The chemical composition and sensory properties of raw, cooked and grilled thigh meat of broiler chickens fed with Fe-Gly chelate

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Abstract The study aimed to determine the effect of Fe-glycinate chelate (Fe-Gly) on the chemical composition and sensory value of thigh meat in Ross 308 broiler chickens. Two experimental factors were introduced: (1) organic or inorganic Fe, and (2) Fe level at 40, 20 or 10 mg/kg of feed. No negative effect of using 40, 20 or 10 mg Fe-glycine chelate was recorded on the chemical composition (crude protein, fat, ash, total cholesterol, Cu, Zn, Ca and total fatty acids: SFA, MUFA, PUFA and UFA, and the n-3 and n-6 fatty acid ratio) and on the sensory properties of raw, cooked and grilled thigh meat. However, an increase in Fe content in the meat of birds receiving 40 and 20 mg of Fe-Gly was found, which had no significant effect on the sensory attributes of meat. Based on the study results it can be concluded that Fe-Gly can be used in broiler feed instead of Fe sulphate.

Keywords Ferrous-glycine complexes · Chicken meat · Quality and sensory attributes of meat

Introduction

The chemical composition of poultry meat is strongly influenced by the bird feeding method (Pisulewski 2005; Kiczorowska et al. 2015). Modifications in the chemical composition of meat are connected with the assimilability of nutrients from feed and with their ratios. The nutrition can result either in an improved or deteriorated quality of meat (Morales-Barrera et al. 2013; Dwiloka et al. 2015; Szkucik et al. 2009; Talukder and Sharma 2010; Yogesh et al. 2015).

The results of studies referring to the inclusion of organic minerals (chelates) in poultry feed have recently been published. It was demonstrated that chelated minerals were characterised by better assimilability, and so could be used at levels even 75% lower than recommended with no significant reduction in the production performance and slaughter yield (Kwieceń et al. 2015; Winiarska-Mieczan and Kwieceń 2015), which reduces the excretion of minerals into the environment. The interest in chelates is connected with an increasing awareness among consumers who want to eat food that is not only highly valuable but is also produced without excessive environmental load. Due to such factors in the coming years chelates are likely to become a basic source of minerals for slaughter animals. Therefore, in the interests of consumers it should be checked whether the inclusion of chelated minerals would not contribute to adverse changes in meat quality. Research has shown that the inclusion of chelated copper, manganese and zinc did not reduce the organoleptic value of meat despite modifying its chemical composition, in comparison to chicks not receiving chelates (Winiarska-Mieczan and Kwieceń 2015; Kwieceń et al. 2014; Tronina et al. 2007).

The presented studies used ferrous-glycine chelate (Fe-Gly) as the experimental factor. The increased

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assimilability of chelated Fe can contribute to its increased concentration in meat. Iron has a beneficial effect on certain organoleptic properties of meat because it is a component of myoglobin responsible for the colour of meat (Mancini and Hunt 2005). However, excessive Fe content in meat can lower the quality of poultry meat since the element, both heme and non-heme, is a catalyst to the process of oxidation of fats in raw and cooked meat and forms an essential element of NADPH-affected lipid peroxidation (Tang et al. 2000). It is particularly important for thigh muscles as they contain more fat than breast muscles. In addition, Fe interacts with other minerals, and in particular with copper, a catalyst in oxidation reactions, which also affects the chemical composition of meat and at the same time its organoleptic properties. The study aimed to determine the effect of including Fe glycinate chelate (Fe-Gly) on the chemical composition and sensory value of thigh meat in broiler chickens.

Materials and methods

Chickens and experimental factors

The experiment was carried out after approval by the 2nd Local Ethics Committee at the University of Life Sciences in Lublin (No. 37/2011 of 17 May 2011). The birds were placed in cages in a room with an initial temperature of 32 °C. The temperature was gradually reduced in the rearing period until the fourth week (22°C). The birds had continual access to feed and water. Two hundred 1-day male Ross 308 chicks were divided at random into 4 treatment groups: Control, Fe-Gly-100%, Fe-Gly-50% and Fe-Gly-25%. Every group was composed of 50 male chicks locked in 5 cages, 10 birds per cage. Birds from the Control group received iron sulphate. In the Control group and Fe-Gly 100% group the birds were fed 40 mg Fe/kg feed. The amount provided full coverage of the mineral requirement of Ross 308 broilers (Aviagen 2013). In the Fe-Gly-50% group broilers were given 20 mg Fe/kg feed (50% of the requirement), while the Fe-Gly-25% received 10 mg Fe/kg feed (25% of the requirement). Wheat, corn and soybean meal-based feed mixtures were optimised according to NRC standards (1994) (Table 1). The production performance of broilers in the presented experiment has been described elsewhere (Kwiecień et al. 2015). The results showed no effect of the experimental factors (organic and inorganic form of Fe and 40, 20 and 10 mg Fe/kg feed) on weight gain on the 1st, 10th, 35th and 42nd day of the experiment, intake and conversion of feed per 1 kg of body weight and percentage share of thigh and breast meat in the carcass.

Meat sampling

On the 42nd day of the experiment, the animals were slaughtered. Ten birds from each group were selected at random for dissection. The birds were plucked immediately after slaughter. After 24 h of cooling at a temperature of 4 °C all meat from both thighs was dissected from the carcasses. Next, they were separated from the skin and placed one by one in hermetic plastic containers. The samples were frozen at a temperature of −20 °C for future chemical analysis.

Preparation of samples for analyses

The meat was thawed at room temperature. Afterwards, each sample was cut into three parts—one part was left unprocessed and two underwent heat treatment by cooking in a 0.6% NaCl solution (1:2 meat/water ratio) for 5 min from the moment the temperature inside the sample reached 76 °C or grilling on a gas grill for 4 min from the moment the temperature inside the sample reached 160 °C, as described elsewhere (Winiarska-Mieczan and Kwiecień 2015).

Chemical analyses

Basic chemical components were determined in raw as well as cooked and grilled muscles using the AOAC method (2000). The content of minerals (Fe, Cu, Zn, Ca) in feed mixtures and meat (550 °C, oxidant—hydrogen peroxide) was determined using the AAS method in a Unicam 939 apparatus (AA Spectrometer Unicam) according to Merck's standards (Germany). The determination methods are described in detail in the paper (Winiarska-Mieczan and Kwiecień 2015). Gas chromatography in a Varian CP-3800 GC-FID apparatus (Varian, Netherlands) using Supelco 37 FAME Mix 47885-U standards (Sigma, UK) was performed to determine the content and identify of fatty acids in feed mixtures and meat after previous extraction of fat by Folch's method in a Velp SER 148 apparatus (Velp, Italy) (Winiarska-Mieczan and Kwiecień 2015). Characteristic of the capillary column: type CP WAX 52CB, DF 0.25 mm × 60 mm, flow rate of gas (helium) carrier—1.4 ml/min, column temperature 120 °C gradually increasing by 2 °C/min up to 210 °C, determination time 120 min, detector FID temperature 260 °C, other gases—hydrogen and oxygen. The content of total cholesterol was determined by the colorimetric method using an EPOLL 20 colorimeter and C3045 standard (Sigma, USA) (Kwiecień et al. 2014; Winiarska-Mieczan and Kwiecień 2015). The pH of raw meat was determined 15 and 45 min after slaughter using a method developed by Santé and Fernandez (2000) in a Testo 205 pH-metre

Table 1 Calculated and determined nutrient composition of basal diet

	Starter (1–21 days)	Grower (22–35 days)	Finisher (36–42 days)
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
Values determined			
Fatty acids (g)			
Myristic (14:0)	0.03	0.07	0.07
Palmitic (16:0)	1.42	1.17	1.15
Stearic (18:0)	0.29	0.32	0.33
Oleic (18:1n-9)	2.25	2.24	2.19
Linoleic (18:2n-6)	4.72	4.95	4.96
Linolenic (18:3n-3)	1.18	0.86	0.89
Fe (mg)			
Control (40 mg Fe)	113.6	109.8	106.7
Fe-Gly 100% (40 mg Fe)	110.3	107.3	104.6
Fe-Gly 50% (20 mg Fe)	90.3	89.8	85.4
Fe-Gly-25% (10 mg Fe)	83.4	79.8	76.9
Cu (mg)	14.0	14.1	13.8
Zn (mg)	99.7	98.5	98.5
Ca (mg)	0.88	0.78	0.75

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%

(Testo AG, Germany), as described elsewhere (Winiarska-Mieczan and Kwiecień 2015). The apparatus was calibrated using certified buffer solutions with a pH of 4.01 and 7.0. All the analyses were performed in three replications.

Organoleptic assessment of cooked and grilled meat

The assessment was carried out in a room at ambient temperature and in daylight. The organoleptic quality of cooked and grilled meat was evaluated according to a 5-point scale as described elsewhere (Winiarska-Mieczan 2010; Kwiecień et al. 2014, Winiarska-Mieczan and Kwiecień 2015). A team of 10 people trained according to ISO 8586-2:1996 evaluated the juiciness, tenderness, aroma (desirability and intensity) and taste (desirability and intensity) of the meat. Each feature was scored from 1 (minimum) to 5 (maximum). The assessors received 25-gram samples of meat in disposable plastic containers with lids. The names of samples were encoded to avoid the carry-over effect. The assessment was repeated twice. To neutralise the taste, the assessors drank hot unsweetened tea between subsequent turns.

Statistical analysis

The results were analysed by statistical methods using Statistica 6.0 software. The arithmetic mean and standard deviation were calculated. Statistically significant differences between average values for respective groups were calculated by a one-factor variance analysis (ANOVA) using the t-Student–Newman–Keuls procedure.

Results

Chemical composition and pH value

The results of basic chemical composition analysis are shown in Table 2. The content of dry matter, crude ash and crude protein, and similarly the pH value in raw, cooked and grilled meat after 15 and 45 min, was not affected ($P < 0.05$) upon the inclusion of Fe-Gly. Raw meat in groups receiving Fe-Gly contained significantly less crude fat in comparison to the Control group; the least ($P < 0.05$) amount of fat was recorded in the Fe-Gly-50% group (Table 2). No significant effect

Table 2 The raw meat pH, and chemical composition of raw, cooked and grilled thigh meat samples

Meat	Control	Fe-Gly-100%	Fe-Gly-50%	Fe-Gly-25%	SEM	<i>P</i> value
Raw (<i>n</i> = 10)						
pH ₁₅	6.12	6.43	6.30	6.35	1.305	0.154
pH ₄₅	5.44	5.41	5.52	5.38	0.448	0.223
Moisture (%)	73.0	73.5	73.7	73.3	0.706	0.061
Crude ash (%)	1.20	1.22	1.10	1.13	2.554	0.054
Crude protein (%)	18.9	19.2	19.6	19.2	1.025	0.074
Crude fat (%)	6.18 ^c	6.04 ^b	5.86 ^a	6.08 ^b	0.114	0.012
Cholesterol (mg/100 g)	88.4 ^b	81.2 ^a	83.1 ^a	84.9 ^{ab}	0.025	0.042
Cooked (<i>n</i> = 10)						
Moisture (%)	68.3	67.2	67.9	67.0	0.710	0.056
Crude ash (%)	1.27	1.31	1.29	1.29	0.238	0.061
Crude protein (%)	19.6	20.1	18.9	21.5	0.022	0.124
Crude fat (%)	8.21	8.19	7.95	8.07	0.148	0.036
Cholesterol (mg/100 g)	95.5	90.4	89.8	94.3	0.887	0.101
Grilled (<i>n</i> = 10)						
Moisture (%)	63.2	64.8	66.6	65.5	1.338	0.513
Crude ash (%)	1.35	1.40	1.37	1.38	0.981	0.201
Crude protein (%)	23.4	22.8	22.6	22.9	0.227	0.063
Crude fat (%)	11.3	12.0	10.8	10.9	0.208	0.114
Cholesterol (mg/100 g)	97.2	91.8	88.7	93.2	0.368	0.059

SEM standard error of the means

^{a,b,c} Means with different superscripts in lines differ at *P* < 0.05; SEM—standard error of the means

of Fe-Gly on the content of crude fat in cooked and grilled meat was recorded. A lower level of total cholesterol in raw meat, compared to the Control group, was noted in the Fe-Gly-100% and Fe-Gly-50% groups. Then again, no significant effect of Fe-Gly on the content of cholesterol in cooked and grilled meat was found. The fatty acids composition of raw, cooked and grilled meat is shown in Table 3. No significant impact of Fe-Gly was recorded on total fatty acids: SFA, MUFA, PUFA and UFA, and the n-3 and n-6 fatty acid ratio in raw, cooked and grilled meat. Even though differences (*P* < 0.05) in the content of certain fatty acids were identified between the groups, the changes were not directional. They mostly referred to raw meat in which—compared to the Control group—the content of C12:0 acid in all Fe-Gly groups was significantly lower; the content of C24:0 acid in the groups Fe-Gly-50% and Fe-Gly-25% was significantly higher; the content of C20:1n-9 acid in the group Fe-Gly-100% was significantly higher and the content of C18:2n-6, C20:3n-9 and C20:5 acids in the group Fe-Gly-25% was significantly higher. In cooked meat—compared to the control group—the content of C16:1n-9 acid in the group Fe-Gly-25% was significantly higher, while the content of C20:1n-9 and C20:5 acids in the group Fe-Gly-50% was significantly lower. Also, the content of C20:3n-9 acid in the groups Fe-Gly-50% and Fe-Gly-25% was significantly lower. In grilled meat—compared to the control group—the content of C6:0 acids in the group Fe-Gly-25%, the content of C12:0 acids in

the groups Fe-Gly-50% and Fe-Gly-25% and the content of C16:1n-9 acids in the group Fe-Gly-50% was significantly lower, while the content of C22:2 in all groups receiving Fe-Gly was higher (*P* < 0.05).

Fe, Cu, Zn and Ca contents

The content of Cu, Zn and Ca in raw, cooked and grilled meat was not affected (*P* < 0.05) upon the inclusion of Fe-Gly (Table 4). In the Fe-Gly-100% group the content of Fe in raw and cooked meat was significantly higher compared to the Control group, while in the Fe-Gly-50% group it was significantly higher in raw and grilled meat in comparison to the Control group. In the group Fe-Gly-25% no statistically significant effect of the experimental factor on the content of Fe in raw, cooked and grilled meat was recorded in comparison to the Control group.

Organoleptic assessment

Table 5 gives the results of the sensory evaluation of thigh meat after cooking or grilling. No statistically significant effect of including Fe-Gly on the juiciness, tenderness, aroma (desirability, intensity) and taste (desirability, intensity) of cooked and grilled poultry meat was found in comparison to the Control group. It may be concluded that the addition of Fe-Gly at different levels does not

Table 3 Fatty acid profile of thigh meat samples (% of total fatty acids)

	Raw					Cooked					Grilled				
	Control					Control					Control				
	Fe-Gly-100%	Fe-Gly-50%	Fe-Gly-25%	SEM	P value	Fe-Gly-100%	Fe-Gly-50%	Fe-Gly-25%	SEM	P value	Fe-Gly-100%	Fe-Gly-50%	Fe-Gly-25%	SEM	P value
6:0	0.01	0.01	0.01	0.004	0.061	0.09	0.08	0.07	0.005	0.105	0.17 ^b	0.20 ^b	0.11 ^a	0.020	0.007
12:0	0.04 ^c	0.01 ^a	0.03 ^b	0.006	0.012	0.02	0.01	0.01	0.005	0.081	0.05 ^b	0.04 ^a	0.04 ^a	0.005	0.042
14:0	0.38	0.41	0.44	0.021	0.120	0.51	0.52	0.48	0.016	0.069	0.65	0.62	0.60	0.015	0.118
15:0	0.12	0.12	0.13	0.012	0.235	0.12	0.10	0.09	0.009	0.215	0.13	0.13	0.12	0.005	0.063
16:0	22.9	23.5	23.8	0.846	0.114	26.5	26.9	25.4	0.371	0.055	28.7	28.4	30.5	0.466	0.207
17:0	0.10	0.09	0.07	0.026	0.110	0.17	0.19	0.20	0.018	0.074	0.12	0.14	0.12	0.010	0.058
18:0	8.35	8.87	8.46	0.183	0.201	7.58	7.62	7.33	0.146	0.220	8.02	7.91	7.65	0.077	0.061
20:0	0.15	0.15	0.12	0.023	0.322	0.11	0.08	0.09	0.008	0.052	0.12	0.12	0.11	0.003	0.055
23:0	0.05	0.04	0.05	0.003	0.043	0.01	0.02	0.02	0.004	0.000	0.08	0.07	0.08	0.004	0.105
24:0	0.01 ^a	0.01 ^a	0.02 ^b	0.003	0.027	0.01	0.01	0.01	0.004	0.008	0.00	0.00	0.00	0.003	0.224
14:1	0.12 ^{ab}	0.09 ^a	0.11 ^{ab}	0.015	0.040	0.15	0.18	0.19	0.009	0.074	0.13	0.15	0.14	0.006	0.061
15:1	0.11	0.11	0.12	0.003	0.085	0.10	0.09	0.11	0.005	0.118	0.19	0.17	0.08	0.024	0.114
16:1n-7	0.48	0.51	0.46	0.028	0.133	0.45	0.48	0.45	0.016	0.071	0.53	0.54	0.55	0.005	0.059
16:1n-9	7.11	6.85	7.05	0.230	0.112	5.35 ^a	5.48 ^a	5.51 ^a	0.199	0.045	4.51 ^b	4.41 ^b	4.48 ^b	0.123	0.041
18:1n-7	1.58	1.60	1.61	0.021	0.060	2.23	2.24	2.15	0.022	0.241	2.36	2.33	2.55	0.055	0.308
18:1n-9	41.2	40.2	40.6	0.833	0.084	40.5	39.8	41.3	0.505	0.108	38.9	39.2	38.2	0.217	0.066
20:1n-7	0.25	0.22	0.22	0.033	0.261	0.18	0.16	0.17	0.031	0.066	0.33	0.33	0.31	0.012	0.091
20:1n-9	0.14 ^a	0.21 ^b	0.15 ^a	0.016	0.040	0.28 ^b	0.27 ^b	0.21 ^a	0.031	0.031	0.33	0.32	0.28	0.011	0.067
18:2n-6	15.8 ^b	15.4 ^{ab}	14.6 ^a	0.290	0.021	14.5	14.4	14.9	0.202	0.118	13.4	13.4	13.3	0.096	0.150
22:2	0.01	0.01	0.01	0.003	0.227	0.02	0.02	0.02	0.006	0.237	0.00 ^a	0.01 ^b	0.01 ^b	0.003	0.041
18:3n-3	0.66	0.56	0.69	0.026	0.078	0.86	0.79	0.81	0.015	0.107	0.77 ^{ab}	0.82 ^b	0.69 ^a	0.030	0.009
18:3n-6	0.02	0.02	0.02	0.003	0.220	0.03	0.03	0.03	0.003	0.084	0.08	0.06	0.08	0.006	0.085
20:3n-6	0.06	0.05	0.06	0.003	0.081	0.09	0.07	0.07	0.011	0.150	0.09	0.07	0.09	0.004	0.218
20:3n-9	0.04 ^b	0.04 ^b	0.03 ^a	0.004	0.048	0.02 ^b	0.02 ^b	0.01 ^a	0.003	0.000	0.01	0.01	0.01	0.000	0.304
20:4n-6	0.35	0.41	0.37	0.017	0.071	0.20	0.21	0.20	0.011	0.066	0.28	0.25	0.32	0.013	0.244
20:5	0.24 ^{bc}	0.21 ^b	0.12 ^a	0.034	0.004	0.09 ^b	0.09 ^b	0.06 ^a	0.006	0.007	0.16	0.18	0.17	0.006	0.068
22:5	0.02	0.02	0.02	0.004	0.318	0.01	0.01	0.01	0.003	0.246	0.01	0.01	0.01	0.003	0.153
Σ SFA	32.1	33.2	33.1	29.2	0.950	0.097	35.1	33.7	0.381	0.118	38.1	38.2	39.3	0.368	0.083
Σ MUFA	51.0	49.8	51.1	53.9	0.857	0.114	49.2	50.1	0.329	0.087	47.3	47.2	46.4	0.222	0.064
Σ PUFA	17.2	16.6	16.0	17.5	0.326	0.059	15.8	16.3	0.180	0.069	14.7	14.8	14.6	0.118	0.121
Σ UFA	68.2	66.4	67.2	71.3	1.082	0.068	64.9	66.4	0.473	0.304	62.0	62.1	61.0	0.296	0.093
Σ PUFA n-6	16.2	15.8	15.2	0.292	0.204	14.7	14.5	15.4	0.196	0.067	13.8	13.9	13.8	0.094	0.604
Σ PUFA n-3	0.66	0.56	0.69	0.028	0.087	0.86	0.79	0.81	0.015	0.105	0.77	0.72	0.69	0.029	0.059
Σ PUFA/SFA	0.54	0.50	0.48	0.026	0.331	0.45	0.44	0.48	0.010	0.124	0.39	0.39	0.40	0.006	0.113
n-6/n-3	24.6	28.2	22.0	25.8	1.292	0.051	17.1	19.0	0.393	0.081	17.9	19.3	19.9	0.620	0.094

SEM standard error of the means, SFA saturated fatty acids, MUFA monounsaturated fatty acids, PUFA polyunsaturated fatty acids, UFA unsaturated fatty acids
^{a,b,c} Means with different superscripts in lines differ at $P < 0.05$

Table 4 Fe, Cu, Zn and Ca content in the thigh meat (mg/100 g)

Meat	Control	Fe-Gly-100%	Fe-Gly-50%	Fe-Gly-25%	SEM	<i>P</i> value
Raw (n = 10)						
Fe	0.591 ^a	0.621 ^b	0.620 ^b	0.608 ^{ab}	0.158	0.040
Cu	0.042	0.040	0.040	0.046	0.033	0.054
Zn	1.784	1.789	1.821	1.803	0.087	0.140
Ca	0.002	0.002	0.002	0.002	0.003	0.052
Cooked (n = 10)						
Fe	1.612 ^a	1.651 ^b	1.614 ^a	1.589 ^a	0.298	0.055
Cu	0.032	0.034	0.035	0.031	0.115	0.063
Zn	1.873	1.878	1.889	1.902	0.048	0.064
Ca	0.001	0.001	0.001	0.001	0.027	0.097
Grilled (n = 10)						
Fe	1.582 ^a	1.610 ^{ab}	1.618 ^b	1.589 ^a	0.333	0.148
Cu	0.033	0.030	0.031	0.031	0.830	0.081
Zn	1.984	2.014	1.973	2.044	0.212	0.055
Ca	0.001	0.001	0.001	0.001	0.058	0.068

SEM standard error of the means

^{a,b} Means with different superscripts in lines differ at *P* < 0.05**Table 5** The sensory characteristic of cooked and grilled thigh meat of chicken (points: 1—minimum, 5—maximum)

Meat	Control	Fe-Gly-100%	Fe-Gly-50%	Fe-Gly-25%	SEM	<i>P</i> value
Cooked (n = 10)						
Juiciness	4.77	4.69	4.73	4.73	0.188	0.057
Tenderness	4.75	4.82	4.81	4.78	0.348	0.210
Aroma						
Desirability	4.85	4.82	4.78	4.72	0.860	0.061
Intensity	4.59	4.66	4.60	4.63	0.024	0.055
Taste						
Desirability	4.56	4.48	4.51	4.53	0.042	0.223
Intensity	4.33	4.37	4.35	4.36	0.204	0.070
Grilled (n = 10)						
Juiciness	4.44	4.46	4.44	4.52	0.341	0.059
Tenderness	4.68	4.67	4.55	4.59	0.018	0.232
Aroma						
Desirability	4.83	4.88	4.90	4.89	0.311	0.102
Intensity	4.75	4.77	4.61	4.59	0.027	0.068
Taste						
Desirability	4.75	4.82	4.79	4.69	0.335	0.073
Intensity	4.64	4.66	4.70	4.68	0.013	0.114

SEM standard error of the means

negatively influence the quality of meat, compared to iron sulphate (Control group).

Discussion

The presented studies were carried out to check whether the inclusion of Fe-glycine chelates in broiler chicken feed would deteriorate the quality of thigh meat (chemical

composition, organoleptic assessment) compared to birds receiving Fe-sulphate used as a standard in feed mixtures for poultry available in Poland. It was determined that the inclusion of Fe-Gly in the mixtures contributed to the modification of only some chemical components in raw, cooked and/or grilled meat. However, it should be emphasized that such modifications did not reduce the nutritive value of the meat. Similar conclusions were drawn during analysis of the chemical composition of the breast meat of

broiler chickens receiving Fe-glycine chelate (40, 20 or 10 mg) (Kwiecień et al. 2014). The results of studies investigating the inclusion of Cu- and Zn-glycine chelates in broiler chicken feed presented elsewhere showed no negative impact on the chemical composition of meat either. Although some modifications were found in the content of Fe, total fat and respective fatty acids, they had no adverse effect on the organoleptic properties of meat (Winiarska-Mieczan and Kwiecień 2015; Tronina et al. 2007).

The present study revealed that the raw meat of chickens receiving Fe-Gly chelate contained significantly less total cholesterol than the meat of chickens receiving Fe-sulphate. Similarly, the level of cholesterol in raw breast meat of chickens receiving 40, 20 and 10 mg Fe-Gly chelate/kg was significantly lower in comparison to the meat of chickens receiving Fe-sulphate (Kwiecień et al. 2014). The available literature contains little information about the effect of including Fe-chelates on the cholesterol content in muscles. However, it can be supposed that Fe in an easily assimilable organic form has a more effective influence on lipid transformations in the animal body than inorganic Fe. Iron is a part of adrenodoxin—one of the components of the cholesterol desmolase complex triggering the transformation of cholesterol into pregnenolone (Harteneck 2013). It has been shown that the rate at which cholesterol is converted into pregnenolone depends on the concentration of adrenodoxin (Tuckey and Headlam 2002). During the heat treatment of meat, cholesterol moves from the adipose tissue to muscles, so meat after culinary treatment contains more cholesterol than raw meat (Swize et al. 1992). The fundamental reason of the higher content of total cholesterol in the cookery processed meat is, after all, a change in the proportion of chemical components caused by the water content decrease.

The presented studies have shown that copper-glycine chelate did not significantly modify the content of Cu, Zn and Ca in raw and heat-treated meat. However, an increased Fe content was found in the meat of birds receiving chelate covering 100 and 50% of the requirement (40 and 20 mg Fe/kg). It can be supposed that the increase in Fe content in the meat of chickens from these groups is connected with the higher bioavailability of Fe administered in the form of chelates in comparison to sulphate (Pineda and Ashmead 2001; Nollet et al. 2008). Moreover, studies by some authors revealed that Fe sourced from complexes with glycine was more assimilable than with other aminoacids (Pineda and Ashmead 2001; Ettle et al. 2008). According to Ma et al. (2012) the inclusion of Fe-Gly in broiler chicken feed contributes to an increased accumulation of Fe in tissues compared to iron sulphate. Studies by Seo et al. (2008a, b) also demonstrated an increased content of Fe in the meat from the legs of broilers receiving 100 or 200 ppm Fe as a

chelate with methionine compared to chickens receiving iron sulphate.

Iron has a beneficial effect on certain organoleptic properties of meat because it is a component of myoglobin, responsible for the colour of meat (Mancini and Hunt 2005). Because of heat treatment iron in metmyoglobin is oxidised and a brown iron hemichrome is formed (Faustman et al. 2010). Then, the colour of meat irrevocably turns from red to brown. An excessive content of Fe in meat can adversely affect meat quality since Fe is a catalyst to the process of oxidation of fats, both in raw and cooked meat (Tang et al. 2000). In addition, Fe interacts with other minerals and in particular with copper, a catalyst in oxidation reactions. As a result of lipid oxidation in meat low-molecule volatile compounds are formed that are responsible for the undesirable rancid aroma and taste, unacceptable to consumers (Coulon and Priolo 2002). Oxidation of meat lipids also has an adverse effect on its colour and texture (Coulon and Priolo 2002) and nutritive value, mostly because of destroying unsaturated fatty acids and lipophilic vitamins (Chwastowska-Siwiecka et al. 2014) and causing the formation of toxic cholesterol oxidation products (Boselli et al. 2012). It is particularly important for thigh muscles as they contain more fat than breast muscles.

The content of chemical components in meat is reflected in meat quality, including organoleptic characteristics (Nowak et al. 2005). The palatability of meat is a result of the combination of two sensory factors: aroma and taste. Aroma, sensed more easily than taste, is deemed a more important and more characteristic feature. The aroma of meat is determined, in the first place, by proportions between saturated and unsaturated fatty acids, and by aldehydes, ketones and alcohols (Ramarathnam et al. 1993). Polyunsaturated fatty acids increase sensitivity to peroxidation, leading to unpleasant odours (Coulon and Priolo 2002). Changes in proportions between saturated and unsaturated acids are also an adverse phenomenon from the dietary point of view. The presented studies did not find any significant effect of Fe-Gly chelate on the proportions between saturated and unsaturated fatty acids (MUFA, PUFA, UFA), despite noted differences in the content of certain acids between the groups. Since the nature of the modifications was not directional, according to the obtained results the effect of including Fe-Gly chelate and of the dose of the chelate on the fatty acids profile in the thigh meat of broiler chickens cannot be clearly determined.

The aroma and taste of heat-treated meat is an effect of the interaction of proteins and peptides with volatile odorants (Pérez-Juan et al. 2008), Maillard reactions involving amino compounds and carbonyl compounds (Mottram 1998) and oxidation of fatty acids producing

volatile and non-volatile products (Gandemer 2002). In the presented studies the organoleptic assessment (juiciness, tenderness, aroma—intensity and desirability, taste—intensity and desirability) of the meat of chickens receiving Fe-Gly chelate did not significantly differ from the meat of chickens fed standard diets (with sulphate being the source of Fe). This is mainly due to slight modifications in the chemical composition of meat of experimental chickens compared to the control group. Also, analysis of the organoleptic quality of the breast meat of broiler chickens receiving 40, 20 or 10 mg Fe-Gly chelate/kg of feed revealed no negative effect of the inclusion of chelate (Kwiecień et al. 2014).

Conclusion

Based on the obtained results it can be concluded that the inclusion of Fe-glycine chelate in the feed for broiler chickens has no negative effect on the chemical composition, and juiciness, tenderness, aroma and taste of thigh meat. In addition, the previously published results of the experiment showed that the chelate had no negative effect on the chemical composition and organoleptic properties of breast meat (Kwiecień et al. 2014) and production performance and slaughter yield (Kwiecień et al. 2015). Based on such observations it can be concluded that Fe-Gly chelate can be used in broiler feed instead of Fe-sulphate.

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