне борошно, комбікорм, жива маса, прирости живої маси, споживання корму, витрати корму.

Introduction. Quail production has the potential to complement the poultry industry in Ukraine by supplying meat and eggs. Modern poultry production is developing rapidly, and balanced feeding is essential for realizing the genetic growth potential of birds. Studies of the protein requirements of growing Japanese quail have

demonstrated the importance of adequate protein nutrition for growth and performance (Bawa et al., 2012). Rising prices for conventional protein feeds and the continued expansion of poultry production have increased interest in alternative protein sources. Hydrolyzed feather meal is a potential option because of its high crude protein content. Its use may provide a lower-cost dietary protein ingredient and contribute to the management of by-products generated during poultry slaughter and processing. Feathers account for approximately 5–10% of the live weight of an adult chicken. Protein constitutes more than 90% of feather mass, predominantly in the form of keratin. Owing to its structural properties, particularly disulfide cross-links, keratin has low solubility and resists conventional digestive enzymes, limiting its digestibility in poultry (Adler et al., 2018; He et al., 2018; Verma, 2023). Hydrolysis is therefore used to process feathers. The resulting product may contain a mixture of amino acids, peptides, proteins, glycoproteins, and free fatty acids (Solcova et al., 2021). However, its nutritional value varies with the composition of the starting material and processing conditions, including pressure and hydrolysis duration (Sinhorini et al., 2024; Liu et al., 2026). Hydrolysis can improve the availability of feather-derived protein and amino acids to livestock, making HFM a promising high-protein feed ingredient.

Recent studies on the use of HFM in poultry nutrition indicate that feather-derived feed products can affect growth performance and feed utilization. For example, supplementing a feather meal-containing broiler diet with keratinase at 200,000 U/kg improved body-weight gain and feed conversion during certain experimental periods (Xu et al., 2022).

Identifying an appropriate dietary inclusion level is an important consideration when alternative protein sources are used in poultry feeds. The effectiveness of feather meal depends on its nutritional value and nutrient digestibility, both of which must be considered when formulating complete feeds (Liu et al., 2026).

Research in meat-type quail has shown that inclusion of alternative plant-derived ingredients may alter selected performance traits. In one study, incorporating Camelina sativa cake at 15% of the diet impaired feed conversion compared with the control treatment ($p = 0.0004$), although no substantial adverse effect on carcass yield or meat quality was observed (Cullere et al., 2023).

Another study investigated diets containing corticated marama bean (Tylosema esculentum) meal pretreated with a fibrolytic multienzyme preparation. As the enzyme inclusion level increased, final live body weight of quail decreased linearly ($p = 0.037$). Significant quadratic responses were also observed for blood hemoglobin concentration and breast muscle color saturation measured one hour postmortem ($p < 0.05$). Nevertheless, enzyme pretreatment did not improve the feeding value of corticated marama bean meal for quail (Marareni et al., 2024).

A study in which mopane worm meal partially replaced soybean meal in quail diets found no statistically significant effects on blood biochemical indices or growth performance, although some meat-quality characteristics changed. The authors concluded that mopane worm meal could serve as an alternative to soybean meal without compromising productive performance or health; however, an optimal inclusion level was not established (Marareni & Mnisi, 2020).

In Jumbo quail, dietary inclusion of olive pomace above 150 g/kg was associated with impaired growth performance and carcass characteristics. No major effects on blood biochemical indices were observed, although high inclusion levels affected certain meat-color traits. The authors suggested that high dietary levels of olive pomace would require measures to improve nutrient availability, including fiber degradation (Hlatshwayo et al., 2023).

ISSN 3083-7987 print

Researchers in the Czech Republic reported that defatted black soldier fly larval meal improved body-weight gain during the starter phase in Japanese quail compared with the control diet. By contrast, defatted yellow mealworm meal adversely affected selected growth indices, ileal morphology, and apparent ileal crude protein digestibility. Overall, the findings supported defatted black soldier fly larval meal as an alternative protein source for Japanese quail at an inclusion level of 100 g/kg (Kudlová et al., 2026).

Balanced dietary formulation is particularly important for meat-type quail. Previous research has shown that dietary crude protein concentration and amino acid composition can influence body-weight gain and feed utilization during rearing (dos Anjos Lima et al., 2024).

Studies of dietary nutrient density and alternative feed ingredients in meat-type quail further emphasize the need to optimize feed formulations using several complementary performance outcomes (Ashour et al., 2022; Irmak et al., 2025).

The effects of alternative protein sources on poultry performance must also be considered. In broilers, replacing approximately 33% of soybean meal with enzymatically or bacterially treated HFM did not adversely affect growth or feed conversion, whereas increasing the replacement level to 67% reduced performance (Salehizadeh et al., 2025).

Taken together, these findings underscore the importance of determining suitable inclusion levels for high-protein alternative feed ingredients in meat-type quail diets, considering body weight, body-weight gain, feed intake, and feed efficiency. However, limited information is available specifically on the effects of different dietary levels of HFM in quail, warranting further investigation.

The aim of this study was to evaluate the effects of different dietary inclusion levels of HFM on the productive performance of growing Pharaoh quail, with particular emphasis on body weight, body-weight gain, feed intake, and feed conversion.

Materials and Methods. A feeding trial was conducted with growing Pharaoh quail at the Educational, Research and Practical Laboratory of Poultry Production Technologies of the National University of Life and Environmental Sciences of Ukraine. The experimental period lasted 35 days. The experimental design is presented in Table 1.

Table 1

Experimental design of the feeding trial

Treatment	Dietary HFM, %	Replicate 1, birds	Replicate 2, birds	Total birds
Control	0	50	50	100
Treatment 1	3	50	50	100
Treatment 2	5	50	50	100
Treatment 3	7	50	50	100

The rearing period was divided into two phases: days 1–21 and days 22–35 of age. Performance variables were recorded throughout the experiment.

Birds were offered complete mash diets. The control group received a diet without HFM; the experimental diets contained 3, 5, or 7% HFM, respectively. Control and experimental formulations were developed to accommodate the specified HFM inclusion levels. The calculated nutrient composition of the diets is given in Table 2.

Table 2

Calculated nutrient composition of quail diets (per kg of compound feed)

Nutrient	Phase							
	Days 1–21				Days 22–35			
	Control	T1	T2	T3	Control	T1	T2	T3
Metabolizable energy, MJ/kg	12.6	12.6	12.6	12.6	12.89	12.89	12.89	12.89
Crude protein, %	25	25	25	25	20.5	20.5	20.5	20.5
Crude fat, %	4.48	4.8	4.53	4.53	4.6	4.6	4.8	4.71
Crude fiber, %	5.07	5.08	5.07	5.05	5.4	5.36	5.34	5.31
Lysine, %	1.35	1.35	1.35	1.35	1.06	1.06	1.06	1.06
Methionine, %	0.64	0.64	0.64	0.64	0.85	0.85	0.85	0.85
Methionine + cystine, %	0.96	0.96	0.96	0.96	1.13	1.13	1.13	1.13
Threonine, %	0.96	0.96	0.96	0.96	1.2	1.2	1.2	1.2
Tryptophan, %	0.31	0.31	0.31	0.31	0.24	0.24	0.24	0.24
Calcium, %	1	1	1	1	1	1	1	1
Total phosphorus, %	0.75	0.75	0.75	0.75	0.8	0.8	0.8	0.8
Available P, %	0.46	0.46	0.46	0.46	0.57	0.57	0.57	0.57
Sodium, %	0.18	0.18	0.18	0.18	0.25	0.25	0.25	0.25
Chloride, %	0.3	0.3	0.3	0.3	0.33	0.33	0.33	0.33

Commercially produced HFM was purchased from a feed supplier. The product was manufactured by PJSC Dniprovskyi Poultry Complex. Specific processing parameters were unavailable because they are considered proprietary information by the manufacturer.

Feed was provided twice daily, in the morning and evening. The amounts of feed offered and refused were recorded to estimate feed intake.

Body weight was determined by individually weighing quail at the designated ages. Absolute, average daily, and relative body-weight gains, feed intake, and feed conversion were calculated from the recorded data. Feed intake was determined as the difference between feed offered and feed refusals.

Statistical analysis involved calculating arithmetic means (M) and their standard errors (m). Differences among treatments were evaluated by one-way analysis of variance (ANOVA); two-sided Student's t-tests for independent samples were used to compare individual experimental groups with the control. Individual birds were treated as observational units for the analysis of individual measurements. Significance thresholds were set at $p < 0.05$, $p < 0.01$, and $p < 0.001$. Results are presented as $M \pm m$.

Birds were housed in groups. Feeder space was 1.5 cm per bird, and stocking area was approximately 73.5 cm² per bird. Housing and feeding conditions were identical across groups, except for dietary HFM inclusion level.

The study was approved by the Bioethics Committee of the National University of Life and Environmental Sciences of Ukraine (Decision No. 011/2024, 28 March 2024).

Results. Body weight increased markedly over the experimental period in all treatments, as shown in Table 3.

ISSN 3083-7987 print

Table 3

Body weight of growing quail, g (M ± m)

Age, days	Treatment				ANOVA, p	n
	Control	T1	T2	T3		
1	11.60	11.56	11.59	11.79	-	-
7	32.72 ± 0.60	32.35 ± 0.51	32.29 ± 0.57	30.67 ± 0.59*	0.055	100/100/100/100
14	77.84 ± 1.63	81.32 ± 1.37	75.67 ± 1.21	71.34 ± 1.51**	< 0.001	98/98/99/96
21	138.86 ± 2.41	135.60 ± 1.87	135.37 ± 1.74	125.81 ± 2.11***	< 0.001	96/97/97/92
28	190.28 ± 2.50	193.78 ± 2.42	189.60 ± 2.17	179.64 ± 3.06**	< 0.001	94/97/96/91
35	237.65 ± 2.76	241.24 ± 2.68	242.01 ± 2.37	226.70 ± 3.82*	< 0.001	93/97/96/91

Body weight increased progressively in all groups throughout the trial. At the start of the experiment, mean body weight was 11.60 g in the control group and 11.56, 11.59, and 11.79 g in experimental groups 1, 2, and 3, respectively. Thus, the groups had similar mean initial body weights.

At 7 days of age, mean body weight was 32.72 g in the control group, compared with 32.35 and 32.29 g in experimental groups 1 and 2, respectively. The lowest value occurred in experimental group 3 (30.67 g), which was 6.3% below the control ($p < 0.05$ according to Student's t-test). However, one-way ANOVA did not detect a statistically significant overall difference among the groups ($p = 0.055$).

Differences in body weight became more pronounced from day 14 onward. Mean body weights were 77.84 g in the control group and 81.32 and 75.67 g in experimental groups 1 and 2, respectively. The lowest value was recorded in experimental group 3 (71.34 g), 8.35% below the control ($p < 0.01$). Overall differences among groups were statistically significant by one-way ANOVA ($p < 0.001$).

The same pattern persisted on day 21. Mean body weights were 138.86 g in the control group, 135.60 g in experimental group 1, and 135.37 g in experimental group 2. Experimental group 3 again had the lowest value (125.81 g), which was 9.40% below that of the control group ($p < 0.001$). The overall treatment effect was statistically significant according to one-way ANOVA ($p < 0.001$).

At 28 days of age, mean body weight was 190.28 g in the control group, 193.78 g in experimental group 1, and 189.60 g in experimental group 2. The lowest body weight was observed in experimental group 3 (179.64 g), 5.59% below the control ($p < 0.01$). One-way ANOVA indicated a significant overall difference among groups ($p < 0.001$).

At the end of the experiment (35 days of age), mean body weight was 237.65 g in the control group. Corresponding values in experimental groups 1 and 2 were 241.24 and 242.01 g, exceeding the control by 1.51 and 1.83%, respectively. The lowest final weight was recorded in experimental group 3 (226.70 g), representing a 4.61% reduction relative to the control ($p < 0.05$). One-way ANOVA indicated statistically significant overall differences among the groups ($p < 0.001$).

Analysis of body-weight development throughout the trial showed that dietary HFM inclusion at 3 or 5% was not associated with lower final live body weight compared with the control diet. By contrast, birds receiving 7% HFM had lower live body weight than the control birds, with this difference becoming evident from day 14 onward.

Recorded survival rates during the experimental period were 93% in the control group and 97, 95, and 91% in experimental groups 1, 2, and 3, respectively.

Absolute body-weight gain varied with bird age and the duration of the respective rearing interval (Table 4).

Table 4

Absolute body-weight gain, g (M ± m)

Age, days	Treatment				ANOVA, p
	Control	T1	T2	T3	
1–7	21.11 ± 0.30	20.79 ± 0.71	20.70 ± 0.43	18.88 ± 0.53	0.1135
8–14	44.99 ± 5.92	48.90 ± 3.67	43.35 ± 2.48	40.51 ± 3.96	0.6001
15–21	60.89 ± 0.18	54.36 ± 3.68	59.67 ± 1.32	53.87 ± 4.98	0.3915
22–28	51.72 ± 6.76	58.24 ± 1.70	54.40 ± 4.32	52.76 ± 9.81	0.8913
29–35	47.38 ± 0.11	47.37 ± 2.79	52.35 ± 1.58	46.27 ± 7.99	0.7613
1–35	226.10 ± 0.84	229.66 ± 0.36	230.47 ± 1.15	212.30 ± 26.20	0.7528

During the first week, absolute body-weight gain in the control group was 21.11 g. Corresponding values were 20.79 and 20.70 g in experimental groups 1 and 2, respectively, and 18.88 g in experimental group 3. One-way ANOVA showed no statistically significant differences among groups ($p = 0.1135$).

During days 8–14, experimental group 1 exhibited the highest absolute gain (48.90 g), compared with 44.99 g in the control group and 43.35 and 40.51 g in experimental groups 2 and 3, respectively. The differences among groups were not statistically significant by one-way ANOVA ($p = 0.6001$).

During days 15–21, absolute body-weight gain was 60.89 g in the control group, 54.36 g in experimental group 1, 59.67 g in experimental group 2, and 53.87 g in experimental group 3. No statistically significant between-group differences were detected by one-way ANOVA ($p = 0.3915$).

For days 22–28, the highest absolute gain was recorded in experimental group 1 (58.24 g). The corresponding values were 51.72 g in the control group and 54.40 and 52.76 g in experimental groups 2 and 3, respectively. One-way ANOVA found no statistically significant differences among groups ($p = 0.8913$).

During days 29–35, absolute gain was 47.38 g in the control group and 47.37, 52.35, and 46.27 g in experimental groups 1, 2, and 3, respectively. Differences were not statistically significant ($p = 0.7613$).

Across the full trial, birds fed diets containing 3 or 5% HFM had absolute body-weight gains comparable to those of the control group. Birds receiving 7% HFM tended to show lower absolute gain than control birds, although the between-group differences were not statistically significant.

Changes in average daily gain generally followed the pattern observed for absolute gain (Table 5).

During days 1–7, average daily gain was 3.52 g/day in the control group, 3.46 and 3.45 g/day in experimental groups 1 and 2, respectively, and 3.15 g/day in experimental group 3. There were no statistically significant differences among groups ($p = 0.1135$).

Table 5

Average daily body-weight gain, g/day (M ± m)

Age, days	Treatment				ANOVA, p
	Control	T1	T2	T3	
1–7	3.52 ± 0.05	3.46 ± 0.12	3.45 ± 0.07	3.15 ± 0.09	0.1135
8–14	6.43 ± 0.85	6.99 ± 0.52	6.19 ± 0.35	5.79 ± 0.57	0.6001
15–21	8.70 ± 0.03	7.77 ± 0.53	8.52 ± 0.19	7.70 ± 0.71	0.3915
22–28	7.39 ± 0.97	8.32 ± 0.24	7.77 ± 0.62	7.54 ± 1.40	0.8913
29–35	6.77 ± 0.02	6.77 ± 0.40	7.48 ± 0.23	6.61 ± 1.14	0.7613
1–35	6.65 ± 0.02	6.75 ± 0.01	6.78 ± 0.03	6.24 ± 0.77	0.7528

For days 8–14, experimental group 1 had the highest average daily gain (6.99 g/day), compared with 6.43 g/day in the control group and 6.19 and 5.79 g/day in experimental groups 2 and 3, respectively. No statistically significant differences were detected (p = 0.6001).

During days 15–21, average daily gain was 8.70 g/day in the control group, 7.77 g/day in experimental group 1, 8.52 g/day in experimental group 2, and 7.70 g/day in experimental group 3. Differences among groups were not statistically significant (p = 0.3915).

Average daily gain values became somewhat more similar across groups during subsequent periods of the trial.

During days 22–28, the highest average daily gain occurred in experimental group 1 (8.32 g/day). Corresponding values were 7.39 g/day in the control group and 7.77 and 7.54 g/day in experimental groups 2 and 3, respectively. The overall difference was not statistically significant (p = 0.8913).

During days 29–35, average daily gain was 6.77 g/day in both the control group and experimental group 1, 7.48 g/day in experimental group 2, and 6.61 g/day in experimental group 3. Differences among groups were not statistically significant (p = 0.7613).

Relative body-weight gain generally decreased with increasing age across all experimental groups (Table 6).

Table 6

Relative body-weight gain, % (M ± m)

Age, days	Treatment				ANOVA, p
	Control	T1	T2	T3	
1–7	95.28 ± 0.11	94.66 ± 2.48	94.36 ± 0.84	88.94 ± 2.40	0.1774
8–14	81.14 ± 5.74	85.99 ± 4.49	80.28 ± 2.04	79.38 ± 5.14	0.7512
15–21	56.50 ± 3.44	50.18 ± 3.99	56.63 ± 2.48	54.80 ± 1.63	0.4810
22–28	31.53 ± 4.65	35.35 ± 0.73	33.46 ± 2.55	34.54 ± 3.38	0.8431
29–35	22.14 ± 0.02	21.78 ± 1.37	24.26 ± 0.95	22.87 ± 1.42	0.4781
1–35	181.38 ± 0.26	181.71 ± 0.23	181.73 ± 0.15	179.80 ± 1.88	0.5074

During days 1–7, relative body-weight gain was 95.28% in the control group and 94.66, 94.36, and 88.94% in experimental groups 1, 2, and 3, respectively. No statistically significant differences were observed (p = 0.1774).

During days 8–14, the highest relative gain occurred in experimental group 1 (85.99%), compared with 81.14% in the control group and 80.28 and 79.38% in experimental groups 2 and 3, respectively. Differences were not statistically significant ($p = 0.7512$).

For days 15–21, relative gain was 56.50% in the control group, 50.18% in experimental group 1, 56.63% in experimental group 2, and 54.80% in experimental group 3. Differences among groups were not statistically significant ($p = 0.4810$).

During days 22–28, the highest relative body-weight gain was observed in experimental group 1 (35.35%). Corresponding values were 31.53% in the control group and 33.46 and 34.54% in experimental groups 2 and 3, respectively. No statistically significant differences were detected ($p = 0.8431$).

During days 29–35, relative gain was 22.14% in the control group, 21.78% in experimental group 1, 24.26% in experimental group 2, and 22.87% in experimental group 3. Differences were not statistically significant ($p = 0.4781$).

The relative body-weight gains of quail fed 3 or 5% HFM were similar to those of control birds. At 7% HFM, relative gains tended to be lower than in the control group, but no statistically significant differences were detected.

Feed intake increased with age, as shown in Table 7.

Table 7

Average daily feed intake, g/bird/day (M ± m)

Age, days	Treatment			
	Control	T1	T2	T3
1–7	5.92 ± 0.20	5.96 ± 0.07	5.91 ± 0.14	5.70 ± 0.04
8–14	13.91 ± 0.91	14.19 ± 0.27	14.27 ± 0.09	14.14 ± 0.65
15–21	21.25 ± 0.99	20.71 ± 0.52	21.71 ± 0.16	22.18 ± 1.45
22–28	25.81 ± 0.47	25.86 ± 1.00	25.81 ± 2.00	26.94 ± 1.34
29–35	31.00 ± 3.13	31.41 ± 2.72	32.15 ± 1.73	34.80 ± 1.61
1–35	19.54 ± 1.17	19.68 ± 0.63	19.99 ± 0.12	20.49 ± 0.56

During days 1–7, average daily feed intake was 5.92 g/bird in the control group and 5.96, 5.91, and 5.70 g/bird in experimental groups 1, 2, and 3, respectively.

During days 8–14, average daily feed intake increased in all groups to 13.91 g/bird in the control group and 14.19, 14.27, and 14.14 g/bird in experimental groups 1, 2, and 3, respectively.

During days 15–21, mean daily feed intake was 21.25 g/bird in the control group and 20.71, 21.71, and 22.18 g/bird in experimental groups 1, 2, and 3, respectively.

In the fourth rearing interval (days 22–28), mean daily feed intake was 25.81 g/bird in the control group and 25.86, 25.81, and 26.94 g/bird in experimental groups 1, 2, and 3, respectively.

During the final rearing interval (days 29–35), feed intake reached its highest values: 31.00 g/bird/day in the control group and 31.41, 32.15, and 34.80 g/bird/day in experimental groups 1, 2, and 3, respectively.

Thus, during the final rearing interval, the highest average daily feed intake was recorded in experimental group 3, whose diet contained 7% HFM.

Cumulative feed intake increased across successive age intervals, as presented in Table 8.

Table 8

Feed intake per rearing interval, g/bird (M ± m)

Age, days	Treatment			
	Control	T1	T2	T3
1–7	41.44 ± 1.39	41.69 ± 0.45	41.40 ± 1.01	39.93 ± 0.25
8–14	97.40 ± 6.40	99.33 ± 1.86	99.92 ± 0.63	99.00 ± 4.52
15–21	148.72 ± 6.96	144.97 ± 3.64	151.97 ± 1.14	155.28 ± 10.14
22–28	180.68 ± 3.28	181.01 ± 6.97	180.66 ± 14.02	188.57 ± 9.37
29–35	216.97 ± 21.93	219.85 ± 19.05	225.03 ± 12.08	243.58 ± 11.30
1–35	683.88 ± 40.81	688.84 ± 22.19	699.49 ± 4.09	717.02 ± 19.49

Over days 1–7, feed intake was 41.44 g/bird in the control group and 41.69, 41.40, and 39.93 g/bird in experimental groups 1, 2, and 3, respectively.

In the second week (days 8–14), feed intake increased in all groups, reaching 97.40 g/bird in the control group and 99.33, 99.92, and 99.00 g/bird in experimental groups 1, 2, and 3, respectively. During days 15–21, feed intake was 148.72 g/bird in the control group and 144.97, 151.97, and 155.28 g/bird in experimental groups 1, 2, and 3, respectively.

During the fourth week (days 22–28), feed intake was 180.68 g/bird in the control group and 181.01, 180.66, and 188.57 g/bird in experimental groups 1, 2, and 3, respectively.

During the last week (days 29–35), feed intake was highest, reaching 216.97 g/bird in the control group and 219.85, 225.03, and 243.58 g/bird in experimental groups 1, 2, and 3, respectively.

Overall, feed intake per weekly rearing interval increased progressively with age. A tendency toward greater cumulative feed intake was also observed as dietary HFM inclusion increased to 7%.

The feed conversion ratio (FCR) expresses feed consumed relative to body-weight gain. Calculated FCR values are reported in Table 9.

Table 9

Calculated feed conversion ratio, kg feed/kg body-weight gain (M ± m)

Age, days	Treatment			
	Control	T1	T2	T3
1–7	1.962 ± 0.039	2.008 ± 0.091	2.000 ± 0.007	2.117 ± 0.072
8–14	2.184 ± 0.145	2.040 ± 0.115	2.311 ± 0.117	2.478 ± 0.354
15–21	2.443 ± 0.122	2.684 ± 0.249	2.547 ± 0.037	2.925 ± 0.458
22–28	3.546 ± 0.400	3.107 ± 0.029	3.322 ± 0.006	3.736 ± 0.872
29–35	4.581 ± 0.473	4.634 ± 0.130	4.296 ± 0.101	5.470 ± 1.189
1–35	3.025 ± 0.192	2.999 ± 0.092	3.035 ± 0.033	3.441 ± 0.516

Calculated FCR varied with bird age and dietary HFM inclusion level. During days 1–7, FCR was 1.962 kg/kg in the control group and 2.008, 2.000, and 2.117 kg/kg in experimental groups 1, 2, and 3, respectively.

FCR increased during subsequent age intervals as the rate of body-weight gain declined with age.

During days 8–14, FCR was 2.184 kg/kg in the control group and 2.040, 2.311, and 2.478 kg/kg in experimental groups 1, 2, and 3, respectively.

During days 15–21, FCR was 2.443 kg/kg in the control group and 2.684, 2.547, and 2.925 kg/kg in experimental groups 1, 2, and 3, respectively.

During days 22–28, FCR was 3.546 kg/kg in the control group and 3.107, 3.322, and 3.736 kg/kg in experimental groups 1, 2, and 3, respectively.

The highest FCR values were observed during days 29–35: 4.581 kg/kg in the control group and 4.634, 4.296, and 5.470 kg/kg in experimental groups 1, 2, and 3, respectively.

Calculated FCR increased with age in all experimental groups. Dietary HFM inclusion at 3 or 5% was not associated with an appreciable deterioration in feed conversion. At 7% HFM, a tendency toward higher feed use per unit of body-weight gain was observed.

Discussion. Analysis of body weight development showed that including 3 or 5% HFM in complete feeds did not reduce final body weight compared with the control diet. A similar pattern was observed in a study of meat-type quail in which fig seed meal was included as an alternative protein source. Inclusion at up to 5% did not impair key growth traits, whereas 10% reduced weight gain and worsened feed conversion (Irmak et al., 2025).

By contrast, quail fed 7% HFM in the present study had lower mean body weight than control birds, particularly from day 14 onward. Brazilian researchers have likewise demonstrated that dietary nutrient density can affect selected growth and performance traits in meat-type quail, although their experiment was conducted under heat-stress conditions (dos Anjos Lima et al., 2024).

In our study, inclusion of 3 or 5% HFM did not result in reduced absolute body-weight gain compared with the control group. At 7% HFM, a numerical reduction in absolute gain was observed. A related dependence of performance on the inclusion level and processing method of feather meal was reported by researchers in Taiwan, who found that the level of enzymatically treated feather meal and the application of additional two-stage fermentation influenced broiler growth performance (Yeh et al., 2023).

The pattern for average daily gain was similar. Values in the groups receiving either 3 or 5% HFM were close to those in the control group, whereas the 7% HFM group showed a numerical tendency toward lower average daily gain.

Relative body-weight gain was likewise comparable between the control group and birds fed 3 or 5% HFM. Birds receiving 7% HFM tended to have lower relative gain, but between-group differences were not statistically significant. Previous work in meat-type quail under heat stress also found that dietary protein concentration and amino acid composition were related to growth and feed-utilization responses (dos Anjos Lima et al., 2024).

Feed intake increased with bird age in all groups, consistent with increasing live body weight and nutrient requirements. Similar age-related changes were reported in growing Japanese quail in Egypt: feed intake during weeks 3–6 was higher than during weeks 1–3 (Mohamed et al., 2024).

Related findings were reported by Indonesian researchers who investigated hydrolyzed feather meal combined with keratinolytic Bacillus spp. Birds fed feather meal supplemented with the bacterial preparation showed greater body-weight gain and a lower FCR than birds given feather meal without that supplement (Prasetyo et al., 2023).

Our results are partly consistent with the performance of experimental group 3: increasing dietary HFM inclusion to 7% increased feed intake without a corresponding improvement in body-weight gain, resulting in a higher calculated FCR. These

observations are also consistent with a broiler study in which inclusion of 15% enzymatically treated feather meal was associated with a statistically significant reduction in body-weight gain during days 1–35 (Yeh et al., 2023).

Conclusions.

1. Feeding growing Pharaoh quail diets containing 3 or 5% HFM over the 35-day experimental period did not reduce final body weight compared with the control diet. At 35 days, mean body weight was 237.65 g in the control group and 241.24, 242.01, and 226.70 g in groups receiving 3, 5, and 7% HFM, respectively. At the 7% inclusion level, final body weight was lower than in the control group ($p < 0.05$). Absolute gain over the experimental period was 226.10 g in the control group and 229.66, 230.47, and 212.30 g in the 3, 5, and 7% HFM groups, respectively. Corresponding average daily gains were 6.65, 6.75, 6.78, and 6.24 g/day, while relative gains were 181.38, 181.71, 181.73, and 179.80%. No statistically significant differences among groups were found for absolute, average daily, or relative body-weight gain.

2. During the entire trial (days 1–35), calculated cumulative feed intake was 683.88 g/bird in the control group and 688.84, 699.49, and 717.02 g/bird in groups receiving 3, 5, and 7% HFM, respectively. Calculated FCR was 3.025, 2.999, 3.035, and 3.441 kg feed/kg gain, respectively. The lowest FCR was observed in the 3% HFM group, whereas the 7% group had the highest mean cumulative feed intake and calculated FCR.

3. Considering body weight, absolute, average daily, and relative gain, feed intake, and calculated feed conversion together, dietary inclusion of 3 or 5% HFM was not associated with deterioration of the main performance indices of growing Pharaoh quail relative to the control diet. At 7% HFM, final live body weight was lower, mean gains were numerically lower, and feed intake and calculated FCR were higher than in the control group. These results support further investigation of HFM inclusion at 3–5% in diets for growing meat-type quail.

Acknowledgments. The authors thank Professor Mykhailo Sychov, Head of the Department of Animal Nutrition and Feed Technology, and Ruslan Kononenko, Dean of the Faculty of Livestock Raising and Water Bioresources at the National University of Life and Environmental Sciences of Ukraine, for their support in organizing the study and providing access to the faculty's research infrastructure.

References

Adler, S. A., Slizyte, R., Honkapää, K., & Løes, A. K. (2018). In vitro pepsin digestibility and amino acid composition in soluble and residual fractions of hydrolyzed chicken feathers. *Poultry Science, 97*(9), 3343–3357. https://doi.org/10.3382/ps/pey175

Ashour, E. A., Alabdali, A. Y. M., Aldhalmi, A. K., Taha, A. E., Swelum, A. A., & Abd El-Hack, M. E. (2022). Impacts of varying dietary energy and crude protein levels on growth, carcase traits and digestibility coefficients of growing Japanese quail (Coturnix Coturnix Japonica) during the summer season. *Italian Journal of Animal Science, 21*(1), 1402–1410. https://doi.org/10.1080/1828051X.2022.2118625

Bawa, G. S., Lombin, L. H., Shamaki, D., Karsin, P., & Musa, U. (2012). Protein requirement of Japanese quail (Coturnix corturnix japonica) chicks in Nigeria. *Nigerian Journal of Animal Production, 39*(1), 153–160. https://doi.org/10.51791/njap.v39i1.2270

Cullere, M., Singh, Y., Pellattiero, E., Berzuini, S., Galasso, I., Clemente, C., & Dalle Zotte, A. (2023). Effect of the dietary inclusion of Camelina sativa cake into quail

diet on live performance, carcass traits, and meat quality. *Poultry Science, 102*(6), 102650. https://doi.org/10.1016/j.psj.2023.102650

dos Anjos Lima, L. A., Maia, M. I. L., Morais, L. K. D. C., Veríssimo, T. N. S., dos Santos, J. D. C., da Silva, A. L., dos Santos, N. R., Caetano Gonçalves dos Santos, S. G., Moura, J. H. A., Souza, R. G., da Silva, J. H. V., Costa, F. G. P., Carvalho, L. R. R. A., & Saraiva, E. P. (2024). How does the adoption of nutritional plans influence the performance of meat quail during the growth phase in hot environments? *Frontiers in Veterinary Science, 11*, 1469516. https://doi.org/10.3389/fvets.2024.1469516

He, Z., Sun, R., Tang, Z., Bu, T., Wu, Q., Li, C., & Chen, H. (2018). Biodegradation of feather waste keratin by the keratin-degrading strain Bacillus subtilis 8. *Journal of Microbiology and Biotechnology, 28*(2), 314–322. https://doi.org/10.4014/jmb.1708.08077

Hlatshwayo, I. S., Mnisi, C. M., & Egbu, C. F. (2023). Effect of dietary olive (Olea europea) pomace on productive performance, and physiological and meat quality parameters in Jumbo quail. *Scientific Reports, 13*, 6162. https://doi.org/10.1038/s41598-023-33495-3

Irmak, M., Denli, M., Şahin, N., Tufan, T., Irak, K., Kayri, V., Çelik, Ö. Y., Özcan, C., & Ipçak, H. H. (2025). Use of fig seed meal as a new alternative feed source in quails: Effect on growth performance, carcass characteristics, antioxidant capacity and serum biochemistry. *Veterinary Medicine and Science, 11*(5), e70533. https://doi.org/10.1002/vms3.70533

Kudlová, L., Novotný, J., Čumplík, L., Dvořáčková, N., Řiháček, M., Zálešáková, D., Horáková, L., Pavlata, L., & Šťastník, O. (2026). The effect of two different defatted insect meals in Japanese quail diets on the performance, ileal morphometry, apparent ileal digestibility and blood parameters. *Poultry Science, 105*(5), 106654. https://doi.org/10.1016/j.psj.2026.106654

Liu, J., Loh, T. C., Azizi, M. N., Chung, E. L. T., Foo, H. L., Fatihah, N. H., & Haziq, F. (2026). Nutritional profile and digestibility of feather meal and mixed meal in broiler chickens. *Poultry, 5*(3), 35. https://doi.org/10.3390/poultry5030035

Marareni, M., Egbu, C. F., Lebopa, C. K., & Mnisi, C. M. (2024). Responses of Jumbo quail to a diet containing corticated marama bean (Tylosema esculentum) meal pre-treated with fibrolytic multi-enzymes. *Life, 14*(10), 1242. https://doi.org/10.3390/life14101242

Marareni, M., & Mnisi, C. M. (2020). Growth performance, serum biochemistry and meat quality traits of Jumbo quails fed with mopane worm (Imbrasia belina) meal-containing diets. *Veterinary and Animal Science, 10*, 100141. https://doi.org/10.1016/j.vas.2020.100141

Mohamed, L. A., Dosoky, W. M., Kamal, M., Alshehry, G., Algarni, E. A., Aldekhail, N. M., Mohamed, H. S., Abd El-Hack, M. E., & Farag, S. A. (2024). Growth performance, carcass traits and meat physical characteristics of growing Japanese quail fed ginger powder and frankincense oil as feed additives. *Poultry Science, 103*(7), 103771. https://doi.org/10.1016/j.psj.2024.103771

Prasetyo, E. N., Hidayat, M. T., & Koentjoro, M. P. (2023). Effect of feed supplement modifications using keratinolytic bacteria on growth performance and meat chemical composition of domesticated quail. *The Indian Journal of Animal Sciences, 93*(10), 1015–1020. https://doi.org/10.56093/ijans.v93i10.135704

Salehizadeh, M., Tajabadi Ebrahimi, M., Mousavi, S. N., Sepahi, A. A., & Orooji, R. (2025). Transforming feather meal into a high-performance feed for broilers.

Veterinary Medicine and Science, 11(1), e70199. https://doi.org/10.1002/vms3.70199

Sinhorini, M. R., Balbinot-Alfaro, E., Aguiar, W., Ferreira, E. S., Sbardelotto, P. R. R., & Alfaro, A. T. (2024). Blood addition and processing conditions: Improving protein content and digestibility value of hydrolyzed feather meal. *Revista Brasileira de Zootecnia, 53*, e20220108. https://doi.org/10.37496/rbz5320220108

Solcova, O., Knapek, J., Wimmerova, L., Vavrova, K., Kralik, T., Rouskova, M., Sabata, S., & Hanika, J. (2021). Environmental aspects and economic evaluation of new green hydrolysis method for waste feather processing. *Clean Technologies and Environmental Policy, 23*(6), 1863–1872. https://doi.org/10.1007/s10098-021-02072-5

Verma, P. (Ed.). (2023). *Enzymes in the valorization of waste: Enzymatic hydrolysis of waste for development of value-added products*. CRC Press. https://doi.org/10.1201/9781003187684

Xu, K.-L., Gong, G.-X., Liu, M., Yang, L., Xu, Z.-J., Gao, S., Xiao, M.-Y., Ren, T., Zhao, B.-J., Khalil, M. M., Zhao, L., & Sun, L.-H. (2022). Keratinase improves the growth performance, meat quality and redox status of broiler chickens fed a diet containing feather meal. *Poultry Science, 101*(6), 101913. https://doi.org/10.1016/j.psj.2022.101913

Yeh, R.-H., Hsieh, C.-W., & Chen, K.-L. (2023). Two-stage fermented feather meal enhances growth performance and amino acid digestibility in broilers. *Fermentation, 9*(2), 128. https://doi.org/10.3390/fermentation9020128