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ORIGINAL PAPER

NUTRITIONAL VALUE AND CONTENT OF MINERAL ELEMENTS IN THE MEAT OF BROILER CHICKENS FED *BOSWELLIA SERRATA* SUPPLEMENTED DIETS

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Abstract

The aim of the study was to assess the effect of different levels of *Boswellia serrata* supplementation in broiler chicken diet on the basic chemical composition and the Ca, Mg, Cu, Fe, and Zn content in breast and drumstick muscles. The analyses involved 200 Ross 308 chickens divided into 4 groups. The broiler chickens were fed diets containing 0 (C), 3 (BSR3), 4 (BSR4), and 5% (BSR5) of *Boswellia serrata* resin. In the chicken breast and drumstick muscles, the contents of dry mass, total protein, crude fat, and crude ash were determined and their energy value (net Atwater equivalents) was calculated. Additionally, the Ca, Mg, P, Fe, Zn, and Cu levels were determined. In the present study, there were no differences in the proportion of the breast and drumstick muscles in the carcass or in their dry mass, total protein, and crude ash content. The supplementation of broiler chicken diets with 3% (BSR3) and 4% (BSR4) of *Boswellia serrata* resin decreased quadratically ($P < 0.05$) the content of crude fat and the calorific value of the breast and drumstick muscles. An increased level of Ca (control vs. BSR diets, and linear, $P < 0.05$) in the breast muscles and P (control vs. BSR diets, and quadratic, $P < 0.05$) in the drumstick muscles was noted in the BSR3 and BSR4 chicken groups. The Mg content in the muscles of the examined broiler chickens remained at a similar level, irrespective of the amount of the supplement added. The BSR supplementation reduced Cu (in the breast and drumstick muscles) ($P < 0.05$) and Fe retention (in the drumstick muscles) (C vs. BSR, linear, $P < 0.05$). Further investigations are necessary to elucidate the mechanisms associated with the effect of *Boswellia serrata* on the level of microelement retention in muscles. In summary, *Boswellia serrata* can be considered a good feed additive with a positive impact on the dietary value of poultry meat.

Keywords: poultry meat, basic composition, mineral elements, *Boswellia serrata* resin.

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INTRODUCTION

Phytobiotics are being increasingly used in modern poultry production. With their content of bioactive compounds, they have a beneficial impact on the breeding efficiency and health status of poultry as well as the nutritional properties and meat flavor values (Cho et al. 2014). Herbs, e.g. oregano, thyme, garlic, basil, or mint are the most common additives (Alfaig et al. 2013, Kirkpinar et al. 2014, Zeng et al. 2015).

Currently, this group of supplements also comprises resins, e.g. from *Boswellia serrata*, which are exotic additives on the European market. The resin is a botanical feed additive approved for use in poultry production by the European Union Register of Feed Additives pursuant to Regulation (EC) No 1831/2003 (EURFA 2016). *Boswellia serrata* resin is widely used in Ayurvedic medicine, as it exerts a multidirectional impact on the organism, i.e. anti-inflammatory, antiseptic, analgesic, antibacterial, anticancer, hepatoprotective, hypolipidemic, hypocholesterolaemic, immunomodulatory, and antiproliferative action, which is associated with its favorable chemical composition (Ammon 2010). Its potential to be applied in poultry production has been still insufficiently explored; however, this issue has already been partly investigated and preliminary results confirm the beneficial impact of diet supplementation with *Boswellia serrata* resin on the efficiency of broiler chicken breeding (Kiczorowska et al. 2016*a*,*b*, Tabatabaei 2016).

Therefore, the aim of the study was to determine the effect of different levels of *Boswellia serrata* resin supplementation in diets for broiler chickens on the content of basic nutrients and selected minerals in breast and drumsticks muscles.

MATERIALS AND METHODS

Two-hundred 1-day-old broiler chickens (Ross 308, Aviagen, Cracow, Malopolskie province, Poland) were randomly assigned to 4 dietary treatments with 5 cages per treatment and 5 females and 5 males per cage. The experiment lasted 6 weeks. The experiment was carried out after an approval issued by the Second Local Ethics Committee at the University of Life Sciences in Lublin (No. 27/2014).

The basal feed diets were made from cereal meal middlings (wheat and corn) and post-extraction soybean meal as recommended (Aviagen 2014). The broiler chickens were fed 3 types of diets: starter (0 to 21 day), grower (21 to 35 day), and finisher (35 to 42 day), the detailed composition of the diets in each stage of animal feeding was presented in our previous research (Kiczorowska et al. 2016*a*) – Table 1. The starter diet was fed to the broiler chickens in a crumbled form, and the grower and finisher diets were delive-

Table 1

Dietary ingredients and the nutrient content of the experimental diets (as-fed basis)

Item	Diets*											
	starter (0 to 21 day)				grower (21 to 35 day)				finisher (35 to 42 day)			
	C	BSR3	BSR4	BSR5	C	BSR3	BSR4	BSR5	C	BSR3	BSR4	BSR5
Ingredients (%)												
Wheat	20.0	20.0	20.0	20.0	23.0	23.0	23.0	23.0	26.0	26.0	26.0	26.0
Soybean meal, 46% CP **	39.47	38.47	39.47	39.47	36.76	36.76	37.26	37.26	32.13	31.13	31.13	31.13
Maize	30.0	30.0	28.0	27.0	29.0	28.0	27.0	26.0	30.0	30.0	29.0	28.0
Boswellia serrata (resin)	-	3.0	4.0	5.0	-	3.0	4.0	5.0	-	3.0	4.0	5.0
Soybean oil	6.0	4.0	4.0	4.0	7.0	5.0	4.5	4.5	8.0	6.0	6.0	6.0
Dicalcium phosphate	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Limestone	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0	0.7	0.7	0.7	0.7
NaCl	0.33	0.33	0.33	0.33	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
DL-Met ***	0.36	0.36	0.36	0.36	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
L-Lys ****	0.34	0.34	0.34	0.34	0.36	0.36	0.36	0.36	0.34	0.34	0.34	0.34
Vitamin-mineral premix *****	0.5	0.5	0.5	0.5	0.25	0.25	0.25	0.25	0.2	0.2	0.2	0.2
Chemical composition												
MEn ****** (MJ kg^{-1})	12.55	12.55	12.55	12.55	12.97	12.97	12.97	12.97	13.39	13.39	13.39	13.39
CP (g kg^{-1})	212.2	211.9	212.4	212.6	192.1	192.8	193.4	193.5	185.4	185.5	185.9	185.6
Lys (g kg^{-1})	13.81	13.79	13.84	13.76	12.91	12.84	12.86	12.95	11.36	11.33	11.41	11.45
Met + Cys (g kg^{-1})	10.53	10.48	10.54	10.51	9.83	9.76	9.86	9.81	9.03	8.94	9.11	9.08
Ca (g kg^{-1})	9.67	9.54	9.59	9.63	8.74	8.67	8.65	8.73	7.93	7.95	7.88	7.96
P (g kg^{-1})	5.79	5.69	5.76	5.85	5.31	5.33	5.41	5.38	3.93	3.98	3.79	4.01
Na (g kg^{-1})	1.68	1.73	1.75	1.74	1.71	1.69	1.65	1.74	1.76	1.62	1.78	1.64

*Treatments: C = control diet without *Boswellia serrata* supplementation; BSR3 = diet with 3% *Boswellia serrata* supplementation, BSR4 = diet with 4% *Boswellia serrata* supplementation; BSR5 = diet with 5% *Boswellia serrata* supplementation;
** CP = crude protein;
*** Evonik Degussa Gmbh, Essen, Germany (per kg of 990 g Met);
**** Ajinomoto Eurolysine S.A.S., Amiens. France (per kg of 780 g Lys);
***** Added minerals and vitamins per kg of starter diet: Mn, 100 mg; I, 1 mg; Fe, 40 mg; Zn, 100 mg; Se, 0.15 mg; Cu, 10 mg; vitamin A, 15,000 IU; vitamin D_3, 5,000 UI; vitamin E, 75 mg; vitamin K_3, 4 mg; vitamin B_1, 3 mg; vitamin B_2, 8 mg; vitamin B_6, 5 mg; vitamin B_{12}, 0.016 mg; biotin, 0.2 mg; folic acid, 2 mg; nicotic acid, 60 mg; pantothenic acid, 18 mg; choline, 1,800 mg. Added minerals and vitamins per kg of grower diet: Mn, 100 mg; I, 1 mg; Fe, 40 mg; Zn, 100 mg; Se, 0.15 mg; Cu, 10 mg; vitamin A, 12,000 IU; vitamin D_3, 5,000 UI; vitamin E, 50 mg; vitamin K_3, 3 mg; vitamin B_1, 2 mg; vitamin B_2, 6 mg; vitamin B_6, 4 mg; vitamin B_{12}, 0.016 mg; biotin, 0.2 mg; folic acid, 1.75 mg; nicotic acid, 60 mg; pantothenic acid, 18 mg; choline, 1,600 mg. Added minerals and vitamins per kg of finisher diet: Mn, 100 mg; I, 1 mg; Fe, 40 mg; Zn, 100 mg; Se, 0.15 mg; Cu, 10 mg; vitamin A ,12,000 IU; vitamin D_3, 5,000 UI; vitamin E, 50 mg; vitamin K_3, 2 mg; vitamin B_1, 2 mg; vitamin B_2, 5 mg; vitamin B_6, 3 mg; vitamin B_{12}, 0.011 mg; biotin, 0.05 mg; folic acid, 1.5 mg; nicotic acid, 35 mg; pantothenic acid, 18 mg; choline, 1,600 mg; and
****** MEn = metabolizable energy (ME) in the diets corrected to zero nitrogen balance.

red in a granulated form. The resin was obtained from *Boswellia serrata* trees by incision of a bark-less trunk and left to dry in natural conditions (direct information from the seller). Fragmented natural *Boswellia serrata* resin (BSR) was obtained commercially (Baghdad, Iraq). The resin added to the mixtures contained 95.34% of dry matter, 1.59% d.m. of ash, 2.65% d.m. of protein, 63.88% d.m. of fat. Dietary treatments consisted of the control (C) and the control supplemented with 3% (BSR3), 4% (BSR4), or 5% (BSR5) of *Boswellia serrata* resin. All the diets were iso-energetic and iso-nitrogenous.

One female and 1 male broiler chickens with the body weight close to the average were selected from each cage for dissection, which was carried out according to the method described by Ziołecki, Doruchowski (1989). For slaughter analysis, breast and drumstick muscles were sampled and the basic nutrients and selected mineral elements were determined.

The contents of dry matter, total protein, ether extract, and crude ash were determined in the experimental material according to standard procedures (AACC 2000). The energy value was estimated using net Atwater equivalents (considering protein and fat).

The contents of Ca, Mg, Cu, and Zn were measured using flame atomic absorption spectrophotometry (FAAS) (Unicam 939/959AA-6300, Shimadzu Corp., Tokyo, Japan), according to the Polish Standard (PN-EN ISO 6869:2002), and the total P content was determined colorimetrically (PN-76/R-64781:1976) with a Helios Alpha UV-VIS apparatus (Spectronic Unicam, Leeds, United Kingdom).

Each cage was used as a statistical unit. The data obtained were elaborated with the ANOVA method using one-way analysis of variance (a = 95; $P < 0.05$) and calculating the mean values for the treatments ($\overline{x}$) and the standard error of the mean (SEM). Linear and quadratic polynomial contrasts were used to evaluate the effects of different dietary levels of *Boswellia serrata* resin. The direction and intensity of the relationships between the level of *Boswellia seratta* resin addition and the basic nutrients and mineral elements (r_1 in text only), and between each basic nutrient and mineral content in the broiler chickens meat were determined using the Pearson correlation coefficients (r_2 in Table 2). The significance of differences was determined with Statistica 10.0 software (StatSoft Inc. 2011).

RESULTS AND DISCUSSION

The contents of nutrients in chicken meats differed, depending mainly on the type of meat (Tables 1, 3). Similar concentrations of the basic nutrients, macroelements and trace elements in the muscles of broiler chickens were reported in the available literature (Kunachowicz et al. 2015, USDA 2016). The *Boswellia serrata* resin (BSR) supplementation in the

Table 2

The correlation coefficients between basic nutrients and mineral elements in the breast and drumstick muscles (r_2^*)

Drumstick muscles	Breast muscles									
	Ca	Mg	P	Cu	Fe	Zn	Dry matter	Crude protein	Ether extract	Crude ash
Ca	**0.922**	-0.454	-0.109	**0.608**	**0.988**	0.554	-0.067	**0.740**	**-0.983**	0.105
Mg	**-0.879**	-0.129	**0.652**	**-0.798**	**0.793**	**-0.728**	-0.509	**-0.892**	**0.914**	0.475
P	**-0.670**	**0.784**	-0.482	-0.323	**-0.796**	0.025	**0.628**	-0.220	**0.699**	**-0.658**
Cu	**-0.765**	**0.699**	-0.192	-0.596	**-0.789**	-0.280	0.362	-0.506	**0.884**	-0.397
Fe	**0.840**	0.269	**-0.754**	**0.793**	0.625	0.671	**0.626**	**0.917**	**-0.847**	-0.596
Zn	**0.765**	0.435	**-0.858**	**0.758**	0.477	**0.998**	**0.754**	**0.783**	**-0.740**	**-0.729**
Dry matter	**-0.886**	-0.093	**0.625**	**-0.898**	**-0.754**	**-0.914**	-0.478	**-0.985**	**0.928**	0.444
Crude protein	**0.670**	**-0.791**	0.325	0.481	**0.959**	0.146	-0.486	0.383	**-0.811**	0.519
Ether extract	**-0.905**	0.492	0.066	**-0.782**	**-0.994**	-0.517	0.110	**-0.711**	**0.974**	-0.148
Crude ash	**0.793**	0.548	**-0.917**	-0.215	0.359	**0.998**	**0.833**	**0.951**	**-0.647**	**-0.811**

* the following scale was used in the interpretation of the correlation coefficient: $0 < r < 0.3$ – a low degree of correlation; $0.3 \leq r < 0.5$ – moderate correlation; $0.5 \leq r < 1$ – a high degree of correlation. Significance values are in bold, $P < 0.05$.

broiler chicken diets quadratically decreased the ether extract in the breast and drumstick muscles ($P < 0.05$); also there was a noted decrease in this nutrient contained in muscles compared to the control group (C), ($P < 0.05$ – Tables 3, 4). The other nutrients determined in the muscles of chickens from all the treatment groups were on similar levels. There was no effect of the BSR supplementation on the proportion of the breast and drumstick muscles in the carcass (Tables 3, 4).

The improvement of the dietary value of the poultry meat observed upon the BSR supplementation can be ascribed to the properties of boswellic acid, which is the major constituent of the resin (AL-YASIRY, KICZOROWSKA 2016). The acid has potent antibacterial and immunostimulatory activity, which optimally stabilizes the intestinal microbiota (HAMIDPOUR et al. 2015). Previous investigations conducted by the authors of the present paper confirmed the favorable effect of BSR on the structure of intestinal villi, gastrointestinal microflora and chicken health status, which was reflected in improved breeding performance and feed nutrient intake (KICZOROWSKA et al. 2016*a*,*b*). Change in the fat content resulted in a quadratically decreased calorific value of the breast muscles ($P = 0.041$) and drumstick muscles ($P = 0.038$) in the broiler chickens from the BSR3 and BSR4 treatments.

Table 3

The content of basic nutrients and mineral elements in drumstick muscle of broiler chickens in natural matter * ($\bar{x}$)

Item	Proportion in chilled carcass (%)	Basic nutrients (g kg^{-1})				Energy (kcal)	Mineral elements (mg kg^{-1})					
		dry matter	crude protein	ether extract	crude ash		Ca	Mg	P	Cu	Fe	Zn
Treatments**												
C	17.45	26.04	19.32	5.69	1.03	128.49	8.07	21.11	194.12	0.078	0.647	1.520
BSR3	19.21	25.41	19.79	4.64	0.98	116.92	6.12	23.05	203.08	0.049	0.656	1.463
BSR4	19.08	25.01	18.98	4.97	1.06	120.17	6.03	22.18	211.20	0.051	0.704	1.498
BSR5	16.89	25.91	18.23	6.71	0.97	136.59	5.34	24.01	215.19	0.054	0.624	1.452
SEM	0.43	0.56	0.37	0.04	0.01	19.78	0.05	<0.01	27.31	<0.01	0.03	0.09
P-value												
C vs. BSR	0.089	0.249	0.197	0.013	0.089	0.024	0.145	0.238	0.047	0.032	0.139	0.246
Linear	0.214	0.345	0.459	0.348	0.164	0.417	0.078	0.468	0.036	0.348	0.267	0.478
Quadratic	0.348	0.291	0.634	0.047	0.379	0.038	0.257	0.362	0.264	0.674	0.078	0.261

* Data represent the mean of 5 cages (2 broiler chickens/cage) per treatment
**Treatments: C = control diet without *Boswellia serrata* supplementation; BSR3 = diet with 3% *Boswellia serrata* supplementation, BSR4 = diet with 4% *Boswellia serrata* supplementation; BSR5 = diet with 5% *Boswellia serrata* supplementation

Table 4

The content of basic nutrients and mineral elements in breast muscle of broiler chickens in natural matter * ($\bar{x}$)

Item	Proportion in chilled carcass (%)	Basic nutrients (g kg^{-1})				Energy (kcal)	Mineral elements (mg kg^{-1})					
		dry matter	crude protein	ether extract	crude ash		Ca	Mg	P	Cu	Fe	Zn
Treatments**												
C	20.19	25.89	23.74	1.03	1.12	104.23	28.02	16.43	240.01	0.045	0.473	0.496
BSR3	23.47	25.07	23.06	0.87	1.14	100.07	31.13	15.13	238.12	0.034	0.467	0.516
BSR4	20.46	25.22	23.25	0.85	1.12	100.65	33.24	16.26	232.07	0.039	0.453	0.548
BSR5	19.87	25.14	22.93	1.08	1.13	101.44	26.09	16.07	236.24	0.029	0.414	0.509
SEM	0.59	0.76	0.63	0.01	0.03	12.42	0.41	0.013	24.01	<0.01	<0.01	<0.01
P-value												
C vs. BSR	0.187	0.278	0.157	0.021	0.345	0.028	0.037	0.168	0.203	0.019	0.025	0.138
Linear	0.248	0.672	0.297	0.363	0.197	0.352	0.023	0.267	0.109	0.458	0.019	0.674
Quadratic	0.315	0.547	0.346	0.031	0.621	0.041	0.492	0.574	0.378	0.649	0.376	0.537

* Data represent the mean of 5 cages (2 broiler chickens/cage) per treatment
** Treatments: C = control diet without *Boswellia serrata* supplementation; BSR3 = diet with 3% *Boswellia serrata* supplementation, BSR4 = diet with 4% *Boswellia serrata* supplementation; BSR5 = diet with 5% *Boswellia serrata* supplementation

A beneficial effect of the *Boswellia serrata* resin on the Ca content in breast muscles (control vs. BSR diets, linear, $P < 0.05$) – Table 3 and P content in drumstick muscles (control vs. BSR diets, quadratic, $P < 0.05$) was noted in the BSR3 and BS4 treatment groups (Table 4). Additionally, a strong negative correlation was found between the Ca content in the breast muscle and the P content in the drumstick muscle (r_2 = -0.670) – Table 2. Simultaneously, the P content was positively correlated with the level of BRS supplementation (r_1 = 0.980). 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 such additives as phytobiotics (herbs, essential oils, and oleoresins) to poultry diet may exert an effect on the level of element retention in tissues and their status in the organism. The favorable mechanisms of phytobiotics include alteration of the gastrointestinal functions, induction and inhibition of metabolic enzymes and transport proteins, beneficial modification of the intestinal microbiota, increased digestibility and nutrient absorption, enhanced nitrogen absorption, histological modifications of the gastrointestinal tract, and appetite stimulation (Fasinu et al. 2012, Stef, Gergen 2012, Iranparast et al. 2014, Kumar et al. 2014, Al-Yasiry, Kiczorowska 2016, Kiczorowska et al. 2016*a*,*b*). The presence of BSR in the chicken diets, in particular at the level of 3 and 4%, contributed to the maintenance of normal proportions and relationships between Ca and P in the organisms of broiler chickens, which was reflected in the content of these elements in the muscles. Maintenance of an optimal Ca:P ratio determines proper homeostasis of these elements in broiler organisms and improves nutrient digestion and absorption (Proszkowiec-Węglarz, Angel 2013). On the other hand, supplementation of chicken diet with *Boswellia serrata* resin resulted in a higher Ca level accompanied by a reduced fat content in the meat. This is desirable from the nutritional point of view, as calcium compounds in combination with fat contained in the gastrointestinal tract can form insoluble substances, thus reducing Ca availability and causing fat indigestibility (Choi, Jeung 2008, Dolińska et al. 2009).

The BSR supplementation altered muscular (breast and drumstick muscles) Cu and Fe accumulations in 42-day-old broilers (Tables 3 and 4). Compared with the control treatment, the addition of BSR significantly decreased Cu accumulation in the breast and drumstick muscles ($P < 0.05$; r_1 = -0.718; r_1 = -0.502, respectively). In turn, the content of Fe decreased only in the breast muscles with the increasing BSR level (control vs. BSR diets, linear, $P < 0.05$; r_1 = -0.637). The BSR treatments did not have a significant effect on muscular zinc retention. The presented result is partly consistent with the findings reported by Wójcik et al. (2012), who found that application of an aqueous extract of herbs (galega [*Herb. Galegae*], stinging nettle [*Herb. Utricae*], lemon balm [*Fol. Melissae*] and sage [*Fol. Salviae*]) in broiler chickens seven days prior slaughter resulted in a reduced iron content in chicken breast muscles. In contrast, Yilmaz et al. (2014) obtained different results upon addition of carvacrol to diets of juvenile rainbow trout. The muscle Cu levels in the fish were significantly increased at 1 g carvacrol per kg diet supplementation, whereas addition of 1 and 5 g kg^{-1} significantly reduced the muscle Zn content. Similarly, Ahmed et al. (2016) found that addition of a dietary herb combination (pomegranate, *Ginkgo biloba*, licorice) in a natural or fermented form to the diet of grower-finisher pigs increased the Fe content in *longissimus dorsi* muscle, and the effect was more pronounced in the case of the fermented herb. The authors explained that this might be related to the increased availability of minerals associated with the concentration of total polyphenols, flavonoids and tannins in fermented herb that was reduced by microbial fermentation (Mohite et al. 2013). Such discrepant results concerning the effect of phytobiotics on retention of trace element in muscles in production animals are probably related to the different content of phytochemicals. The active compounds of phytobiotics include terpenoids (mono- and sesquiterpenes, steroids, etc.), alkaloids (alcohols, aldehydes, ketones, esters, ethers, lactones, etc.), glycosides and phenolics (tannins), which can differ in their effect on the availability of mineral compounds (Afsana et al. 2004, Grashorn 2010, Fasinu et al. 2012, Stef, Gergen 2012, Kumar et al. 2014).

The values of the correlation coefficients (r_2) between basic nutrients and some elements in the breast and drumstick muscles of broiler chickens supplemented with BSR are presented in Table 2. Strong correlations were mainly found between the content of the basic nutrients and elements of muscles. A similar direction and intensity of the correlation (r_2 > 0.6) was observed for the following nutrients pairs: Ca – ether extract (-), Mg – crude protein (-), P – crude ash (-), Fe – crude protein (+), ether extract (-) ($P < 0.05$). The values of the correlation coefficients and the trends obtained for the components may be related to their similar physico-chemical properties, antagonistic or synergistic interactions, bioavailability, and co-existence and co-participation with other components in physiological and metabolic processes.

CONCLUSIONS

The use of the 3 and 4% addition of the *Boswellia serrata* resin in the diets decreased the ether extract in the breast and drumstick muscles, as well as their calorific value. The BSR contributed to the increase in the Ca content in the breast muscles and the P content in the drumstick muscles, but decreased the muscular Cu and Fe retention. There is a need for further investigations to elucidate the mechanisms associated with the ability of *Boswellia serrata* resin to potentiate the element retention. To sum up, the resin of *Boswellia serrata* can be considered as a good feed additive, which can have positive effects on the nutritional value of chicken meat.

REFERENCES

AACC. 2000. *Approved Methods of the AACC, 10th ed. American Association of Cereal Chemists.* The Association, St. Paul, Minnesota, US.

Afsana K., Shiga K., Ishizuka S., Hara H. 2004. *Reducing effect of ingesting tannic acid on the absorption of iron, but not zinc, copper and manganese in rats.* Biosci. Biotechnol. Biochem., 68: 584-592. DOI: 10.1271/bbb.68.584

Ahmed S.T., Mun H.S., Islam M.M., Ko S.Y., Yang C.J. 2016. *Effects of dietary natural and fermented herb combination on growth performance, carcass traits and meat quality in grower -finisher pigs.* Meat Sci., 122: 7-15. DOI: 10.1016/j.meatsci.2016.07.016

Alfaig E., Angelovicova M., Kral M., Vietoris V., Zidek R. 2013. *Effect of probiotics and thyme essential oil on the texture of cooked chicken breast meat.* Acta Sci. Pol. Technol., 12(4): 379-384. http://www.food.actapol.net/issue4/volume/5_4_2013.pdf

Al-Yasiry A.R.M., Kiczorowska B. 2016. *Frankincense – therapeutic properties.* Post. Hig. Med. Dosw., 70: 380-391. http://www.phmd.pl/fulltxt.php?ICID=1200553

Ammon H.P.T. 2010. *Modulation of the immune system by Boswellia serrata extracts and boswellic acids.* Phytomedicine, 17: 862-867. DOI: 10.1016/j.phymed.2010.03.003

Aviagen, 2014. *Ross 308 broiler: Nutrition specifications.* http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross308BroilerNutritionSpecs2014-EN.pdf Accessed April 2016

Cho J.H., Kim H.J., Kim I.H. 2014. *Effects of phytogenic feed additive on growth performance, digestibility, blood metabolites, intestinal microbiota, meat color and relative organ weight after oral challenge with Clostridium perfringens in broilers.* Livest. Sci., 160: 82-88. DOI: 10.1016/j.livsci.2013.11.006

Choi KC, Jeung EB. 2008. *Molecular mechanism of regulation of the calcium-binding protein calbindin-D9k, and its physiological role(s) in mammals: a review of current research.* J Cell Mol Med., 12: 409-420. DOI: 10.1111/j.1582-4934.2007.00209.x

Dolińska B., Woźniak D., Ryszka, F. 2009. *Intenstinal absorption of calcium.* Farm. Prz. Nauk, 10: 35-38. http://fpn.sum.edu.pl/archiwum/publikacje/2009/publikacja6_nr10_2009.pdf (in Polish)

EURFA. 2016. *European Union Register of Feed Additives pursuant to Regulation* EC No 1831/2003. Edition 238. Annex I, category - 2, functional group - b, subclassification - natural products, botanically defined (released 27.07.2016). http://ec.europa.eu/food/safety/docs/animal-feed-eu-reg-comm_register_feed_additives_1831-03.pdf. Accessed 30 July 2016

Fasinu P.S., Bouic P.J, Rosenkranz B. 2012. *An overview of the evidence and mechanisms of herb-drug interactions.* Front. Pharmacol., 3(69): 1-19. DOI: 10.3389/fphar.2012.00069

Grashorn M.A. 2010. *Use of phytobiotics in broiler nutrition – An alternative to infeed antibiotics.* J. Anim. Feed Sci., 19: 338-347.

Hamidpour S.H., Hamidpour M., Shahlari M., Hamidpour R. 2015. *Chemistry, pharmacology and medicinal property of frankincense (Boswellia species): from the selection of traditional applications to the novel phytotherapy for the prevention and treatment of serious diseases.* GJMR, 15: 1-9. https://globaljournals.org/GJMR_Volume15/3-Chemistry-Pharmacology-and-Medicinal.pdf

Iranparast F., Parsaei S., Houshmand M., Naghiha A. 2014. *The effect of oral consumption of guggul (Commiphora mukul) resin on performance and humoral immunity response of broilers.* Int. J. Adv. Biol. Biom. Res., 2(3): 802-810. http://www.ijabbr.com/article_7237_c88f2b6f14b9d63e28ab48d317528e06.pdf

Kiczorowska B., Al-Yasiry A.R.M., Samolińska W., Marek A., Pyzik E. 2016*a*. *The effect of dietary supplementation of the broiler chicken diet with Boswellia serrata resin on growth performance, digestibility, and gastrointestinal characteristics, morphology, and microbiota,* Livest. Sci., 191: 117-124. DOI: 10.1016/j.livsci.2016.07.019

Kiczorowska B., Samolińska W., Al-Yasiry A.R.M., Kowalczyk-Pecka D. 2016*b*. *Effect of Boswellia serrata dietary supplementation on growth performance, gastrointestinal microflora, and morphology of broilers.* Ann. Anim. Sci., 16(3): 835-849. DOI: 10.1515/aoas-2016-0007

Kirkpinar F., Ünlü H.B., Serdaroğlu M., Turp G.Y. 2014. *Effects of dietary oregano and garlic essential oils on carcass characteristics, meat composition, colour, pH and sensory quality of broiler meat.* Br. Poult. Sci., 55(2): 157-166. DOI: 10.1080/00071668.2013.879980

Kumar M., Kumar V., Roy D., Kushwaha R., Vaiswani S. 2014. *Application of herbal feed additives in animal nutrition - a review.* Int. J. Livest. Res., 4(9): 1-8.

Kunachowicz H., Nadolna I., Iwanow K., Przygoda B. 2015. *Nutritional value of selected food products and typical dishes.* Wyd. Lek. PZWL. (in Polish)

Mohite B.V., Chaudhari G.A., Ingale H.S., Mahajan V.N. 2013. *Effect of fermentation and processing on in vitro mineral estimation of selected fermented foods.* Int. Food Res. J., 20(3): 1373-1377. http://www.ifrj.upm.edu.my/20%20(03)%202013/49%20IFRJ%2020%20(03)%20 2013%20Chaudhari%20(190).pdf

Polish Standard, PN-76/R-64781. 1976. *Feed. determination of phosphorus content.* Polish Committee for Standardization, Warsaw, Poland. (in Polish)

Polish Standard, PN-EN ISO 6869. 2002. *Animal feeding stuffs - Determination of the contents of calcium, copper, iron, magnesium, manganese, potassium, sodium and zinc - Method using atomic absorption spectrometry.* Polish Committee for Standardization, Warsaw, Poland. (in Polish)

Proszkowiec-Węglarz M., Angel R. 2013. *Calcium and phosphorus metabolism in broilers: Effect of homeostatic mechanism on calcium and phosphorus digestibility.* J. Appl. Poult. Res., 22(3): 609-627. DOI: 10.3382/japr.2012-00743

StatSoft, Inc., 2011. STATISTICA (data analysis software system). version 10. www.statsoft.com

Stef D.S., Gergen I. 2012. *Effect of mineral-enriched diet and medicinal herbs on Fe, Mn, Zn, and Cu uptake in chicken.* Chem. Cent. J., 6(1): 1-9. DOI: 10.1186/1752-153X-6-19

Tabatabaei S.N. 2016. *Effect of olibanum (Boswellia thurifera) as a feed additive on performance, some blood biochemical and intestinal morphology in broiler chicks.* Res. Opin. Anim. Vet. Sci., 6: 130-134. DOI: 10.20490/ROAVS/16-022

US Department of Agriculture (USDA) 2016. Agricultural Research Service, Nutrient Data Laboratory. USDA *National Nutrient Database for Standard Reference,* Release 28. Version Current: September 2015. http://www.ars.usda.gov/ba/bhnrc/ndl. Accessed 6 June 2016

Wójcik A., Pomianowski J. F., Tońska E., Sowińska J., Mituniewicz T., Witkowska D., Chorąży Ł., Piotrowska J., Kwiatkowska-Stenzel A., Rudnicki Z., Murawska D., Mielcarek S. 2012. *Content of selected minerals in meat derived from broiler chickens subjected to various pre-slaughter handling procedures.* Żywn-Nauk. Technol. Ja. (ŻNTJ), 19(1): 164-174. http://www.pttz.org/zyw/wyd/czas/2012,%201(80)/164_174_13_Wojcik.pdf

Yilmaz E., Yilmaz S., ErgÃn S., Kaya H., Kizilkaya B., SoytaÅŸ N. 2014. *A preliminary study of the effect of phytoadditive carvacrol on the trace elements (Cu, Mn and Zn) content in fish tissues.* J. BioSci. Biotechnol., 3(1): 43-47.

Zeng Z., Zhang S., Wang H., Piao X. 2015. *Essential oil and aromatic plants as feed additives in non-ruminant nutrition: a review.* J. Anim. Sci. Biotechnol., 6(1): 7. DOI: 10.1186/s40104-015-0004-5

Ziołecki J., Doruchowski W. 1989. *The method of assessment of slaughter poultry.* COBRD Publishing. Poznań, Poland. (in Polish)