Research Note: Growth and meat features of broiler chicken with the use of halloysite as a technological additive to feed and peat litter

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ABSTRACT The current trends in the production of broiler chickens indicate the need to look for natural solutions that affect the efficiency of production and the quality of meat. The aim of the study was to evaluate the growth performance and quality of broiler chicken meat with the addition of halloysite in feed and litter. Two hundred Ross 308 were used and divided into 2 groups (10 replicates each). The control group (**C**) did not have any additive, while in the experimental group (**H**) 0.5% halloysite was used in feed and 0.500 kg/m^2 in peat litter. The production results and litter traits were checked. The presence of footpad dermatitis (**FPD**) was assessed. After 42 d, 20 birds were randomly selected and slaughtered. Dissection was performed. The slaughter yield and the percentage of carcass elements were calculated, including offal. Breast and leg muscles were analysed qualitatively (pH, colour, water-holding capacity, drip loss, chemical composition). In group H there were no changes to FPD, and in group C there were 6 cases of benign lesions and 1 with severe damage and scabs on the soles of the feet. Significantly higher preslaughter body weight was shown, as well as carcass and wings weight in group H. The H group had a higher pH$_{24}$ than the C group, as well as higher protein and water content, and lower intramuscular fat and salt, both in the breast and leg muscles. No significant differences were found in growth performance carcass, meat' colour or water-holding capacity features. The litter with halloysite was characterized by a lower pH but without statistical confirmation. Addition of halloysite to feed and litter reduced the occurrence of skin lesions and had a positive effect on higher protein content and lower intramuscular fat in the breast and leg muscles. This demonstrates the potential for the practical use of halloysite in the production of broiler chickens, both as a feed and peat litter additive.

Key words: chicken, peat, aluminosilicate, growth performance, meat quality

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INTRODUCTION

The efficiency of poultry meat production is influenced by many factors, including management, which can be understood as ensuring production conditions at an optimal level, as well as the quality of the raw material obtained (Suwarta and Hanafie, 2018). In the production of broiler chickens, a very important issue is footpad dermatitis (**FPD**). It is a disease entity of skin lesions on the soles of the feet and is a well-known problem in poultry production, affecting the efficiency as well as the preservation of bird welfare (Škrbić et al., 2015). For a good production results, maintaining appropriate conditions for birds and to obtain good quality meat, various feed and litter additives are used. Interesting solution with potential in poultry production is the use of clay minerals, including halloysite. Its production is concentrated mainly in New Zealand and USA, and in Europe, the halloysite mine is located in Poland, and its deposits are estimated at 10 million tons (Sołtys et al., 2013). Halloysite can be a cheap, accessible and natural solution as it is common in soils and weathered rock (Joussein et al., 2018). Halloysite is characterized by the ability to eliminate (reduce) growing fungi, reduce the level of heavy metals in the organs of animals, they can affect digestive processes, as well as the quality of litter and reduce harmful gas emissions (Kulok et al., 2005). As described by the cited authors, the beneficial effects of using aluminosilicates in animal feeding have been shown. By reducing impurities in the feed (or litter), halloysite can affect body weight gain, because the feed quality allows the full use of nutrients (Korniewicz et al., 2006). Other studies were conducted by Pizzaro et al. (2009), where the characteristics of the litter and the presence of FPD were controlled with the use of

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aluminosilicates. Lowered pH of the litter and ammonia was demonstrated, however in both groups the occurrence of changes on the soles of the feet was similar. The quality of the meat in terms of colour is important to consumers, but it also shows that the meat is not defective (PSE or DFD). Lightness (L*) is closely related to the pH of meat, as well as water-holding capacity (or drip loss) and the chemical composition of meat (Fletcher, 2002). Mineral clays can improve chickens' growth and quality of meat (Dhama et al., 2014). The aim of the study was to evaluate the production indicators and meat characteristics of broiler chickens that were kept with 0.500 kg/m^2 of halloysite to peat litter and fed with 0.5% halloysite added to feed.

MATERIAL AND METHODS

The rearing of broiler chickens and the performance of the experiment was in accordance with the law and EU directive no. 2010/63/EU.

Chickens Rearing

Two hundred male Ross 308 broiler chickens were reared. The rearing was carried out in a closed building, in a litter system, using peat litter for 42 d. The rearing conditions were in accordance with Ross 308 broiler chicken keeping standards with some modifications. On the day of insertion, the average temperature in the chicken house was 30°C and after 3 d it gradually decreased to 20°C (29th d of rearing). For the first 3 d, a continuous lighting system was used, similarly for the last 2 d of rearing (with a period of lower light intensity for 1 h), and in the remaining period, the chickens were kept with blackout period for at least uninterrupted 6 h between 15 and 21 d of rearing (possibility for regeneration). Humidity was on average 65% and ventilation was around 0.5 m^3/s. The lighting of the broiler house was 20 lx. Birds had access to feed and fresh water ad libitum. The feed was a commercial complete mix divided into 3 feeding stages: starter, grower 1, and grower 2. Chickens were divided into 2 groups of equal numbers, in accordance with the principle of randomization of trials. Each group was divided into 10 repetitions of 10 birds. The pens were made of stainless material with dimensions of 1 × 1 m. The feeders were mounted on the walls of the pens (1 per pen), with easy access to them, and 2 nipple drinkers per pen were provided. The first group was the control group (**C**). In the experimental group (**H**), the addition of halloysite to feed and litter was applied. In the feed, 0.5% halloysite was added in each feeding period. Halloysite was added at the feed production stage, so it was a homogeneous mixture. The halloysite was in a loose (dusty) form, and had a specific surface area of 65 to 86 m^2/kg, bulk density 0.70 to 0.85 g/cm^3, and also contained aluminum (13.00%), silicon (12.00%), calcium (0.40%), mangesium (0.30%), sodium (0.10%), potassium (0.08%), phosphorus (0.30%), iron (9.00%), titanium (1.00%), and manganese (0.20%). Feed was pelleted form. The composition of the feed was suitable for broiler chickens, in line with the nutritional requirements (feeds came from a commercial feed factory). The feed was produced in accordance with the rules and hygiene of feed production for broiler chickens. Characteristics of halloysite were presented on the basis of the supplier's declaration. During the entire rearing period, the litter was sprinkled with halloysite in the amount of 0.500 kg/m^2 in the dusty form (on the days of the feed change).

Growth Performance

During the rearing period, the chickens were weighed (BW) on the day of insertion (d 1), as well as during the feed changes (d 14, 22) and on the day of slaughter (d 42). The feed consumption (**FI**) was recorded. Based on the collected data, body weight gain (**BWG**) as well as feed conversion ratio (**FCR**) were calculated for each feeding period and for the entire rearing period. The European Broiler Index (**EBI**) was also calculated from formula: (average grams gained/day of rearing × % survival rate)/FCR × 10. The deaths of chickens were recorded.

Peat Litter Quality and Footpad Dermatitis

During the rearing period, the moisture content of the litter as well as its pH and nitrogen content were measured. This was to record changes taking place in the peat. For the pH and total nitrogen content tests, peat was collected on d 1, 14, 22, and 42. Collective peat samples from each group, weighing 1 kilogram, were collected into string bags. There were 5 replications (1 replication was from 2 pens). The pH was determined by the potentiometric method (Sukovata et al., 2010) according to the standards (PN-ISO 10390:1997) using the Orion 2 Star Thermo pH meter, at a temperature of 20°C with automatic reading. The percentage of total nitrogen was determined according to the PN-EN ISO 5983-1:2006 standard. FOSS Kjeltec 8400 Analyzer Unit, Sampler 8420 and FOSS Tecator Digestor were used. In addition, on the day of slaughter, the condition of the soles of the chickens' feet was checked in order to determine the presence of footpad dermatitis using the point scale with 3 grades: 0, means no change or very small, slight superficial discoloration and mild epidermal keratosis; 1, means mild skin changes, discoloration, superficial lesions and dark spots on the pads; 2, means severe damage, ulcers, scabs, hemorrhages, and swelling of the paws. The results are given as the percentage of birds with skin lesions in each group.

Features of Broiler Chicken Meat

In 42nd d, 10 chickens from each group were randomly selected and slaughtered. Previously, the birds were starved for 10 h (fresh water access was provided). The birds were stunned and made a quick cut between the cervical vertebrae and the occipital condyle for rapid bleeding. The slaughter was carried out by qualified workers in accordance with the humanity standards. After slaughter, the carcasses were immersed in water at 65°C for 5 s and plucked. Then the feet in the ankle joint were cut off and the carcasses were eviscerated, leaving edible offal (heart, gizzard, and liver). After 45 min of slaughter, a pH_{45} was measured in the *pectoralis major muscle.* The carcasses were placed sequentially with numbers, which ensure the accuracy of the analyses performed. The carcasses were then cooled in a cold store (Hendi, Poznan, Poland) at 4°C for 24 h. After the time has elapsed, the pH_{24} measurement has been repeated. Carcasses and offal were weighed. Dissection was performed, cutting off the neck with skin, wings, abdominal fat, skin with subcutaneous fat, breast muscles (*m. pectoralis major* and *minor*), and leg muscles (deboned). The remains of the carcass included the trunk and bones of the legs. The dressing percentage as well as the percentage of individual elements in the carcass were calculated. The breast and leg muscles were intended for qualitative analysis. Right breast and leg muscles were assessed using a colorimeter (Konica Minolta, Tokyo, Japan), using the CIE Lab scale, where L*, brightness; a*, redness; b*, yellowness. The color assessment was performed on the outer side of the muscles. Then right breast muscles were weighed (M1) and placed in string bags with incisions. These were placed in larger bags and suspended in a cold store for 24 h at 4°C. Based on the value, the percentage of water loss by the drip loss method was calculated. Left breast and leg muscles were ground in a meat homogenizer to perform water-holding capacity and chemical composition. The water-holding capacity was achieved by weighting a sample of meat with weight of 0.300 g ±5% (M1). The tests were placed between 2 pieces of Whatmann tissue paper and put on weights of 2 kg for 5 min. The trials (M2) were then weighed. The percentage of water loss was calculated. The chemical composition of the meat was carried out using spectrometry (FoodScan, Foss, Hilleroed, Denmark) using near-infrared transmission (**NIT**). The percentage of protein, collagen, salt, intramuscular fat and water was analyzed. All of quality analyses were done in 10 replications. Analyses where described by Banaszak et al. (2020).

Statistical Analysis

The data were compiled in a statistical program (Statistica software, 13.3, 2017, Cracow, Poland). Mean values and standard error of the mean (**SEM**) have been calculated. Using Student's *t*-test between groups, for independent variables, statistically significant differences were verified, with the significance level *P*-value <0.05. For the production results 10 replications were done in each group. For the quality of carcass and meat, 10 replications were provided. For the litter features 5 replications were done, although 1 sample was done from 2 pens. The results for the presence of footpad dermatitis were not statistically analyzed as they were calculated for the whole group, without division into replicates.

RESULTS AND DISCUSSION

Growth Performance

No statistically significant differences between body weight groups were demonstrated when analyzing Table 1, as well as body weight gain, feed intake and feed conversion ratio ($P > 0.05$). Deaths were recorded during the rearing. In the first 3 d, 3 chicks were died in group C and 6 chicks in group H. However, deaths were associated with weak and crippled chicks, which was not dependent on the research factor.

Peat Litter Quality and Footpad Dermatitis

In both groups pH of peat litter at 6.10-6.55 level was shown, and dry matter content was above 94%, expressed as a mean value from the mentioned days of sampling. Nitrogen content in peat litter was 6.10-6.55. There were no statistically significant differences ($P >$ 0.05). In group C, 6% of birds showed mild skin lesions, discoloration, superficial damage and dark spots (1 point), as well as serious damage and scabs (2 points) in 1%. In group H, no skin lesions were shown that could be attributed to score 1 or 2 (0, no lesions or very small, slight superficial discoloration and mild keratosis of the epidermis) (Table 1). The assumptions may be made with the effect of the addition of halloysite to peat. Peat The quality of the bedding depends on the material as well as the building conditions and even the feeding of the poultry, including what additives are used (Škrbić et al., 2015). Liuskanto (2015) concluded that the addition of halloysite to peat increases moisture absorption and phosphate, nitrate or potassium retention by exchanging cations and anions or creating deposits. It is thought that litter and living conditions were optimal in the building, in all groups, as most scientific reports suggest as pH value of litter in the production of chickens at a level close to 8.0 (this may be related to the type of litter, and time of analyses).

Features of Broiler Chicken Meat

The birds to be slaughtered were randomly selected from each group. Statistically significantly higher body weight ($P = 0.019$) and carcass weight ($P = 0.030$) were shown in group H, but this did not influence into dressing percentage as no statistically significant differences were found ($P = 0.442$). A statistically significant higher wings weight was found in group H compared to group C ($P = 0.003$). No statistically significant differences ($P > 0.05$) were found in the other characteristics shown in carcasses. Group H, where halloysite was used to feed and peat litter, had a significantly higher pH_{24} compared to group C ($P = 0.033$) in the breast muscles. In the

Table 1. Growth performance of broiler chickens, peat litter features and footpad dermatitis scores.

Item N = 100	Group C	Group H	SEM	*P*-value*
BW (g)				
1-d old chicks	40.92	41.04	0.18	0.745
14 d	310.66	305.48	3.13	0.423
22 d	1230.04	1222.72	13.16	0.789
42 d	3098.57	3059.30	38.23	0.621
BWG (g)				
1−13 d	269.74	264.44	3.17	0.418
14−21 d	919.38	917.25	11.28	0.928
22−42 d	1868.53	1836.57	30.61	0.615
1−42 d	3057.65	3018.26	38.25	0.620
FI (g; per bird)				
1−13 d	300.00	288.70	3.46	0.104
14−21 d	1232.30	1261.40	10.84	0.187
22−42 d	2797.11	2760.72	26.06	0.500
1−42 d	4440.57	4510.34	51.23	0.511
FCR (kg/kg)				
1−13 d	1.11	1.09	0.01	0.428
14−21 d	1.34	1.38	0.01	0.236
22−42 d	1.50	1.51	0.02	0.908
1−42 d	1.46	1.49	0.02	0.265
EBI	489	452	13.71	0.191
Deaths (birds)	3	6	-	-
Peat litter features				
pH	6.55	6.10	0.18	0.264
Dry matter [%]	94.67	94.75	0.95	0.971
Nitrogen [g/kg]	3.27	3.47	0.48	0.854
Footpad dermatitis [% in group]				
0, means no changes or very small, slight superficial discoloration and mild epidermal keratosis;			93	100
1, means mild skin changes, discoloration, superficial lesions and dark spots on the pads			6	0
2, means severe damage, ulcers, scabs, hemorrhages and swelling of the paws			1	0

*No significant differences were found between group C and H, with P-value > 0.05; C, control group; H, halloysite group: 0.5% of halloysite in feed and 0.500 kg/m^2 in peat litter.Abbreviations: BW, body weight; BWG, body weight gain; EBI, European Broiler Index; FCR, feed conversion ratio; FI, feed intake.Feeding stage: 1−13 d, starter feed; 14−21 d, grower feed; 22−42 d, finisher feed, N − number of samples.

Table 2. Carcass features and meat quality of broiler chicken.

Item n = 10	Group C	Group H	SEM	*P*-value
Preslaughter body weight (g)	2993.80[b]	3205.50[a]	46.77	0.019
Weight of carcass (g)	2251.49[b]	2441.10[a]	44.74	0.030
Dressing percentage (%)	75.14	76.15	0.64	0.442
Neck with skin (g)	103.89	108.54	4.03	0.579
Neck with skin (%)	4.63	4.44	0.16	0.552
Wings (g)	211.50[b]	241.47[a]	5.52	0.003
Wings (%)	9.44	9.91	0.20	0.247
Heart (g)	15.54	14.93	0.62	0.638
Gizzard (g)	29.90	31.99	1.78	0.570
Liver (g)	65.31	64.58	2.51	0.889
Carcass remains (g)	611.10	662.72	35.30	0.480
Breast muscles (g)	681.57	773.67	38.94	0.247
Breast muscles (%)	30.19	31.68	1.55	0.645
Leg muscles (g)	464.33	477.62	11.98	0.593
Leg muscles (%)	20.59	19.59	0.36	0.174
Total muscles (g)	1145.90	1251.29	45.02	0.252
Total muscles (%)	50.78	51.26	1.61	0.887
Skin with subcutaneous fat (g)	198.55	197.35	4.67	0.902
Skin with subcutaneous fat (%)	8.82	8.12	0.19	0.066
Abdominal fat (g)	25.60	26.08	2.08	0.911
Abdominal fat (%)	1.13	1.07	0.09	0.734
Total fat (g)	224.15	223.43	6.01	0.954
Total fat (%)	9.95	9.18	0.23	0.104
Quality features of breast muscle				
pH_{45}	6.46	6.36	0.04	0.165
pH_{24}	6.11[b]	6.26[a]	0.03	0.033
Color				
L*	53.04	52.96	0.64	0.953
a*	3.46	3.96	0.33	0.469
b*	5.69	5.86	0.38	0.832

(continued)

Table 2 (*Continued*)

Item n = 10	Group C	Group H	SEM	*P*-value
Water holding capacity (%)	35.10	35.69	0.42	0.501
Drip loss (%)	1.02	1.25	0.10	0.276
Protein (%)	21.91[b]	22.07[a]	0.02	< 0.001
Collagen (%)	0.96	0.95	0.02	0.793
Salt (%)	0.26[a]	0.19[b]	0.01	< 0.001
Intramuscular fat (%)	2.92[a]	2.61[b]	0.04	< 0.001
Water (%)	73.95[b]	74.18[a]	0.04	< 0.001
Quality features of leg muscle				
Color				
L*	50.00	49.18	0.47	0.396
a*	4.05	4.69	0.33	0.351
b*	4.23	3.88	0.35	0.625
Water holding capacity (%)	37.93	36.54	0.41	0.093
Protein (%)	18.73[b]	18.86[a]	0.02	< 0.001
Collagen (%)	1.46	1.41	0.01	0.075
Salt (%)	0.31[a]	0.27[b]	0.01	0.001
Intramuscular Fat (%)	7.95[a]	7.46[b]	0.06	< 0.001
Water (%)	71.55[b]	72.00[a]	0.05	< 0.001

[a,b]Different letters in a row (between groups C and H) indicate statistically significant differences, at the level of *P*-value <0.05; C, control group; H, halloysite group: 0.5% of halloysite in feed, and 0.500 kg/m^2 in peat litter; **, $pH_{45,}$ 45 min after slaughter; pH_{24}, 24 h after slaughter; L*, lightness; a*, redness; b*, yellowness, n − number of samples.

breast muscles, the protein and water content of group H was statistically significantly higher, at the same time significantly lower intramuscular fat and salt content than in group C ($P < 0.001$). In the leg muscles also statistically significantly higher protein and water content, and lower intramuscular fat and salt was shown in group H, compared to group C ($P < 0.001$; salt, $P = 0.001$). Values of L*, a*, b*, drip loss and water-holding capacity in the breast and leg muscles shown in Table 2, did not differ statistically significantly ($P > 0.05$). Studies of Prvulovic et al. (2008) showed using 5 g/kg hydrated aluminosilicate (antitoxic nutrient-**ATN**) for feed showed significantly higher protein content and lower fat content in the breast muscles which corresponds to our results. The pilot studies (Banaszak et al., 2020) concluded that the addition of halloysite affects the higher height of intestinal villi and their width and surface area, as well as the depth of intestinal crypts, and this is associated with digestive functions (increased). The use of kaolin, bentonite and zeolite also affected the quality characteristics of meat (Safaei et al., 2016). The authors discussed that the addition of silicate minerals increases protein digestibility, increases protein in meat and reduces intramuscular and abdominal fat. This is related to the relationship of reduced lipid oxidation and improved protein digestibility. Similar conclusions were made by other authors, using different aluminosilicates in the production of broiler chickens and their impact on the quality and chemical composition of meat (Christaki et al., 2006; Safaei et al., 2014). The pH value is associated with perimortem and postmortem glycolysis porcess (Swatland, 2008). Slower pH decrease (toward meat acidification) was associated with lower water loss from meat (Le Bihan-Duval et al., 2008). In addition, it is suggested that low pH promotes lipid oxidation, thus the less intramuscular fat in related to the lower the oxidation (Gong et al., 2010). The research results indicate no negative effect of halloysite in peat litter and feed on production results and meat quality. The addition of halloysite positively influenced the condition of the soles of the feet. Further research, including microbiological mechanisms, could be continued.

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DISCLOSURES

The authors declare that they have no conflicts of interest.

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