The effects of copper-glycine complexes on chemical composition and sensory attributes of raw, cooked and grilled chicken meat

Anna Winiarska-Mieczan · Malgorzata Kwiecień

Revised: 26 May 2014 / Accepted: 3 August 2014 / Published online: 13 August 2014
© Association of Food Scientists & Technologists (India) 2014

Abstract To determine the influence of glycine-Cu chelates (Gly-Cu) on chemical composition and sensory characteristic of chickens meat, two hundred of Ross 308 broilers were fed diets containing 16 mg kg⁻¹ of copper sulfate (S-Cu; control group) or 16, 8 and 4 mg/kg of Cu-glycine chelate (Gly-Cu). The chemical composition was determined in crude and prepared (cooked and grilled) breast and thigh samples. No significant influence of Gly-Cu on the content of the protein, fat and ash in the breast meat was found. Substituting S-Cu with Gly-Cu at different doses in feed did not significantly modify the fatty acids profile of the meat. The breast meat from chickens administered with Gly-Cu contained significantly less cholesterol than that in S-Cu. No different effect of the experimental agent was observed regarding the content of Cu, Zn and Ca in the breast meat, while in chickens from all the groups administered Gly-Cu there was more significantly Fe ($P<0.01$) in comparison with the S-Cu group. The thigh meat revealed significantly ($P<0.01$) higher levels of Zn and Ca in comparison with the 16 mg S-Cu group. No significant effect of the diet on the sensory characteristics of the meat was observed.

Keywords Gly-Cu chelates · Breast meat · Thigh meat · Meat quality · Sensory characteristic

This work was financially by the project NN 311543540 from the Ministry of Science and Higher Education, Poland.

A. Winiarska-Mieczan (✉)
Department of Bromatology and Food Physiology, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
e-mail: anna.mieczan@up.lublin.pl

M. Kwiecień
Department of Animal Nutrition, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland

Abbreviations

S	starter diet
G	grower diet
F	finisher diet
S-Cu	copper sulphate
Gly-Cu	glycine-Cu chelates
SFA	saturated fatty acids
MUFA	monounsaturated fatty acids
PUFA	polyunsaturated fatty acid
UFA	unsaturated fatty acid

Introduction

Chicken meat consumption is systematically increasing in Poland (Borys 2007). Due to its dietetic properties (Dinh et al. 2011) some authors (Pisulewski 2005; Betti et al. 2007) claim that could be considered as a functional food, after some modifications in its chemical composition (e.g. increasing the ratio of PUFA and CLA isomers by adding these components to the feed).

Currently, large-scale production of chicken meat tends to limit the usage and extraction of minerals and reduce environmental pollution (Abdallah et al. 2009). That is why analyses of chelates of selected minerals and amino acids, including copper (Chowdhury et al. 2004; Wang et al. 2007), are performed. Some authors suggested that mineral components from organic combinations (chelates) are assimilated much better than those from mineral combinations (Aoyagi and Baker 1993; Liotta et al. 2009), involving the reduction of the administration of minerals and, in consequence, the cost of breeding. Since such chelates may soon be introduced on a mass scale to feed for broiler chickens, it should be considered their impact in the nutritional value and the sensory quality of

chicken meat. Consumers pay attention to safety and nutritional value of food and afterwards to the environmental impact of the manufacturing processes (Resurreccion 2003; Floros et al. 2010).

Copper is regarded as a growth promoter in poultry aspect of breeding (Kim et al. 2011; Kwiecień and Winiarska-Mieczan 2011; Igbasan and Akinsanmi 2012), taking into account that the use of antibiotic as growth promoters has been prohibited by the European Union (Yegani and Korver 2010). Moreover, copper can reduce cholesterol in chicken tissues (Konjufca et al. 1997; Ševčíková et al. 2003). Igbasan et al. (2011) observed that dietary supplementation of Cu enhanced the oxidative stability of chicken meat. Some research suggested that copper is a very active catalyst in reactions occurring during peroxidation of lipids (Lauritzen and Martinsen 1999). Poultry meat contains a significant percentage of unsaturated fatty acids; therefore, its composition is deemed beneficial for human health (de Almeida et al. 2006). Concerning to the effect of organic sources of copper on the fatty acids profile data available the literature were not conclusive. Ševčíková et al. (2003) found that in the breast meat of chickens receiving copper-glycinate, chelate contained less polyunsaturated fatty acids and more saturated fatty acids compared to the group receiving copper sulphate. In turn, Makarski et al. (2006) found that in turkeys receiving Cu-lysine, chelate changed into a fatty acid profile: a statistically significant increase in the content of acid, 18:1, and a decrease in saturated acids, 14:0, 16:0 and 22:0, was identified. It must be verified whether copper administered to chickens in a more easily assimilable organic form will alter the profile of fatty acids in meat, and in particular the ratio between saturated and unsaturated acids. The saturated and unsaturated fatty acid rate also affect the organoleptic properties of meat and in particular its flavour (Ramarathnam et al. 1993).

The objective of the study was to determine the influence of glycine-Cu chelates (Gly-Cu) on the chemical composition, fatty acids profile and sensory characteristics of raw, cooked and grilled chicken breast and thigh meat. For this purpose, different levels of Gly-Cu were added to a standard diet and were compared to the copper sulphate group.

Material and methods

Animals and diets

All procedures used throughout this study were approved by the Local Animal Welfare Committee at the University of Life Sciences in Lublin, Poland. Two hundred Ross 308 male broiler chicks, purchased from a commercial supplier, were used in this experiment. The chicks were individually weighed and divided into four treatment groups. Each treatment consisted of 5 replications in 5 cages (10 birds per cage).

The chickens were fed a starter (S) diet for 21 days, grower (G) diet from day 22 to 35 and finisher (F) diet from day 36 to 42. The basal diets were formulated using NRC (1994) guidelines. Copper requirement of broilers Ross 308 are 16 mg kg⁻¹ feed (Aviagen 2013). In the study, for each phase (S, G and F), four treatment were established: control group, with 16 mg/kg of sulphate of copper was added to the feed (16 mg Cu-S); and 16 mg Gly-Cu, 8 mg Gly-Cu or 4 mg Gly-Cu groups, with 16, 8 or 4 mg/kg of organically complexed Cu-glycine chelate added to the feed, respectively (Table 1). The values corresponded, respectively, to 100 %, 50 % and 25 % of the requirement recommended for Ross broiler chickens. They were selected based on research by other authors (Abdallah et al. 2009; Bao et al. 2007; El-Husseiny et al. 2012), who found that the content of organic forms of trace minerals in

Table 1 Chemical composition of the feed *

	S – Starter **	G – Grower**	F – Finisher**
Values calculated (%)			
Energy (MJ kg ⁻¹)	12.7	13.1	13.2
Crude protein	20.2	18.2	18.1
Crude fibre	3.06	2.99	2.99
Crude fat	4.66	6.08	6.43
Lysine	1.29	1.13	1.09
Met+Cys	0.93	0.83	0.81
Fatty acids (g/100 g of total fatty acids)			
Myristic (14:0)	0.02	0.08	0.07
Palmitic (16:0)	1.39	1.19	1.10
Stearic (18:0)	0.31	0.29	0.35
Oleic (18:1n-9)	2.24	2.20	2.16
Linoleic (18:2n-6)	4.69	4.97	4.92
Linolenic (18:3n-3)	1.16	0.87	0.91
Values determined (mg)			
Cu **			
16 S-Cu	22.10	22.21	21.95
16 Gly-Cu	21.98	22.15	22.02
8 Gly-Cu	14.12	14.21	14.01
4 Gly-Cu	10.10	10.21	9.981
Fe	40.31	39.82	38.61
Zn	99.71	98.50	98.52
Ca	8.810	7.852	7.533

* Composition of the basal mixtures: maize, wheat, soybean meal 46 %, soybean oil, monocalcium phosphate, limestone, sodium bicarbonate, NaCl, vitamin – mineral premix, fat-protein concentrate, DL-methionine 99 %, L-lysine HCl, L-threonine 99 %

** In experiment Cu was added to the mixtures S, G and F in an amount of 16 mg kg⁻¹ in the form of Cu-sulfate (at 100 % recommendation levels for Ross broiler chicks) – group 16 mg S-Cu; or in the form of Cu-glycine chelate in an amount of 16, 8 or 4 mg kg⁻¹ (at 100 %, 50 % and 25 % instead of inorganic forms of those minerals recommend levels for Ross broiler chicks, respectively) – groups 16 mg Gly-Cu, 8 mg Gly-Cu, 4 mg Gly-Cu

doses administered to broiler chickens reduced by 50 and 75 % compared to NRC recommendations had no negative effect on the production parameters. An ad libitum feeding regime and automatic drinkers were used. During the experiment the performance parameters were analysed: daily body weight gain, feed intake and feed conversion ratio (Table 2). At the end of the experimental period (at 42th day), 10 chicks from each treatment were slaughtered and dissected.

Sample treatment

After 24 h' refrigeration at 4 °C the left and right portion of the breast and thigh meat were removed from the carcasses (skinned and deboned) and placed in separate, dark, hermetic sealed bags which is put into a freezer at −20 °C and frozen prior to chemical analysis. The chemical composition was determined in crude and prepared (cooked and grilled) meat samples. Whole samples of both meats were cooked for 5 min in a 0.6 % NaCl solution at 76 °C (temperature measured inside the samples), at a 1:2 meat/water ratio, or grilled at 160 °C (temperature measured inside the samples) under a gas grill for 4 min.

Chemical analysis

The contents of dry matter, crude ash, crude protein and crude fat in meat samples were determined with standard AOAC (2000). The total tissue lipids were extracted according to the method of Folch et al. (1957). The Cu, Fe, Zn and Ca content in feed and meat samples was determined using the AAS flame technique in a Unicam 939 (AA Spectrometer Unicam) apparatus, after ashing at 550 °C, according to the methods of

AOAC (2000). In order to make the calibration line, standard solutions of ions were procured from Merck (Germany). Standard solutions of 20, 40, 60, 80 and 100 milliequivalent per 1 L were used both for Cu, Fe, Zn and Ca. The content of cholesterol was determined by the colorimetric method (Rhee et al. 1982), with an EPOLL 20 colorimeter. Cholesterol reference standard C3045 was purchased from Sigma (USA). The fatty acids profile of the crude meat samples was determined with the gas chromatography method, described by Rotenberg and Anderson (1980), using INCO 505 M apparatus with a TZ 4620 integrator (Laboratorni Pstrojce Praha, Czech Republic). Individual fatty acids were identified by comparing their retention times with those of a standard fatty acid mix, Supelco 37 FAME Mix 47885-U (Sigma, UK). The ultimate pH values of both breast (Pectoralis major) and thigh (Ilio tibialis) meats were determined at 15 and 45 min post mortem from 2 g of meat mixed in 18 mL of a 5 mM iodoacetate solution (Santé and Fernandez 2000), using a portable pH meter (Model 506, Crison Instruments, SA, Spain), equipped with a xerolyte electrode. The pH meter was standardized against standard buffers of pH 4.0 and pH 7.0. All the results obtained from the analytical laboratory were performed in three replications.

Sensory analysis of cooked and grilled meat

The sensory assessment of breast and thigh meat after thermal processing (cooking or grilling) was performed as described by Winiarska-Mieczan (2010). The samples were scored for juiciness, tenderness, flavour (intensity and desirability) and taste (intensity and desirability) on a five-point scale: from 5 (maximum) to 1 point scores (minimum). The sensory

Table 2 The performance of broiler chickens (n=200)

	16 mg S-Cu ^a	16 mg Gly-Cu ^b	8 mg Gly-Cu ^c	4 mg Gly-Cu ^d	SEM	P value
Body weight gain (g/day)						
S (0–21 days)	40.25	41.02	42.16	41.25	7.021	0.215
G (22–35 days)	89.29	91.64	91.21	82.07	2.221	0.415
F (36–42 days)	71.70	75.14	75.65	69.57	1.455	0.141
Feed conversion ratio (g : g)						
S (0–21 days)	1.56	1.52	1.57	1.57	0.012	0.254
G (22–35 days)	1.61	1.64	1.64	1.67	0.018	0.201
F (36–42 days)	1.85	1.79	1.76	1.72	0.027	0.714
Final weight (g)	2430.0	2485.1	2479.0	2359.3	29.15	0.098
Dressing percentage (%)	73.8	74.25	73.69	71.62	0.586	0.105
Content in cold carcass (%)						
Breast meat	23.42	23.94	24.50	22.97	0.330	0.121
Thigh meat	13.04	13.00	12.79	13.11	0.069	0.268

Cu was added to the mixtures S, G and F in an amount of : ^a 16 mg/kg in the form of Cu-sulfate; ^b 16 mg/kg in the form of Cu-glycine chelate; ^c 8 mg/kg in the form of Cu-glycine chelate; ^d 4 mg/kg in the form of Cu-glycine chelate; ^{A, B, C} - means with different superscripts in lines differ at $p \leq 0.05$; SEM – standard error of the means

assessment of meat quality was performed by a team of taste panelist trained according to the ISO 8586–2:1996 standard. After the sample of meat was cooled, it was cut into pieces of equal size and weight (approx. 25 g) and placed in plastic, disposable boxes covered with lids.

All samples for the assessment were assigned individual three-digit codes and served at random in order to avoid the carry-over effect. The sensory analysis was repeated twice. Every tester received 2 sets comprising 1 sample of breast meat and thigh meat from each experimental group (8

Table 3 The crude meat pH, and chemical composition of crude, cooked and grilled breast and thigh meat samples (g/100 g)

	16 mg S-Cu ^a	16 mg Gly-Cu ^b	8 mg Gly-Cu ^c	4 mg Gly-Cu ^d	SEM	P value
Breast meat						
Crude (<i>n</i> =40)						
pH ₁₅	6.23 ^A	6.54 ^B	6.71 ^C	6.35 ^{AB}	0.106	0.005
pH ₄₅	5.34 ^A	5.58 ^B	5.72 ^C	5.43 ^{AB}	0.084	0.008
Dry matter	23.1	22.8	22.7	22.9	0.085	0.555
Crude ash	1.11	1.13	1.11	1.15	0.009	0.167
Crude protein	21.2	21.3	21.3	21.6	0.087	0.587
Crude fat	0.97	0.91	1.00	0.96	0.004	0.113
Cholesterol (mg)	55.2 ^B	45.2 ^A	46.0 ^A	47.6 ^A	2.288	< 0.000
Cooked (<i>n</i> =40)						
Dry matter	30.1	30.2	28.5	29.5	0.390	0.568
Crude ash	0.81	0.83	0.78	0.85	0.015	0.111
Crude protein	27.2	27.3	26.9	26.6	0.158	0.151
Crude fat	3.07	2.99	3.00	2.96	0.023	0.123
Cholesterol (mg)	75.2	75.2	76.0	77.1	0.472	0.818
Grilled (<i>n</i> =40)						
Dry matter	33.3	34.8	35.7	34.9	0.500	0.222
Crude ash	0.81	0.83	0.79	0.81	0.008	0.239
Crude protein	28.1	27.7	28.0	28.5	0.165	0.225
Crude fat	3.04	3.07	2.98	3.05	0.019	0.094
Cholesterol (mg)	85.3 ^B	84.4 ^{AB}	84.9 ^{AB}	82.29 ^A	0.669	0.007
Thigh meat						
Crude (<i>n</i> =40)						
¹ pH ₁₅	6.35 ^A	6.54 ^B	6.39 ^A	6.46 ^{AB}	0.042	0.004
¹ pH ₄₅	5.56	5.55	5.49	5.57	0.018	0.132
Dry matter	23.9	24.2	25.4	24.7	0.328	0.162
Crude ash	1.01 ^A	0.98 ^A	1.16 ^B	1.21 ^B	0.056	0.007
Crude protein	18.1	17.9	18.2	17.5	0.155	0.121
Crude fat	5.04	4.77	5.45	5.45	0.166	0.994
Cholesterol (mg)	89.5 ^B	81.4 ^A	84.6 ^{AB}	85.79 ^{AB}	1.672	0.006
Cooked (<i>n</i> =40)						
Dry matter	30.9	34.4	35.0	34.5	0.943	0.299
Crude ash	1.11 ^A	1.17 ^A	1.36 ^B	1.35 ^B	0.063	0.002
Crude protein	19.9	21.9	20.2	19.9	0.480	0.223
Crude fat	8.11	7.95	7.95	7.85	0.095	0.124
Cholesterol (mg)	93.5	91.1	89.8	95.95	1.398	0.229
Grilled (<i>n</i> =40)						
Dry matter	35.1	34.7	35.9	34.5	0.891	0.992
Crude ash	1.32 ^B	1.18 ^A	1.26 ^B	1.33 ^B	0.051	0.001
Crude protein	23.1	21.9	24.2	23.5	0.302	0.223
Crude fat	15.58	14.97	15.33	15.46	0.134	0.771
Cholesterol (mg)	97.5	95.4	94.9	95.29	1.025	0.886

Cu was added to the mixtures S, G and F in an amount of : ^a 16 mg/kg in the form of Cu-sulfate; ^b 16 mg/kg in the form of Cu-glycine chelate; ^c 8 mg/kg in the form of Cu-glycine chelate; ^d 4 mg/kg in the form of Cu-glycine chelate; ^{A, B, C} - means with different superscripts in lines differ at $p \leq 0.05$; SEM – standard error of the means

samples per set). Every trained panellist was provided with hot tea without sugar to neutralize their taste between subsequent

samples. The assessment was performed in a room at ambient temperature and in daylight.

Table 4 Fatty acid profile of crude breast and thigh meat samples (g/100 g of total fatty acids)

	16 mg S-Cu ^a	16 mg Gly-Cu ^b	8 mg Gly-Cu ^c	4 mg Gly-Cu ^d	SEM	p value
Breast meat						
14:0	0.45	0.44	0.43	0.43	0.009	0.166
15:0	0.11 ^B	0.08 ^A	0.09 ^A	0.10 ^{AB}	0.012	< 0.000
16:0	23.3	22.3	21.2	22.1	0.298	0.323
17:0	0.16	0.15	0.16	0.15	0.003	0.117
18:0	7.40	7.56	7.03	7.41	0.155	0.099
20:0	0.13	0.13	0.13	0.12	0.005	0.333
16:1	4.12 ^{AB}	3.71 ^A	4.24 ^B	4.19 ^B	0.083	0.006
18:1	34.6	35.4	35.5	35.2	0.344	0.186
20:1	0.33	0.34	0.34	0.35	0.009	0.113
18:2 _{n-6}	25.4	25.3	24.9	23.6	0.860	0.412
20:2 _{n-6}	0.35	0.30	0.33	0.32	0.013	0.076
20:4 _{n-6}	2.31	2.41	2.35	2.50	0.344	0.551
18:3 _{n-3}	2.40	2.30	2.28	2.33	0.348	0.130
20:3 _{n-3}	0.15 ^A	0.17 ^{AB}	0.18 ^{AB}	0.22 ^B	0.004	0.007
Σ SFA	31.5	30.6	29.0	30.3	0.508	0.136
Σ MUFA	35.0	35.8	35.9	35.5	0.312	0.494
Σ PUFA	30.6	30.5	30.1	29.0	0.366	0.723
Σ UFA	65.6	66.2	66.0	64.5	0.596	0.728
Σ PUFAn-6	28.0	28.0	27.6	26.4	0.269	0.697
Σ PUFAn-3	2.56	2.47	2.45	2.55	0.334	0.685
Σ PUFA/SFA	0.97	1.00	1.04	0.96	0.098	0.737
n-6/n-3	11.0	11.4	11.3	10.5	0.527	0.480
Thigh meat						
14:0	0.43	0.42	0.41	0.39	0.084	0.400
15:0	0.10	0.09	0.08	0.08	0.079	0.120
16:0	22.7	21.8	20.7	20.1	0.751	0.155
17:0	0.15	0.14	0.15	0.14	0.003	0.144
18:0	7.33 ^{AB}	7.46 ^B	6.93 ^A	6.82 ^A	0.686	0.002
20:0	0.12	0.12	0.12	0.11	0.002	0.734
16:1	4.08 ^{AB}	3.68 ^A	4.21 ^B	3.80 ^A	0.444	< 0.000
18:1	33.5	34.3	34.4	32.2	0.319	0.496
20:1	0.31	0.32	0.32	0.30	0.059	0.287
18:2 _{n-6}	24.9	24.8	24.4	22.9	0.812	0.671
20:2 _{n-6}	0.33	0.28	0.31	0.28	0.071	0.331
20:4 _{n-6}	2.21 ^{AB}	2.31 ^B	2.25 ^{AB}	2.18 ^A	0.310	< 0.000
18:3 _{n-3}	2.37 ^B	2.27 ^{AB}	2.25 ^{AB}	2.14 ^A	0.259	< 0.000
20:3 _{n-3}	0.14 ^A	0.16 ^{AB}	0.17 ^{AB}	0.22 ^B	0.004	0.034
Σ SFA	30.9	30.0	28.4	29.7	0.301	0.114
Σ MUFA	33.8	34.6	34.8	34.4	0.328	0.124
Σ PUFA	29.9	29.8	29.4	28.3	0.257	0.320
Σ UFA	63.8	64.5	64.2	62.7	0.612	0.422
Σ PUFAn-6	27.4	27.4	27.0	25.8	0.478	0.601
Σ PUFAn-3	2.52	2.43	2.41	2.51	0.284	0.275
Σ PUFA/SFA	0.97	1.00	1.04	0.96	0.071	0.667
n-6/n-3	10.9	11.3	11.2	10.4	0.482	0.415

Cu was added to the mixtures S, G and F in an amount of: ^a 16 mg/kg in the form of Cu-sulfate; ^b 16 mg/kg in the form of Cu-glycine chelate; ^c 8 mg/kg in the form of Cu-glycine chelate; ^d 4 mg/kg in the form of Cu-glycine chelate; ^{A, B, C} - means with different superscripts in lines differ at $p \leq 0.05$; SEM – standard error of the means; SFA - saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA - polyunsaturated fatty acids; UFA – unsaturated fatty acids

Statistical analysis

The results were analysed by statistical methods. The arithmetic means and standard error of the mean (SEM) were calculated using STATISTICA 6.0 software (STATSOFT 1995). The significance of differences between mean values calculated for respective groups was evaluated by means of a one-factor variance analysis (ANOVA) using the t-Student-Newman-Keuls procedure. The P value < 0.05 was considered significant.

Results

Growth performance and feed consumption

The addition of Gly-Cu chelate in the chicken diets did not change the growth performance, feed to gain ratio, dressing

percentage and content of breast and thigh meat in carcass (Table 2).

Chemical composition of breast and thigh meat

No statistically significant influence of using Gly-Cu on the content of the crude protein, fat and ash in the breast meat was noted (Table 3). At the same time it was demonstrated that the crude breast meat in chickens receiving the chelate and the crude thigh meat in chickens from group 16 mg Gly-Cu contained significantly less cholesterol than in the birds from the control group (16 mg of S-Cu). The fatty acids profile of the breast and thigh meat in chickens receiving chelates was modified to a small extent compared to the control group (Table 4). No statistically significant effect of the experimental agent was observed regarding the content of Cu, Zn and Ca in the breast meat (Fig. 1). The

Fig. 1 The influence of glycine-Cu chelate on the content of Cu, Fe, Zn and Ca in the breast meat * significant versus group 16 mg S-Cu

treatment influenced the share of Fe in the breast meat; in chickens from all the groups administered Gly-Cu chelate there was significantly ($P<0.05$) more Fe compared to the group given 16 mg of S-Cu. Crude thigh meat revealed significantly higher levels of Zn and Ca compared to the 16 mg S-Cu group (Fig. 2).

Sensory characteristics of breast and thigh meat

Figures 3 and 4 give the results of the sensory evaluation of breast and thigh meat after cooking or grilling. Juiciness, tenderness, flavour (intensity and desirability) and taste (intensity and desirability) were determined. No significant effect of the diet on the sensory characteristics of the meats was observed. Therefore, it may be concluded that the addition of Gly-Cu at different levels does not negatively influence the quality of meat, compared to S-Cu.

Discussion

Commercial broiler diets contained inorganic trace minerals at a rate of 2–10 times more than the amounts recommended by the National Research Council (Inal et al. 2001; Wang et al. 2008). Some authors have suggested that organic minerals (chelates) are much better assimilated than those from inorganic combinations (Aoyagi and Baker 1993; Liotta et al. 2009), involving the reduction of the minerals' administration. Saripinar-Aksu et al. (2012) claim that the optimum level of organically complexed trace elements for poultry was not determined. According to Abdallah et al. (2009) and El-Husseiny et al. (2012) trace minerals, such as Zn, Cu, Mn and Fe, deriving from organic sources can be added to broiler diets at considerably lower levels (50 % of the total mineral requirement recommended for broiler chicks) than their inorganic forms (100 % of currently recommended level) without any negative effect on performance and carcass characteristics. Bao

Fig. 2 The influence of glycine-Cu chelate on the content of Cu, Fe, Zn and Ca in the leg meat * significant versus group 16 mg S-Cu

Fig. 3 Effect of Cu-Gly on the sensory characteristic of breast meat of chicken (points: 1 – minimum, 5 – maximum)

et al. (2007) demonstrated that the supplementation with 4 mg of Cu from organic sources (Bioplex Cu) may be sufficient for normal broiler growth up to day 29 of age. In this study no statistically significant ($P < 0.05$) effects of 16, 8 or 4 mg/kg of Gly-Cu chelate (at 100, 50 and 25 % of those minerals' recommended levels for Ross broiler chicks, respectively, instead of inorganic forms)

on the final weight, average daily gain, average daily intake and feed conversion were noted.

Results showed that the breast meat in chickens receiving the chelate contained significantly ($P < 0.05$) less cholesterol than in chickens receiving inorganic copper. Literature provides little information on the effect of using Cu chelates on the content of cholesterol in the meats, but it may be supposed

Fig. 4 Effect of Cu-Gly on the sensory characteristic of thigh meat of chicken (points: 1 – minimum, 5 – maximum)

that the organic compound of Cu affects lipid transformations in the animals' organisms. Ševčíková et al. (2003) noticed that the addition of 175 mg of copper in the form of Gly-Cu per kg of feed resulted in a statistically significant ($P<0.05$) reduction in the concentration of cholesterol in breast meat, in reference to the groups receiving copper in the inorganic form (35 mg or 175 mg/kg). Lim et al. (2006) demonstrated that the addition of 100 ppm of Cu from methionine-Cu chelate, did not significantly affect the content of cholesterol in blood and in the breast meat. In the study the content of cholesterol was determined in crude meat, while studies by other authors revealed that during thermal processing cholesterol was transferred from the fat tissue to meats, so meat that has been culinary prepared will contain more cholesterol than crude meat (Swize et al. 1992). It is possible, however, that cooked meat contains more cholesterol because thermal processing modifies the proportions between the chemical components of meat (Dinh et al. 2011). Our study showed that breast meat contained nearly half the amount of cholesterol found in thigh meat. Dinh et al. (2008) noted a positive correlation between the content of cholesterol in meat and the amount and level of intramuscular fat.

Our results suggested that the breast meat of chickens receiving organic copper contained more Fe, while the thigh meat was richer in Zn and Ca compared to the group receiving inorganic copper. The change in the ratio of these components in the analysed tissues could be explained by interactions between copper and other metals. Cu reveals some antagonistic activity in relation to Zn and it participates in metabolic processes involving Ca (Pang and Applegate 2007).

In this study, no significant differences ($P<0.05$) in juiciness, tenderness, flavour, or taste were detected among the breast and thigh meat samples from broilers fed Cu-S or Cu-Gly. Thigh meat was characterized by 5-fold higher content of fat in comparison with the breast meat. Many of the flavour components of poultry are fat soluble (Williams and Damron 1998). Fat has a positive effect on the texture and sensory quality of food products (Sasaki et al. 2007) and is a carrier of taste and flavor. In this study, the fatty acids profile of the breast and thigh meat in chickens receiving chelates was modified to a small extent compared to the control group. According to Ševčíková et al. (2003) the fatty acid profile in the breast meat of broiler chickens depends on whether the source of copper is organic or inorganic.

Conclusion

The results of this study demonstrate that an addition of Gly-Cu chelates to the broilers' diet does not negatively influence the chemical composition and sensory characteristics of chicken breast and thigh meat, compared to copper sulphate. Therefore, we suggest that Gly-Cu should be used as an alternative

to Cu-S. Additionally, the fact that the breast meat in chickens administered Gly-Cu contained significantly less cholesterol than that in the control group results in enhancing the health-promoting qualities of chicken meat.

References

- Abdallah AG, El-Husseiny OM, Abdel-Latif KO (2009) Influence of some dietary organic mineral supplementations on broiler performance. *Int J Poult Sci* 8:291–298
- AOAC (2000) Official Methods of Analysis. Intern. 17th ed. AOAC Inter., Gaithersburg, MD, USA.
- Aoyagi S, Baker DH (1993) Nutritional evaluation of copper-lysine and zinc-lysine complexes for chicks. *Poult Sci* 72:165–171
- Aviagen (2013). Ross 308 parent stock nutrition specifications. en.aviagen.com
- Bao YM, Choct M, Iji PA, Bruerton K (2007) Effect of organically complexed copper, iron, manganese, and zinc on broiler performance, mineral excretion, and accumulation in tissues. *J Appl Poult Res* 16:448–455
- Betti M, Schneider BL, Wismer WV, Carney VL, Zuidhof MJ, Renema RA (2007) Omega-3-enriched broiler meat: 2. Functional properties, oxidative stability, and consumer acceptance. *Poult Sci* 88:1085–1095
- Borys A (2007) Trends in industrial production and processing of meat in Poland. *Meat Technol* 48:36–44
- Chowdhury SD, Paik IK, Namkung H, Lim HS (2004) Responses of broiler chickens to organic copper fed in the form of copper-methionine chelate. *Anim Feed Sci Technol* 115:281–293
- de Almeida JC, Perassolo MS, Camargo JL, Bragagnolo N, Gross JL (2006) Fatty acid composition and cholesterol content of beef and chicken meat in Southern Brazil. *Braz J Pharm Sci* 42:109–117
- Dinh TTN, Blanton JR Jr, Brooks JC, Miller MF, Thompson LD (2008) A simplified method for cholesterol determination in meat and meat products. *J Food Comp Anal* 21:306–314
- Dinh TTN, Thompson LD, Galyean ML, Brooks JC, Patterson KY, Boylan LM (2011) Cholesterol content and methods for cholesterol determination in meat and poultry. *Compr Rev Food Sci Food Saf* 10:269–289
- El-Husseiny OM, Hashish SM, Ali RA, Arafa SA, Abd El- Samee LD, Olemly AA (2012) Effects of feeding organic zinc, manganese and copper on broiler growth, carcass characteristics, bone quality and mineral content in bone, liver and excreta. *Int J Poult Sci* 11:368–377
- Floros JD, Newsome R, Fisher W (2010) Feeding the world today and tomorrow: the importance of food science and technology. *Compr Rev Food Sci Food Saf* 9:572–599
- Folch J, Lees M, Stanley GHS (1957) A simple method for the isolation and purification of total lipids from animal tissues. *J Biol Chem* 226: 247–262
- Igbasan FA, Akinsanmi SK (2012) Growth response and carcass quality of broiler chickens fed on diets supplemented with dietary copper sources. *Afr J Agric Res* 11:1674–1681
- Igbasan FA, Akinsanmi SK, Onibi G, Adu OA (2011) The effects of dietary supplementation of copper source and level on the oxidative stability of broiler meat assessed after refrigerated storage. *Int J Agric Res Rev* 1:53–58
- Inal F, Coskun B, Gulsen N, Kurtoglu V (2001) The effects of withdrawal of vitamin and trace mineral supplements from layer diets on egg yield and trace mineral composition. *Br Poult Sci* 42:77–80

- Kim G-B, Seo YM, Shin KS, Rhee AR, Han J, Paik IK (2011) Effects of supplemental copper-methionine chelate and copper-soy proteinate on the performance, blood parameters, liver mineral content, and intestinal microflora of broiler chickens. *J Appl Poult Res* 20:21–32
- Konjufca VH, Pesti GM, Bakalli RI (1997) Modulation of cholesterol levels in broiler meat by dietary garlic and copper. *Poult Sci* 76:1264–1271
- Kwiecień M, Winiarska-Mieczan A (2011) The effect of adding copper glycine chelate on fatty acid profile in chickens' breast muscle. *Zesz Nauk UP Wroc Biol Hod Zw* 580:317–326
- Lauritzen K, Martinsen G (1999) Copper induced lipid oxidation during salting of cod (*Gadus morhua* L.). *J Food Lipids* 6:299–315
- Lim HS, Paik IK, Sohn TI, Kim WY (2006) Effects of supplementary copper chelates in the form of methionine, chitosan and yeast on the performance of broilers. *Asian-Aust J Anim Sci* 19:1322–1327
- Liotta L, Chiofalo V, D'alessandro E, Macri F, Caristina G, Chiofalo B (2009) Use of organometallic chelates in broiler diet: effect on the performance and bone structure. Preliminary results. *Ital J Anim Sci* 8:763–765, Suppl. 2
- Makarski B, Zadura A, Kwiecień M (2006) The effect of Cu-lysine chelate in turkeys diets on the results of slaughter analysis, chemical composition and the fatty acids profile in tissues. *Acta Sci Pol Zootechnica* 5:57–66
- NRC (1994) National Research Council. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.
- Pang Y, Applegate TJ (2007) Effects of dietary copper supplementation and copper source on digesta pH, calcium, zinc, and copper complex size in the gastrointestinal tract of the broiler chicken. *Poult Sci* 86:531–637
- Pisulewski PM (2005) Nutritional potential for improving meat quality in poultry. *Anim Sci Pap Rep* 23:303–315
- Ramarathnam N, Rubin LJ, Diosady LL (1993) Studies on meat flavor. 4. Fractionation, characterization, and quantitation of volatiles from uncured and cured beef and chicken. *J Agric Food Chem* 41:939–945
- Resurreccion AVA (2003) Sensory aspects of consumer choices for meat and meat products. *Meat Sci* 66:11–20
- Rhee KS, Dutson TR, Smith GC, Hostetler RL, Reiser R (1982) Cholesterol content of raw and cooked beef longissimus muscles with different degrees of marbling. *J Food Sci* 47:716–719
- Rotenberg S, Anderson JO (1980) The effect of dietary citrus pectin on fatty acid content of the liver and small intestine in rats. *Acta Agric Scand* 30:8–12
- Santé V, Fernandez X (2000) The measurement of pH in raw and frozen turkey Pectoralis superficialis muscle. *Meat Sci* 55:503–506
- Saripinar-Aksu D, Aksu T, Önel SE (2012) Does inclusion at low levels of organically complexed minerals versus inorganic forms create a weakness in performance or antioxidant defense system in broiler diets? *Int J Poult Sci* 11:666–672
- Sasaki K, Nishioka T, Ishizuka Y, Saeki M, Kawashima T, Irie M, Mitsumoto M (2007) Comparison of sensory traits and preferences between food co-product fermented liquid (FCFL)-fed and formula-fed pork loin. *Asian-Aust J Anim Sci* 20:1272–1277
- Ševčíková S, Skřivan M, Skřivanová V, Tůmová E, Koucký M (2003) Effect of supplementation of copper in copper sulphate and Cu-glycine on fatty acid profile in meat of broiler chickens, cholesterol content and oxidation stability of fat. *Czech J Anim Sci* 4:432–440
- STATSOFT (1995) Statistica for Windows. StatSoft, Tulsa
- Swize SS, Harris KB, Savell JW, Cross HR (1992) Cholesterol content of lean and fat from beef, pork, lamb cuts. *J Food Comp Anal* 5:160–167
- Wang Z, Cerrate F, Coto C, Yan F, Waldroup PW (2007) Evaluation of Mintrex® copper as a source of copper in broiler diets. *Int J Poult Sci* 6:308–313
- Wang Z, Cerrate F, Yan F, Sacakli P, Waldroup PW (2008) Comparison of different concentrations of inorganic trace minerals in broiler diets on live performance and mineral excretion. *Int J Poult Sci* 7:625–629
- Williams SK, Damron BL (1998) Sensory and objective characteristics of broiler meat from commercial broilers fed rendered whole-hen meal. *Poult Sci* 77:329–333
- Winiarska-Mieczan A (2010) The influence of grass pea seeds in pig diets on the fatty acid composition and sensory attributes of pork. *Medycyna Wet* 66:113–117
- Yegani M, Korver DR (2010) Application of egg yolk antibodies as replacement for antibiotics in poultry. *World's Poult Sci J* 66:27–37