Effect of humic substances on the mineral composition of chicken meat

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Abstract

The study was conducted to determine the concentrations of mineral substances calcium (Ca), magnesium (Mg), copper (Cu), and zinc (Zn) in the thigh and breast muscle of broiler chicks after application of humic substances. Eighty-one-day-old broiler chicks were randomly divided into 4 groups of 20 animals. Group 1 (G1) was supplemented with 0.7% Humac Natur (HN), G2 with 0.7% Humac Natur Monogastric (HNM) and G3 with 0.5% HNM and control group (CG) received basal diet without any supplements. The samples of muscles were analyzed using flame atomic absorption spectrometry method (AAS). The statistically significantly higher levels of Ca and Zn (p<0.01) were found in breast and thigh muscles in G1 in comparison to the CG. An addition of the 0.7% HNM in G2 caused the significantly higher levels of the Ca (p<0.05) and Zn (p<0.01) in both types of muscles in comparison to the CG. The addition of 0.7% HNM (p<0.05) and 0.5% HNM (p<0.01) in feed significantly reduced the amount of the Cu in the breast muscle versus the addition of 0.7% HN. Significantly lower Zn contents (p<0.01) were found in the breast and thigh muscle of broilers of CG in comparison to the G1 with addition of 0.7% HN. In the group G1 was achieved a strong positive correlation in the thigh muscle between the Mg and the Zn (r=0.9660) after application of 0.7% HN. According to the results, significant positive correlation between the Zn and the Mg (r=0.8187) in the breast muscle was observed in the group G2. In conclusion, HN and HNM can be considered a good additive with a positive impact on the nutrition value of poultry meat.

Introduction

Chicken meat is relatively inexpensive because chickens can be produced faster and with higher feed efficiency than other commercial meats. Meat is a popular ingredient in our diet, people consume it mainly for its organoleptic qualities (color, taste), but also for nutritional reasons - full of protein, vitamins and minerals. Meat quality can be influenced by handling the feeding of broiler chickens as well as full of protein, vitamins and minerals. Meat quality can be influenced by handling the feeding of broiler chickens [1] as well as postmortem treatment of the carcass. Since the ban on feeding antibiotics fodder, useful applications and aspects of humic substances, including their action and methods for their production and protection of animal and poultry health.

Humic substances have shown strong affinity for binding various substances, such as heavy metals [4], minerals [5] and aflatoxins [6,7]. Feeding humic substances increased levels of some essential minerals (such as Ca, Al and Fe) in serum, liver and poultry muscles [8]. Differentiated effects showed humic acids to trace elements, especially Cu and Zn [2]. Zn, Cu, and Mn are essential trace elements and play multiple biological and physiological roles in the development and health of all animals [9] and they are confirmed mutual interactions among these elements [10]. Several authors have been involved in the appearance of some elements in wild birds and poultry breeding [11-13]. As a potential public health concern, residues of trace metals in chicken meat products have been studied in various countries and regions [14-17]. The aim of this work was to find out the influence of humic substances on the changes of mineral content (Ca, Mg, Cu and Zn) in the thigh and breast muscle of broiler chickens.

Material and method

Animals

Eighty-one-day-old broiler chicks COBB 500 (MACH DRUBEŽ Ltd. Litomyšl, Czech Republic) were randomly divided into 4 groups of 20 animals each. Dietary treatments were as follows: The broilers were fed with commercial feed mixture BR1, diet for fattening broilers within 10 days of age, BR2 diet for growing to 30 days of age and BR3 final fed mixture (AGROCASS plus, Ltd. Čaňa, Slovak Republic) for the duration of the experiment (38 days).

Experimental design and diet

The control group (CG) was fed with basal diet without any supplement. The experimental group G1 was supplemented with 0.7% Humac Natur (HN) which represented 0.7 kg /1000 kg feed. Group G3 was supplemented with 0.7% Humac Natur Monogastric (HNM) which represented enriched in calcium formate. Group G4 was supplemented with 0.5% Humat Natur Monogastric (0.5 g /1000 kg feed). The Humac Natur and Humac Natur Monogastric was obtained from HUMAC Ltd. Košice, Slovak republic. During fattening

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chickens have access to water and feed ad libitum. The broiler chicks were reared on deep litter and microclimatic conditions complied with the requirements for fattening of broilers. Broilers were reared under a conventional temperature regimen at 21°C. The relative humidity was maintained between 60-70%. After fattening, the animals were stunned and killed by cervical dislocation. Subsequently, breast and thigh muscle samples were taken for further laboratory examinations. The experiment was carried out in accordance with the European directive on the protection of vertebrate animals used for experimental and other scientific purposes (86/609/EU) and with the consent of the State Veterinary and Food Administration of the Slovak Republic No. 3090/13-221 in the premises in poultry housing of the University of Veterinary Medicine and Pharmacy in Košice (Slovak republic).

### Composition of BR1 diet for fattening

Maize 35.00%; Wheat 35.00%; Soybean meal 21.30%; Dried blood 1.25%; Limestone 1.00%; Monocalcium phosphate 1.00%; Salt 0.10%; Lysine 1.20%; Methionine 0.60%; Premix 0.50%

**Chemical composition:**
- Metabolic energy 12.01 MJ
- Nitrogenous substance 22%
- Ash 6%
- Fat 2.5 – 5.0%
- Crude fibre max 4.00%
- Non-phytate phosphorus min 0.42%
- Ca min 0.9%
- Na min 0.15%
- Retinol 12 500 mj/kg; Cholecalciferol 3 000 mj/kg; Alfa-tocoferol 50 mg/kg;
- Antioxidants: Propylgallat 100 mg/kg; Coccidiostats: Narazin 70 mg/kg.

### Composition of BR2 diet for growing

Maize 40%; Wheat 35%; Soybean meal 18.70%; Limestone 1.05%; Monocalcium phosphate 0.70%; Salt 0.15%; Lysine 1.15%; Methionine 0.46%; Premix 0.50%

**Chemical composition:**
- Metabolic energy 12.03 MJ
- Nitrogenous substance 19.5%
- Ash 4–6%
- Fat 6 – 8%
- Crude fibre max 4.50%
- Non-phytate phosphorus min 0.40%
- Ca min 0.85%
- Na min 0.14%
- Retinol 12 500 mj/kg; Cholecalciferol 3 000 mj/kg; Alfa-tocoferol 40 mg/kg;
- Antioxidants: Propylgallat 100 mg/kg; Coccidiostats: Salinomycin sodium 70 mg/kg.

### Composition of BR3 final diet

Maize 37%; Wheat 36.80%; Soybean meal 20%; Limestone 1.12%; Monocalcium phosphate 1%; Salt 0.20%; Lysine 0.98%; Methionine 0.40%; Premix 0.50%

**Chemical composition:**
- Metabolic energy 12.37 MJ
- Nitrogenous substance 19%
- Ash 4–6%
- Fat 6–10%
- Crude fibre max 4.00%
- Non-phytate phosphorus min 0.40%
- Ca min 0.85%
- Na min 0.14%
- Retinol 10 000 mj/kg; Cholecalciferol 2 000 mj/kg; Alfa-tocoferol 30 mg/kg;
- Antioxidants: Propylgallat 100 mg/kg.

### Composition of Humac Natur (HN)

powder (particle size up to 100µm) with Humic substances 60%, Fulvic acid 5%, Ca 42.278 g/kg, Mg 5.100 g/kg, Fe 19.046 g/kg, Cu 15 mg/kg, Zn 37 mg/kg, Mn 442 mg/kg, Co 1.24 mg/kg, Se 1.67 mg/kg, V 42.1 mg/kg, Mo 2.7 mg/kg.

### Composition of Humac Natur Monogastric (HN)

powder (particle size up to 100µm) with Humic substances 60%, Fulvic acid 5%, Formic acid 3.24%, Ca 0.0511 g/kg, Mg 4.853 g/kg, Fe 18.094 g/kg, Cu 14.25 mg/kg, Zn 35.15 mg/kg, Mn 135 mg/kg, Co1.18 mg/kg, Se1.59 mg/kg, V 40 mg/kg, Mo 2.57 mg/kg.

### Sample preparation

The samples of the muscles were immediately frozen and stored at -20 °C until analysis. The analyses consisted of a digestion in the microwave oven (MLS-1200 Mega, Milestone) by using 5mL HNO₃ and 1 mL HCl pre 1g of sample. The digested samples were analysed for the presence of Ca, Mg, Cu, and Zn using a flame atomic absorption spectrometry (Unicam Solar, 939). The methodology used for the determination of mineral elements is presented in the List of Official Methods and Laboratory Diagnostic of Food and Feed in Bulletin of the Ministry of Agriculture of the Slovak Republic, 2004.

### Statistical analysis

The differences between means were determined, according to the unpaired t-test using GraphPad Prism 6 software. Correlations between pairs of elements in each tissue were determined by Pearson correlation analyses. Some of these correlations were highly influenced by the samples that had undetectable mineral concentrations and only samples with detectable mineral levels were included in the analysis. Only significant correlations with an r value >0.3 are reported.

### Result and discussion

In our study, we have assumed that potential synergistic effects between minerals and humic acid could result in beneficial effect on nutrition condition of muscles. Application of humic substances in feed or drinking water ensures good animal health and positively affects production parameters. The application of humic substances for animals in feed does not require withdrawal periods. The average concentrations of Ca, Mg, Cu and Zn in broiler muscles are presented in Table 1.

### Calcium

The statistically significantly higher (p<0.01) Ca content was found in the breast and thigh muscle of broilers fed with additions 0.7% HN (0.93; 0.91 g.kg⁻¹) in comparison to the control group. Similarly, higher Ca (p<0.05) content was in muscles also in broilers fed with additions 0.7% HNM (0.89; 0.78 g.kg⁻¹) in comparison to the control group (0.92; 0.31 g.kg⁻¹). A lower significant (p<0.01) Ca content was found in chicken muscle (13.83 ppm) was presented at work from Ebeledike et al. [18]. Higher Ca content in poultry meat (1.72 g.kg⁻¹) was found by

### Table 1. The content of mineral elements in breast and thigh muscle of broiler chickens

| Group | Muscle | Ca g.kg⁻¹ | Mg g.kg⁻¹ | Cu mg.kg⁻¹ | Zn mg.kg⁻¹ |
|-------|--------|-----------|-----------|-----------|-----------|
| **Control** | | | | | |
| breast | 0.42±0.06 | 0.47±0.03 | 6.67±1.85 | 16.85±1.71 |
| thigh | 0.31±0.10 | 0.41±0.04 | 7.03±1.25 | 14.42±1.52 |
| **0.7% HN** | | | | | |
| breast | 0.93±0.31 | 0.53±0.03 | 23.88±3.34 | 20.32±5.55 |
| thigh | 0.91±0.30 | 0.43±0.03 | 6.98±0.06 | 21.70±3.92 |
| **0.7% HNM** | | | | | |
| breast | 0.89±0.33 | 0.53±0.04 | 6.18±0.61 | 21.72±2.27 |
| thigh | 0.78±0.36 | 0.40±0.01 | 6.13±0.69 | 18.32±2.28 |
| **0.5% HNM** | | | | | |
| breast | 0.33±0.08 | 0.45±0.04 | 5.80±0.96 | 15.65±2.37 |
| thigh | 0.34±0.07 | 0.35±0.04 | 7.03±1.85 | 20.55±3.37 |

The data represents the mean of 6 samples of breast and thigh muscles from each group. Control group – diet without the addition of humic substances; 0.7% HN – diet with the addition of Humac Natur; 0.7% HNM – diet with the addition of Humac Natur Monogastric; 0.5% HNM – diet with the addition Humac Natur Monogastric; *P<0.05 ; **P<0.01.
Mamam et al. [19]. Similarly, Straková et al. [20] when compared the nutritional content of muscle of broilers and pheasants in both sexes found that much higher levels of Ca and Mg in the breast muscle (males 2.15; 1.54 g.kg⁻¹ and females 2.03; 1.47 g.kg⁻¹) also in thigh muscle (male 1.80; 1.12 g.kg⁻¹ and female 1.67; 1.13 g.kg⁻¹).

**Magnesium**

A statistically significant increase (p<0.01) of Mg was analyzed in the breast (0.53 g.kg⁻¹) and thigh (0.43 g.kg⁻¹) muscle in the broiler chickens fed with addition 0.7% HN in comparison to control group. Similarly, statistically significant increase (p<0.01) was found in the breast muscle after addition of 0.7% HNM (0.53 g.kg⁻¹) versus the content of Mg in the breast muscle (0.47 g.kg⁻¹) and thigh muscle (0.41 g.kg⁻¹) of the broiler in the control group and in comparison to Mg content of the breast muscle (0.45 g.kg⁻¹) and thigh (0.35 g.kg⁻¹) broilers fed with addition of 0.5% HNM. The Mg content in the muscles of the broiler chickens remained at a similar level, regardless of the application and the amount of the supplement. Introduction of additives as humic substances to poultry diet may exert an effect on the level of element retention or interaction in tissues and their status in the organism. The favourable mechanisms of humic substances include alteration of the gastrointestinal functions, induction and inhibition of metabolic retention or interaction in tissues and their status in the organism.

**Copper**

In the control group of broilers, almost equal average Cu levels were found in the breast and thigh muscles (6.67; 7.03 mg.kg⁻¹), as in broiler muscles from the groups fed with addition of 0.7% HN (7.88; 6.98 mg.kg⁻¹), 0.7% HNM (6.18; 6.13 mg.kg⁻¹) and 0.5% HNM (5.80; 7.03 mg.kg⁻¹). The addition of 0.7% HNM (p<0.05) and 0.5% HNM (p<0.01) in feed significantly reduced the amount of Cu in the breast muscle versus the addition of 0.7% HN. Much higher amounts of the Cu were found in muscles (13.16; 16.50 mg.kg⁻¹) fed with addition of 1% Humac Natur. Several literatures reports lower Cu levels in chicken muscle in Brazil 0.3 - 3.5 mg.kg⁻¹ [22]; 1.00-1.13 mg.kg⁻¹ in Nigeria [23]; in Turkey 0.5-12.3 mg.kg⁻¹ [24]; 0.27 - 0.82 mg.kg⁻¹ in China [11]. The discrepant results concerning the effect of additives on lower levels or retention of trace element in muscles in production animals are probably related to the different content of phytochemicals.

**Zinc**

In our study we found (16.85; 14.42 mg.kg⁻¹) significantly lower Zn contents (p<0.01) in the breast and thigh muscle of broilers fed with no feed additive in comparison to the addition of 0.7% HN (23.30; 21.72 mg.kg⁻¹) and 0.5% HNM (23.38; 21.70 mg.kg⁻¹) in experimental group and in groups with addition of 0.7% HNM (23.30; 21.72 mg.kg⁻¹) and 0.5% HNM in only the thigh muscle (20.55 mg.kg⁻¹). The result of our work was different from that done by Akan et al. [25] who found the Zn concentration (1.1 ppm) in chickens. Mariam et al. [19] found similar Zn levels in the muscles (28.52 ppm) of poultry. In Pakistan, Khan et al. [26] found much higher values in chicken thighs (107.4 ± 7.60; 106.6 ± 7.37 and 106.78 ± 7.48 ppm) and breasts (107.82 ± 7.66; 107.4 ± 7.49 and 107.95 ± 7.73) taken from three different districts. Lower levels of Zn in the breast and thighs muscles (15.14; 19.50 mg.kg⁻¹) were recorded after administration of 1% Humac Natur in broiler feed [27]. Hu et al. [11] found Zn values of 3.27 - 17.90 in the poultry muscle from the food markets region in southern China.

Correlation analysis revealed some relationships between the contents of elements in breast and thigh muscle (Table 2). In the control group, correlation relations were manifested between Ca and Zn (r=0.6399) in the thigh muscle and also in the case of Cu in the thigh muscle to Zn in the breast muscle (r=0.8563). Significantly negative correlation was found in the Mg between the muscles (r= -0.8865). Similarly, negative correlation was observed in the breast muscle between Ca and Cu (r=-0.7447).

The effect of different addition levels of Humat Natur substances on the correlation coefficients of mineral elements in the breast and thigh muscles are shown in Tables 3-5.

The results show that the addition of 0.7% of HN in the feed caused a strong positive correlation in the thigh muscle between the Mg and Ca.

**Table 2.** The correlation coefficients between mineral elements (Ca, Mg, Cu, Zn) in the breast muscle (BM) and thighs muscles (TM) in control group

| Mineral | Control | HNM (0.5%) | HNM (0.7%) |
|---------|---------|-----------|-----------|
| Ca (mg/kg) | Ca BM | Mg BM | Cu BM | Zn BM | Ca TM | Mg TM | Cu TM | Zn TM |
| Ca BM | 1.0 | 0.3501 | -0.7447 | 0.0784 | -0.2205 | -0.4221 | 0.2573 | -0.0576 |
| Mg BM | 1.0 | -0.0606 | 0.2190 | -0.1377 | -0.8865 | 0.5388 | -0.6572 |
| Cu BM | 1.0 | 0.5191 | -0.0089 | 0.4033 | 0.2592 | -0.3540 |
| Zn BM | 1.0 | -0.3649 | 0.2360 | 0.8563 | -0.3515 |

**Table 3.** The correlation coefficients between mineral elements (Ca, Mg, Cu, Zn) in the breast and thighs muscles with additions 0.7% Humat Natur (HN)

| Mineral | HNM (0.5%) | HNM (0.7%) |
|---------|------------|------------|
| Ca (mg/kg) | Ca BM | Mg BM | Cu BM | Zn BM | Ca TM | Mg TM | Cu TM | Zn TM |
| Ca BM | 1.0 | 0.1763 | -0.6582 | -0.5411 | 0.6703 | 0.5600 | 0.3772 | 0.5606 |
| Mg BM | 1.0 | -0.0524 | -0.5715 | 0.3138 | 0.6950 | 0.4792 | 0.6700 |
| Cu BM | 1.0 | 0.2644 | -0.4259 | -0.4508 | 0.3135 | -0.5875 |
| Zn BM | 1.0 | -0.1017 | -0.1680 | 0.6849 | -0.1501 |

**Table 4.** The correlation coefficients between mineral elements (Ca, Mg, Cu, Zn) in the breast muscle (BM) and thigh muscles (TM) with additions 0.7% Humat Natur Monogastric (HNM)

| Mineral | HNM (0.5%) | HNM (0.7%) |
|---------|------------|------------|
| Ca (mg/kg) | Ca BM | Mg BM | Cu BM | Zn BM | Ca TM | Mg TM | Cu TM | Zn TM |
| Ca BM | 1.0 | -0.3276 | 0.3125 | -0.0516 | -0.2834 | 0.2316 | -0.0516 | -0.4333 |
| Mg BM | 1.0 | -0.5292 | 0.8187 | -0.5001 | 0.2857 | -0.5936 | -0.6958 |
| Cu BM | 1.0 | -0.2288 | -0.2157 | -0.3787 | 0.7076 | 0.3775 |
| Zn BM | 1.0 | -0.6972 | 0.1140 | -0.6141 | -0.6603 |
| Ca TM | 1.0 | -0.2702 | 0.0067 | 0.5930 |
| Mg TM | 1.0 | 0.1566 | 0.2690 |
| Cu TM | 1.0 | -0.6387 |
| Zn TM | 1.0 |

**Table 5.** The correlation coefficients between mineral elements (Ca, Mg, Cu, Zn) in the breast muscle (BM) and thigh muscles (TM) with additions 0.5% Humat Natur Monogastric (HNM)

| Mineral | HNM (0.5%) | HNM (0.7%) |
|---------|------------|------------|
| Ca (mg/kg) | Ca BM | Mg BM | Cu BM | Zn BM | Ca TM | Mg TM | Cu TM | Zn TM |
| Ca BM | 1.0 | 0.3290 | 0.5325 | 0.6446 | -0.6191 | -0.1518 | 0.8881 | 0.3534 |
| Mg BM | 1.0 | -0.0465 | 0.5255 | 0.2683 | -0.5103 | 0.2146 | -0.0249 |
| Cu BM | 1.0 | 0.1334 | -0.3730 | 0.1709 | 0.8450 | 0.4763 |
| Zn BM | 1.0 | -0.3601 | 0.0982 | 0.5263 | 0.7077 |
| Ca TM | 1.0 | 0.1804 | -0.6180 | -0.2989 |
| Mg TM | 1.0 | -0.0395 | 0.6140 |
| Cu TM | 1.0 | 0.5207 |
| Zn TM | 1.0 |
the Zn (r=0.9660) and Mg and Ca (r=0.7092). A positive correlation was confirmed in Ca content between the muscles (r=0.6703.) The breast meat was demonstrated with negative correlation between the elements: Ca to Cu (r=-0.6582). The negative correlation was found between Zn content in the breast muscle and Cu content in the thigh muscle (r=-0.6849).

According to the results, broilers fed 0.7% of HNM showed a significant positive correlation in the breast muscle between Zn and Mg (r=0.8187) as well as in the thigh muscle between Cu and Zn (r=-0.6387). The positive correlation (r=0.7076) was confirmed in Cu in the breast versus the thigh muscle. The negative correlation was found between the breast and thigh muscle in the elements: Mg in the breast muscle to Zn in the thigh muscle (r=-0.6958) and Zn in the breast muscle to Ca in the thigh muscle (r=-0.6972).

The positive correlation was also found in the broiler muscles of chicken fed 0.5% of HNM. It was recorded in the breast muscle between Ca and Zn (r=0.6446), in the thigh muscle between Mg and Zn (r=0.7077). Similarly, the positive correlation was observed in Cu from the thigh muscle to Ca from the breast muscle (r=0.8881) and to Cu in the breast muscle (r=0.8450). Negative correlation was occurred in Ca between the thigh muscle versus the breast muscle (r=0.6191) and Cu in the thigh muscle (r=-0.618). Skalická et al. [28] found significant correlation relationships between minerals in the liver and thigh muscle. The negative correlation was confirmed between Cd in muscle and Cr in muscle (r=-0.947) and Cu in liver and Cd in muscle (r=-0.885). The results of this study demonstrate antagonism among selected elements.

Conclusion

According to the results of this experiment, the use of the 0.7% Humat Natur (HN) and 0.7% Humat Natur Monogastric (HNMM) as supplement in the feed had significantly effect and contributed to the increase in the Ca and Zn content in the breast and thighs muscles of broilers chicks. There is a need for further investigations to elucidate the mechanisms. This is related to the ability of humic substances and its formation of chelate bonds with elements. To sum up, the Humac Natur can be considered as a good feed supplement, which can have positive effects on the nutritional value of chicken meat.

Implications

Increased attention as an alternative to feed antibiotics in poultry production is complemented by ecological additives. These organic additives are more acceptable among consumers. The addition of HA in broiler diets improved the palatability and quality of poultry meat.

Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

References

1. Assi JA, King AJ (2007) Assessment of selected antioxidants in tomato pomace subsequent treatment with the edible biomass mushroom, Pleurotus ostreatus, undersolids-statefermentation. J Agric Food Chem 55: 9095-9098. [Crossref]
2. Islam KMS, Schumacher A, Groop JM (2005) Humic acid substances in animal agriculture. Pakistan J Nutr 4: 126-134.
3. Arif M, Alagawany M, Abd El-Hack ME, Saeed M, Arain MA, et al. (2019) Humic acid as a feed additive in poultry diets: a review. Iran J Vet Res 20: 167-172. [Crossref]
4. Madroňová L, Kožler J, Ceziková J, Novák J, Žanos P (2001) Humic acids from coal of the North-Bohemia coal field. III. Metal-binding properties of humic acids-measurements in a column arrangement. Reac Funct Polym 47: 119-123.
5. Elfarissi F, Pefferkorn E (2000) Kaolinite/humic acid interaction in the presence of aluminium ion. Col Surf A: Physicochem Engin Aspects 168: 1-12.
6. Skalická M, Koréneková B (2016) The effects of sodium humate and alfatoxin B1 on body weight of broiler chicks. Iran J Appl Anim Sci 6: 415-421.
7. Van Rensburg CJ, Van Rensburg CEJ, Van Ryssew JB, Caseley NH, Rottinghaus GE (2006) In vitro and in vivo assessment of humic acid as an alfatoxin binder in broiler chickens. Poultry Sci 85: 1576-1583. [Crossref]
8. 25. Stepchenko LM, Zvoria LV, Kravtsova LV (1991) The effect of sodium humate n metabolism and resistance in highly productive poultry. Nauchnye Doki Vys Shkoly Biol Nauki 10: 90-95. [Crossref]
9. Richards JD, Zhao J, Harrrell RJ, Arwell CA, Dibber JJ (2010) Trace mineral nutrition in poultry and swine. Asian-Australasian J Anim Sci 23: 1527-1534.
10. Andreji J, Štrášilai I, Massanyi P, Valent M (2005) Concentration of selected metals in muscle of various fish species. J Environ Sci Health A Tox Hazard Subst Environ Eng 40: 899-912. [Crossref]
11. Hu Y, Zhang W, Chen G, Chen H, Tao S (2018) Public health risk of trace metals in fresh chicken meat products on the food markets of a major production region in southern China. Environ Pollut 234: 667-676. [Crossref]
12. Magali L, Andre JM, Bernadet MD, Gontier K, Gerard G, et al. (2008) Concentrations of metals (Zn, Cu, Cd, Hg) in three domestic ducks in France: Pekin, Muscovy and Mule ducks. J Agric Food Chem 56: 281-288.
13. Skalická M, Koréneková B (2012) Comparison of trace element concentrations in muscle in different poultry species. Proceedings of lectures and posters from the international scientific conference Hygiëna alimentum XXXIII (CD), Vysoké Tatry, The Slovak Republic 2012: 144-144. (In Slovak language).
14. Iwegbue CMA, Nwajei GE, Iyoha EH (2008) Heavy metal residues of chicken meat and gizzard and Turkey meat consumed in southern Nigeria. Bulgarian J Vet Med 11: 275-280.
15. Oforoka NC, Osoji LC, Onwuachu UI (2012) Assessment of heavy metal pollution in muscles and internal organs of chickens raised in Rivers State, Nigeria. J Emer Trends Environ Sci Appl Sci 3: 406-411.
16. Sinkakarimi MH, Mansouri B, Azadi NA, Maleki A, Davari B (2017) Assessment of heavy metals in chicken meat distributed in sanandaj, Iran, and calculating the food consumption risk. J Mazandaran Univ Med Sci 26: 128-138.
17. Uluozlu OD, Tuzen M, Mendl D, Soykal M (2009) Assessment of trace element contents of chicken products from Turkey. J Hazard Mater 163: 982-987. [Crossref]
18. Ebeledeike EU, Nwokedi GIC, Ndu OO, Okoye FBC, Ochogu IS (2010) Calcium and phosphorus contents of body parts of some domestic animal used as meat source in Nigeria. Asian Pac J Trop Med 3: 395-398.
19. Mariam I, Isbail S, Nagra SA (2004) Distribution of some trace and macrominerals in beef, mutton and poultry. Inter J Agric Biol 6: 816-820.
20. Straková E, Suchý P, Karásková K, Jánbor M, Navrátil P (2011) Comparison of nutritional values of pheasant broiler chicken meats. Acta Vet Bolo 80: 373-377. [Crossref]
21. Al-Yasiry AR, Kiczorowska B, Samolinska W (2017) Nutritional value and content of mineral elements in the meat of broiler chickens fed Boswellia serrata supplemented diets. J Elemnt 22: 1027-1037.
22. Ferreira KS, Gomes JC, Chaves JBP (2005) Copper content of commonly consumed food in Brazil. Food Chem 92: 29-32.
23. Onianwra PC, Adeyemo AO, Idowu OE, Ogahie EL (2001) Copper and zinc contents of Nigerian foods and estimates of the adult dietary intakes. Food Chem 72: 89-95.
24. Uluozlu OD, Tuzen M, Mendl D, Soykal M (2009) Assessment of trace element contents of chicken products from Turkey. J Hazard Mater 163: 982-987. [Crossref]
25. Akar JC, Abdulrahman FL, Sadipo OA, Chiroma, YA (2010) Distribution of Heavy Metals in the Liver, Kidney and Meat of Beef, Mutton, Caprine and Chicken from Kasuwan Shanu Market in Maiduguri Metropolis, Borno State, Nigeria. Res J Appl Sci Eng Technol 2: 743-748.
26. Khan Z, Sultan A, Khan R, Khan S, Imranullah, et al. (2016) Concentrations of heavy metals and minerals in poultry eggs and meat produced in Khyber Pakhtunkhwa, Pakistan. Meat Sci Vet Pub Health 1: 4-10.
Skalická M (2019) Effect of humic substances on the mineral composition of chicken meat

27. Skalická M, Koréneková B, Petříková D, Marcinčáková D, Marcinčák S, et al. (2018) Effects of humic acid on the mineral composition of the chickens’ meat. In: Proceedings of lectures and posters from the international scientific conference Hygiëna alimenitorum XXXIX (CD) Štrbské Pleso, 2018 The Slovak Republic: 145-150.

28. Skalická M, Koréneková B, Naď P (2008) Distribution of trace elements in liver and muscle of Japanese quails. Slovak J Anim Sci 41: 187-189.