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Fatty acid composition of quail meat and eggs following dietary supplementation with a humic-based feed additive

M. Stankov

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Article info

Correspondence Author
M. Stankov
E-mail:
putini.old@gmail.com

Odesa State Agrarian University,
Panteleimonivs'ka Str., 13,
Odesa, 65012, Ukraine

Humic acids are among the most effective natural chelating agents due to the wide variety of their functional groups. Compared with other inorganic adsorbents, particularly zeolites, their adsorption capacity is several times higher. In addition, their ability to bind heavy metals, such as cadmium and lead, increases with the atomic mass of the element. Humic acids also exhibit a high affinity for heterogeneous compounds, enabling them to eliminate or reduce the toxic effects of endogenous and exogenous toxins. The present study evaluated the effect of dietary supplementation with the humic substance-based feed additive Humivet and the veterinary preparation Chiktonikvet on the fatty acid composition of quail meat and eggs. Ninety-day-old Phoenix Golden quails were randomly assigned to three groups of 20 birds each. The first group served as the control and received no supplementation. Birds in the second group received 4 mL of Humivet per 1 L of drinking water, whereas birds in the third group received 2 mL of the oral veterinary preparation Chiktonikvet (batch V-022) per 1 L of drinking water. Both preparations were administered for 21 consecutive days. Dietary supplementation with Humivet and Chiktonikvet reduced the concentrations of several saturated fatty acids in quail meat, including arachidic, behenic, myristic, and heptadecanoic acids, compared with the control group. Additionally, the monounsaturated myristoleic acid was decreased. Supplementation with Chiktonikvet increased the contents of linoleic (20.7±1.022, $p<0.05$), α-linolenic (0.42±0.021), and γ-linolenic (0.86±0.042) acids compared with the control. The concentrations of 18 fatty acids were also determined in quail eggs following dietary supplementation with Humivet and Chiktonikvet. Eggs from birds receiving Humivet contained the highest levels of linoleic acid ($p<0.05$), oleic acid (49.0±2.438 %, $p<0.05$), and docosahexaenoic acid (0.30±0.014 %). The obtained results demonstrate that supplementation of quail diets with the humic substance-based feed additive Humivet at a dose of 4 mL/L of drinking water significantly ($p<0.05$) decreased the proportion of saturated fatty acids and increased the proportion of unsaturated fatty acids in meat. In eggs, Humivet supplementation significantly ($p<0.05$) increased the proportions of linoleic and oleic acids.

Keywords: Humivet, Chiktonikvet, saturated fatty acids, unsaturated fatty acids, quails.

Жирнокислотний склад м'яса та яєць перепелів за застосування кормової добавки на основі гумінових речовин

М. М. Станков

Одеський державний аграрний університет,
м. Одеса, Україна

Гумінові кислоти, завдяки широкому спектру функціональних груп, належать до високоефективних природних хелатуючих агентів. Порівняно з іншими неорганічними адсорбентами, зокрема цеолітами, їхня адсорбційна здатність є у кілька разів вищою. Крім того, здатність цих сполук зв'язувати важкі метали (як-от кадмій і свинець) посилюється відповідно до зростання атомної маси елементів. Гумінові кислоти також характеризуються високими адсорбційними властивостями щодо гетерогенних сполук, що дозволяє мінімізувати або повністю усувати токсичний вплив ендогенних та екзогенних токсинів. У цьому дослідженні оцінювали вплив збагачення раціону кормовою добавкою на основі речовин гумінової природи «Гумівет» та препаратом «Чиктоніквет» на жирнокислотний склад м'яса та яєць перепелів. До експерименту було залучено 90-добових перепелів породи «Фенікс золотолистий». Птицю поділили на три групи (по 20 голів у кожній): перша група (контрольна) не отримувала дослідних добавок; птиці другої групи з питною водою задавали добавку «Гумівет» у дозі 4 мл/л; третьої групи – 2 мл ветеринарного препарату для перорального застосування «Чиктоніквет» (серія V-022) на 1 літр води. Препарати застосовували впродовж 21 доби. Установлено, що збагачення раціону перепелів добавками «Гумівет» та «Чиктоніквет» сприяло зниженню вмісту насичених жирних кислот у м'ясі (зокрема арахінової, бегенової, міристинової та гептадеканової) порівняно з контролем, а також призвело до зменшення кількості мононенасиченої міристолеїнової кислоти. За включення до раціону препарату «Чиктоніквет» зафіксовано збільшення вмісту лінолевої (20,7±1,022 %, $p<0,05$), α-ліноленової (0,42±0,021 %) та γ-ліноленової (0,86±0,042 %) кислот порівняно з контрольною групою. Також було визначено вміст 18 жирних кислот у яйцях перепелів. Установлено, що у групі, яка отримувала добавку «Гумівет», відзначено найвищий у яйцях вміст лінолевої жирної кислоти ($p<0,05$), олеїнової (49,0±2,438 %, $p<0,05$) та докозагексаєнової (0,30±0,014 %) кислот. Отримані результати свідчать, що додавання до раціону перепелів кормової добавки гумінової природи «Гумівет» у дозі 4 мл на 1 літр питної води достовірно ($p<0,05$) зменшувало вміст у м'ясі насичених жирних кислот та збільшувало вміст ненасичених жирних кислот. Жирнокислотний склад яєць за збагачення раціону добавкою «Гумівет» характеризувався достовірно ($p<0,05$) вищим відсотком вмісту лінолевої та олеїнової кислот.

Ключові слова: Гумівет, Чиктоніквет, насичені жирні кислоти, ненасичені жирні кислоти, перепілки.

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Introduction

The chemical structure of humic acids (HAs) has not yet been fully elucidated. They contain a wide range of functional groups, including carboxyl, phenolic, carbonyl, hydroxyl, amino, amide, and aliphatic groups. Owing to their structural diversity, humic acids have numerous agricultural applications. They facilitate the transport of micronutrients from soil to plants, improve soil water retention, and stimulate the growth of soil microorganisms. Their ability to form chelate complexes with trace elements and enhance nutrient uptake by plants has also been utilized in crop production and plant breeding [25].

Due to the diversity of their functional groups, humic acids are among the most effective naturally occurring chelating agents. Compared with inorganic adsorbents such as zeolites, their adsorption capacity is several times greater. Their ability to bind heavy metals, including cadmium and lead, also increases with increasing atomic mass [9]. In addition, humic acids effectively adsorb heterogeneous compounds, thereby reducing or eliminating the toxic effects of endogenous and exogenous toxins [6, 24].

The use of humic substances in poultry nutrition has produced promising results. Dietary supplementation with humic substances has shown improvements in feed conversion efficiency and an increase in the final body weight of broiler chickens, although statistically significant differences have not always been observed. Nevertheless, an average increase of 70–90 g in the final body weight of a single bird represents a substantial economic advantage under commercial production conditions, particularly in large flocks [15]. Carcass yield and the yield of individual carcass cuts are important indicators of poultry production efficiency. Positive effects of humic acids on carcass yield have been reported at dietary inclusion levels ranging from 0.25 % to 1.0 %, with the highest carcass yield achieved at a supplementation level of 1 %. Broiler chickens receiving diets containing 1% humic acids also showed significantly higher breast and thigh muscle yields than birds in the control group [12].

During the last decade, humic substances have been extensively investigated as feed additives. Most studies have focused on growth performance, their potential as alternatives to antibiotic growth promoters, improvements in broiler health, and the reduction of antibiotic use [18, 19]. In contrast, considerably less information is available regarding their effects on meat quality [8, 20]. Japanese quails (*Coturnix japonica*) possess several production advantages, including small body size, rapid growth, high productivity, and relatively low production costs, making them suitable for both intensive commercial production and small-scale farming systems [5].

Currently, only limited information is available regarding the effects of humic acids used as feed additives on the fatty acid composition of quail meat and eggs. Therefore, this study was undertaken to investigate the influence of dietary supplementation with humic substances on the fatty acid composition of quail meat and eggs.

The aim of the study

The aim of this study was to determine the fatty acid composition of quail meat and eggs following dietary supplementation with a feed additive based on humic substances.

Materials and methods

The oral feed additive Humivet was prepared using brown coal from the Cherkasy deposit (Ukraine) as the raw material. A sodium humate solution containing 4 % humic acids was obtained [1]. The resulting feed additive had a density of 1.06 g/cm³ and a pH of 7.2.

The experiment involved 90-day-old Phoenix Golden quails. The birds were randomly divided into three groups of 20 birds each. The first group served as the control and received no feed additive. Birds in the second group received 4 mL of Humivet per 1 L of drinking water. Birds in the third group received 2 mL of the oral veterinary preparation Chiktonikvet (batch V-022) per 1 L of drinking water. Both preparations were administered for 21 consecutive days.

At the end of the supplementation period, the birds were humanely slaughtered in accordance with the Requirements for Ensuring Animal Welfare During Slaughter and Killing (Order of the Ministry of Agrarian Policy and Food of Ukraine No. 628 dated August 29, 2022) [4], were humanely slaughtered. Five carcasses from each experimental group were collected and transported to the laboratory. In addition, five eggs were collected from each group. All samples were delivered to the laboratory within 24 h under appropriate transportation conditions.

The analyses were carried out at the Chemical and Toxicological Department of the State Scientific Research Institute for Laboratory Diagnostics and Veterinary Sanitary Expertise. The fatty acid composition of meat and eggs was determined according to DSTU ISO 5509:2002 [2] (preparation of fatty acid methyl esters) and DSTU ISO 5508:2001 [3] (gas chromatographic analysis of fatty acid methyl esters in animal and vegetable fats and oils).

Statistical analysis was performed using OpenEpi software (Dean AG, version 3.01). Differences between the corresponding means were considered statistically significant at ($p<0.05$).

Results and discussion

Since poultry have only a limited capacity to elongate and desaturate long-chain fatty acids, the fatty acid profile of muscle tissue largely reflects the composition of the diet. The fatty acid composition of quail meat from the experimental and control groups is presented in ***Table 1*.**

Dietary supplementation with Humivet and Chiktonikvet reduced the concentrations of several saturated fatty acids in quail meat, including arachidic, behenic, myristic, and heptadecanoic acids, compared with the control group.

Table 1
Fatty acid composition of quail meat following dietary supplementation with Humivet and Chiktonikvet (%)

Fatty acid	Group I (Control)	Group II (Humivet)	Group III (Chiktonikvet)
Arachidic	0.10±0.005	0.07±0.0035	0.08±0.004
Behenic	0.12±0.006	0.02±0.001	0.04±0.002
Lauric	0.02±0.001	0.04±0.002	0.04±0.002
Linoleic	18.4±0.907	19.9±0.994*	20.7±1.022*
Myristic	0.74±0.038	0.72±0.038	0.69±0.036
Myristoleic	0.24±0.012	0.13±0.006	0.19±0.010
Oleic	44.08±2.195	45.3±2.256*	44.08±2.195
Palmitic	19.5±0.990	20.22±1.010	19.76±1.005
Palmitoleic	10.2±0.513	6.73±0.322	8.36±0.422
Stearic	3.44±0.172	5.12±0.256	3.77±0.189
Pentadecanoic	0.10±0.005	0.09±0.005	0.18±0.009
Heptadecanoic	0.37±0.019	0.12±0.005	0.30±0.015
Heptadecenoic	0.05±0.003	0.08±0.004	0.08±0.004
α-Linolenic	0.36±0.018	0.59±0.029	0.42±0.021
γ-Linolenic	0.73±0.036	0.96±0.042*	0.86±0.042
Eicosenoic	0.16±0.002	0.16±0.009	0.18±0.009
Eicosadienoic	0.04±0.002	0.10±0.003	0.06±0.003
cis-8,11,14-Eicosatrienoic	0.20±0.010	0.41±0.009*	0.19±0.009

Note: * p<0.05 compared with the control group.

Table 2
Fatty acid content in quail eggs following dietary supplementation with Humivet and Chiktonikvet (%)

Fatty acid	Group I (Control)	Group II (Humivet)	Group III (Chiktonikvet)
Arachidic	0.18±0.009	0.17±0.008	0.22±0.011*
Behenic	0.08±0.004	0.11±0.005	0.11±0.005
Linoleic	9.26±0.457	11.7±0.58*	10.6±0.523
Myristic	0.62±0.032	0.52±0.027	0.58±0.03
Myristoleic	0.08±0.004	0.09±0.005	0.09±0.005
Oleic	48.1±2.39	49.0±2.438*	45.6±2.267
Palmitic	23.7±1.203	24.7±1.253	26.3±1.337
Palmitoleic	5.88±0.296	6.19±0.312	6.81±0.343
Stearic	7.38±0.36	7.25±0.377	7.53±0.377
Pentadecanoic	0.03±0.002	0.06±0.003	0.07±0.004
Heptadecanoic	0.14±0.007	0.19±0.008	0.22±0.011*
Heptadecenoic	0.13±0.007	0.06±0.003	0.07±0.004
α-Linolenic	0.16±0.008	0.19±0.009	0.07±0.003
γ-Linolenic	0.26±0.013	0.26±0.014	0.2±0.01
cis-8,11,14-Eicosatrienoic	1.20±0.058	1.10±0.053	1.0±0.049
Eicosapentaenoic	0.20±0.01	0.17±0.008	0.16±0.008
Heneicosanoic	0.10±0.005	0.08±0.004	0.09±0.004
Docosahexaenoic	0.13±0.015	0.30±0.014	0.22±0.01

Note: * p<0.05 compared with the control group.

More specifically, the content of arachidic acid decreased by 0.03 % in Group II and by 0.02 % in Group III relative to the control. The concentration of myristic acid decreased by 0.02 % and 0.05 %, respectively, while heptadecanoic acid decreased by 0.25 % and 0.07 %. Additionally, the monounsaturated myristoleic acid decreased by 0.12 % and 0.05 %, respectively. In contrast, stearic acid, which also belongs to the saturated fatty acids, was present at a higher concentration in the supplemented groups. Its content increased by 1.68 % ($p<0.05$) in Group II and by 0.33 % in Group III compared with the control.

Adding Humivet increased the proportion of several unsaturated fatty acids in quail meat relative to the control group. The contents of oleic acid increased by 1.22 % ($p<0.05$), γ-linolenic acid by 0.23 % ($p<0.05$), eicosadienoic acid by 0.06 %, and cis-8,11,14-eicosatrienoic acid by 0.21 % ($p<0.05$).

Birds receiving Chiktonikvet also showed higher concentrations of linoleic acid (20.7±1.022, $p<0.05$), α-linolenic acid (0.42±0.021), and γ-linolenic acid (0.86±0.042) than the control birds.

Overall, supplementation with humic substances significantly improved the fatty acid profile of quail meat by increasing the proportion of polyunsaturated fatty acids.

The concentrations of 18 fatty acids were also determined in quail eggs following dietary supplementation with Humivet and Chiktonikvet (***Table 2***).

Eggs from birds receiving Humivet contained the highest levels of linoleic acid ($p<0.05$), oleic acid (49.0±2.438 %, $p<0.05$), and docosahexaenoic acid (0.30±0.014 %).

In Group III, where birds received Chiktonikvet, the concentrations of arachidic acid (0.22±0.011 %, $p<0.05$), palmitic acid (26.3±1.337 %), stearic acid (7.53±0.377 %), and heptadecanoic acid (0.22±0.011 %, $p<0.05$) were higher than those in the control group.

Quail eggs from the control group contained higher concentrations of eicosapentaenoic (0.20±0.01 %), *cis*-8,11,14-eicosatrienoic (1.20±0.058 %), and heptadecenoic (0.13±0.007 %) acids. Thus, dietary supplementation with feed additives of different compositions affects the fatty acid profile of quail eggs.

Numerous studies have examined the effect of humic substance supplementation during the fattening period, although the results remain inconsistent [14, 26]. Quail meat is valued for its favorable fatty acid profile, with unsaturated fatty acids typically accounting for 65–70 % of total fat content. Its high content of cardioprotective oleic acid makes it a highly nutritious dietary meat option [23]. A lower proportion of saturated fatty acids in quail meat is generally regarded as an indicator of high dietary value, reflecting a greater content of health-beneficial polyunsaturated fats, an appropriate diet, and well-optimized metabolic processes [23]. Our findings showed that dietary supplementation with the feed additives reduced the percentage of saturated fatty acids in quail meat, with a more pronounced reducing effect observed for Humivet. Oleic acid naturally accounts for approximately 25–40 % of the total fatty acid content of quail eggs [22]. In our study, oleic acid content reached 49.0±2.438 % in eggs and 45.3±2.256 % ($p<0.05$) in the meat of quails receiving Humivet. An increase in stearic acid content in quail meat can be regarded as a neutral, and in some respects even a beneficial, factor [21]. Our findings showed that, with Humivet supplementation, the content of this acid in meat increased substantially.

It is well established that ω-3 fatty acids are essential for optimal human health. The three principal ω-3 fatty acids are α-linolenic, docosahexaenoic, and eicosapentaenoic acids [11]. The content of ω-3 fatty acids in eggs was highest (0.66 %) in the group of quails receiving the humic substance-based feed additive. Other studies have shown that dietary supplementation with humic-based preparations enriches eggs with polyunsaturated ω-3 fatty acids [10]. Quail eggs contain approximately 0.9 to 1.3 g of ω-6 fatty acids per 100 g (or about 0.1 to 0.15 g per egg, given an average egg weight of 10–12 g). The principal ω-6 fatty acid in quail eggs is linoleic acid, which typically accounts for 13 % to 20 % of the total fatty acid profile [16]. In our study, the average linoleic acid content in eggs was lowest in the control group (9.26±0.457 %) and highest in the second experimental group (11.7±0.58 %). Other sources report a linoleic acid content of 10.28 % in quail eggs based on the assessment of their saturated and unsaturated fatty acid profile [22]. Nutritionists use data on myristic, palmitic, and stearic acid contents to calculate the overall atherogenic index of a product, which reflects the risk of cardiovascular disease associated with frequent consumption [17]. Our findings showed that in the third group, the sum of these acids reached 34.41 %, compared with 32.47 % in the second group and 31.7 % in the control group. Chiktonikvet supplementation is unlikely to have a direct effect on increasing the content of the above-mentioned acids in eggs; rather, this regulation appears to occur through hepatic lipid synthesis [13]. Humic acids indirectly improve the fatty acid composition of poultry meat and eggs by optimizing digestive processes and modulating the gut microflora [7].

Conclusions

Dietary supplementation of quail diets with the humic substance-based feed additive Humivet, containing 4 % humic acids, at a dose of 4 mL per 1 L of drinking water, significantly ($p<0.05$) decreased the meat content of saturated fatty acids, with the exception of stearic acid, and increased the content of unsaturated fatty acids. Humivet supplementation also significantly ($p<0.05$) increased the proportions of linoleic and oleic acids in the fatty acid composition of eggs.

DECLARATIONS

Ethical Statement

The study was conducted in accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986), Directive 2010/63/EU, and the ARRIVE guidelines. Animal welfare during slaughter was strictly maintained pursuant to the national legislation, specifically complying with the Requirements for Ensuring Animal Welfare During Slaughter and Killing approved by the Ministry of Agrarian Policy and Food of Ukraine [4].

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Conflict of Interest

The author states that there is no conflict of interest.

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Declaration of AI and AI-assisted technologies

During the preparation of this manuscript, the authors used the AI assistant Claude (Anthropic) for limited language editing, improving readability, and translation assistance. The tool was strictly not used for data analysis, interpretation of experimental results, or the generation of original scientific content. Following the use of this technology, the authors thoroughly reviewed, verified, and edited the text as needed, and they take full responsibility for the accuracy and integrity of the final manuscript.

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ORCID

M. Stankov https://orcid.org/0009-0002-3817-6266