Animal Nutrition 5 (2019) 152–155

Contents lists available at ScienceDirect

Animal Nutrition

journal homepage: http://www.keaipublishing.com/en/journals/aninu/

Original Research Article

Growth performance, meat quality, and bone-breaking strength in broilers fed dietary rice hull silicon*

Sarawoot Nakhon, Sonthaya Numthuam, Rangsun Charoensook, Wandee Tartrakoon, Papichaya Incharoen, Tossaporn Incharoen*

Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanulok 65000, Thailand

A R T I C L E I N F O

Article history:
Received 20 March 2018
Received in revised form
12 November 2018
Accepted 20 November 2018
Available online 24 December 2018

Keywords:
Broilers
Bone breaking strength
Meat quality
Rice hull silicon

A B S T R A C T

Bone problems have been a key issue that perilously affects broilers' health and welfare, resulting in severe economic loss. The present study was aimed at investigating the influence of dietary rice hull silicon (RHS) on the performance, meat quality, and bone-breaking strength of broilers. One hundred 10-day-old Arbor Acres chicks were used in the study. The birds were divided into 5 groups: one group was kept as the control, and other groups were provided with 2.5, 5.0, 7.5, and 10.0 mg/kg dietary RHS along with their basal diets. Results showed that diets containing various levels of dietary RHS did not adversely affect ($P > 0.05$) the body weight, feed intake, and feed conversion ratio. Drip loss of thigh meat showed a reduced value in the group supplemented with 7.5 mg/kg dietary RHS compared with other groups ($P < 0.05$), and the lowest thawing loss was observed in the same group; however, it showed no significant difference among other groups. Similarly, thawing loss of breast meat tended to decrease in the dietary RHS groups and significantly decreased ($P < 0.05$) in the 7.5 mg/kg RHS group. The shear force of breast meat was higher in all RHS groups, and the highest was in the 7.5 mg/kg RHS group ($P < 0.05$). Although tibia breaking strength increased significantly ($P < 0.05$) in the 7.5 mg/kg RHS group ($P < 0.05$), but a significant difference in femur breaking strength was not found among groups. In conclusion, dietary RHS can be used as a natural mineral supplement for improving bone-breaking strength and reducing drip and thawing loss of breast and thigh muscles, particularly RHS at a level of 7.5 mg/kg in broiler diets.

1. Introduction

Modern commercial broiler strains are bred to maximize the feed conversion ratio and growth rate in a minimum period of time. Certain approaches used by broiler breeders have resulted in improved growth rate, as within 5 to 6 weeks birds gain about 2.5 to 3.0 kg. However, this rapid weight gain has also been the single main cause of increased skeletal and leg deformities in broilers. It has been well-documented that minerals are important components of bones. Bone mineralization makes bones harder, which enables the skeleton to withstand gravity and additional loading (Shim et al., 2012). Traditionally, calcium and phosphorus are accepted as primary minerals in animal diets, while other trace minerals have been ignored, especially silicon. Recently, silicon has been classified as an essential trace mineral for cartilage growth, normal bone development, and improved bone quality (Pietak et al., 2007; Incharoen et al., 2016). Some evidence indicates that silicon is associated with calcium metabolism and the formation and stabilization of extracellular bone matrix (Reffitt et al., 2003; Jugdaohsingh, 2007). With calcium, silicon can regulate calcium turnover influencing the processes of bone calcification and decalcification (Boguszewska-Czubara and Pasternak, 2011). Maehira et al. (2009) reported that silicon acts synergistically with calcium to stimulate bone formation

* Corresponding author.
E-mail address: tossaporni@nu.ac.th (T. Incharoen).

* Presented at the 2nd International Conference on Animal Nutrition and Environment, Khon Kaen, Thailand, November 1 to 4, 2017.

Peer review under responsibility of Chinese Association of Animal Science and Veterinary Medicine.

Production and Hosting by Elsevier on behalf of KeAi

https://doi.org/10.1016/j.aninu.2018.11.003

and to reduce bone resorption, resulting in improvement of bone quality. Identically, Kim et al. (2009) noted that silicon supplementation in diets significantly increased bone mineral density of the femur and tibia in calcium-inadequate rats. A study by Incharoen et al. (2016) has also suggested that dietary silicon can be used as a mineral additive to enhance the bone and meat quality in broilers. According to recent information, silicon can be perceived as supporters and inhibitors of bone formation and mineralization, especially in dietary low calcium.

Thailand is an agricultural country where rice is a major crop. Rice hulls are obtained as a major by-product when rice is processed at rice mills. Recent studies have indicated that rice hulls are a rich source of silicon, and when extracted from the hulls (96.15% SiO_2), it may be positively associated with the bone-breaking strength of broilers, especially at a dose rate of 0.75% (Incharoen et al., 2016). Thus, the aim of the current study was to confirm the advantageous effects of dietary rice hull silicon (RHS) on the performance, meat quality, and bone-breaking strength of broilers at different dietary supplementation levels.

2. Materials and methods

Animal-related trials of the present study (No. 590506) were approved and regulated by the Naresuan University Animal Care and Use Committee (NUACUC). Sampling protocols were followed according to the Naresuan University Animal Care and Use Committee (NUACUC) guidelines.

2.1. Rice hull silicon preparation

Rice hulls were used as a raw material for RHS production. At first, rice hulls were collected from the commercial rice mill in Phitsanulok province, Thailand. Four kilogram of rice hulls were burned in an electric incinerator at 700 °C for 24 h. One kilogram of ash was loaded onto a glass flask and NaOH solution (3.0 mol/L) was poured and boiled at 100 °C for 3 h. Afterward, the suspended solid was filtered using filter paper and left at room temperature to cooled down. They were titrated with 2.5 mol/L H_2SO_4 by constantly stirring until it reached pH 2. The resulting solution was precipitated and NH_4OH was added until the solution achieved pH 8. The pellet was filtered using filter paper and dried in a hot air oven at 120 °C for 18 h. Finally, the dried sample was ground and weighed using digital balance. The resultant RHS was about 0.8 to 0.9 kg and kept in a dry cabinet until used in the feeding experiment. RHS sample consisted of 96.15% SiO_2, 0.91% Na_2O and 0.60% K_2O.

2.2. Experimental design and birds management

Arbor Acres broiler chicks were purchased from a commercial hatchery (Charoen Pokphand Foods PCL., Thailand). All chicks were placed in a brooding zone and immediately supplied with water and feed. At 10 d of age, a total of 100 chicks were divided into 5 groups, each with 4 replicates of 5 chicks. The control group was fed a basal diet (Table 1), and other groups were fed the basal diet supplemented with RHS at 2.5, 5.0, 7.5, and 10.0 mg/kg, respectively. Experimental diets and water were provided *ad libitum* throughout the study period. Birds were maintained according to the guidelines for hybrid strains till 45 d of age. The body weight and feed intake of each bird were recorded weekly.

2.3. Data collection and measurement

At the end of the trial, 4 birds from each group were euthanized to assess meat quality and bone-breaking strength. Broiler carcasses were scalded in warm water (60 ± 5 °C), de-feathered, and eviscerated. Muscle samples were collected from both sides of the breast and the thighs to evaluate meat quality. The collected meat samples were dissected, weighed, and then transferred into polyethylene bags. Samples were stored in a refrigerator at 4 °C for 24 h. After refrigeration, each sample was individually wiped and weighed to check drip loss, which was expressed as a percentage of the initial weight.

To measure thawing loss, each fresh meat sample was individually weighed, placed into a polyethylene bag, and then transferred to a deep-freezer at −21 °C for 48 h. Subsequently, the frozen samples were thawed for 24 h in the refrigerator at 4 °C and finally weighed. Thawing loss was expressed as a percentage of the initial weight. For determination of the shear force, skinless breast and thigh meat, samples were first cooked and then assessed with a texture analyzer (model QTS20, Brookfield Instruments, UK). To assess bone-breaking strength, samples of tibias and femurs were used. After separating the bones from the meat, samples were collected and then dried in a hot oven at 95 °C overnight. Bone-breaking strength was measured by using a universal testing machine (model 441, Instron, Ltd., England), according to the method modified by Incharoen et al. (2016).

Table 1
Ingredients and chemical composition of the basal diet.

Item	Grower diet	Finisher diet
Ingredients, %		
Corn	12.50	13.20
Broken rice	45.47	44.00
Soybean meal (45% CP)	30.38	29.86
Palm oil	4.10	5.10
Fish meal (57% CP)	7.00	7.00
Calcium carbonate	0.50	0.50
Dicalcium phosphate	0.10	0.10
Concentrate mixture[1]	0.20	0.20
DL-methionine	0.20	0.20
Total	100.00	100.00
Calculated chemical composition, %		
Crude protein	22.00	20.00
Crude fat	6.16	7.14
Crude fiber	2.69	2.66
Calcium	0.63	0.76
Phosphorus	0.52	1.20
ME, kcal/kg	3,150.00	3,200.00

[1] Concentrate mixture provided the following per kilogram of complete diet: 14,000,000 IU of vitamin A; 3,000,000 IU of vitamin D_3; 2,500 IU of vitamin E; 35 g of vitamin K; 2.5 g of vitamin B_1; 6.5 g of vitamin B_2; 275 g of vitamin B_6; 25 mg of vitamin B_{12}; 11.00 g of pantothenic acid; 35 g of nicotinic acid; 15 mg of biotin; 250 g of choline chloride; 1.5 g of copper; 60 g of manganese; 1.5 g of iron; 45 g of zinc; 400 mg of iodine; 150 mg of selenium.

2.4. Statistical analysis

Statistical analysis was performed by One-way Analysis of Variance using the Statistical Package for the Social Sciences (SPSS), version 17.0 (SPSS Inc., Chicago, USA). Differences among the groups were analyzed using the Duncan's multiple range test. Probabilities ($P < 0.05$) were considered significant.

3. Results and discussion

The results for the effects of dietary RHS on broiler performance are presented in Table 2. No negative impact of RHS on body weight, feed intake, or feed conversion ratio was observed in any birds of the groups from 10 to 45 d of age. These results suggested that dietary RHS had no adverse effect on broiler performance during the grower and finisher phases. These results are in agreement with

Table 2
Effects of dietary rice hull silicon (RHS) on growth performance of broilers from 10 to 45 d of age.

Item	Control	Dietary RHS, mg/kg				*P*-value
		2.5	5.0	7.5	10.0	
Body weight, g/bird	2,519	2,508	2,477	2,580	2,528	0.598
Feed intake, g/bird	4,445	4,618	4,460	4,566	4,679	0.146
Feed conversion ratio	1.66	1.73	1.70	1.71	1.70	0.320

Incharoen et al. (2016), who noted that no significant differences on broiler performance were observed among the dietary 0.5% to 1.0% silicon groups. Similarly, Bintas et al. (2014) also reported that a dietary 0.8% silicon-based supplement did not significantly affect the overall body weight gain, feed intake, or feed conversion ratio of broiler chickens. Furthermore, supplementation at 2% level of a silicon-based natural or modified clinoptilolite did not have significant impacts on total broiler productivity from 1 to 42 d of age (Wu et al., 2013). Conversely, some researchers have reported that dietary supplementation with 2% silicon-based clinoptilolites improves the health status, body weight gain, and feed efficiency of the animals (Papaioannou et al., 2004). Tran et al. (2015) also reported positive effects on ammonia reduction, weight gain, and feed conversion in turkeys in their work with dietary 0.02% silicon. Some other reports indicated that a concentrated mixture with 70% silicon enhanced nutrient digestibility of growing-finishing swine (Yan et al., 2010). The variable effects of dietary silicon-based supplements may be induced by other factors such as pureness, origin, nature, chemical components, concentration, particle size, etc.

Drip loss of breast meat tended to be lower in the dietary RHS groups, and the lowest value was in the 7.5 mg/kg RHS group (Table 3). Likewise, thawing loss tended to decrease in the dietary RHS groups and significantly decreased ($P < 0.05$) in the 7.5 mg/kg RHS group. Concurrently, the shear force was higher in all RHS groups, and the highest was in the 7.5 mg/kg RHS group ($P < 0.05$). Regarding drip loss, thawing loss, and shear force of thigh meat, no significant differences were showed ($P > 0.05$) among groups, but an exception was found in the 7.5 mg/kg RHS group, which showed the lowest drip loss and a significant difference among groups ($P < 0.05$). The present results are comparable with those of Incharoen et al. (2016), who reported that dietary silicon is an essential mineral for improving meat quality in terms of decreasing cooking and thawing losses, especially at the 0.75% level in broiler diets. Although 72% silicon-based mineral products also have beneficial impacts on muscle firmness, this phenomenon might be affected by the interaction or metabolism of metal ions and subsequently caused an alteration in the mineral content of tissues (Yan et al., 2010). Therefore, the results of the present study are due more likely to dietary RHS-induced mineral component modification of muscular tissue, resulting in improvements in the texture and meat quality in terms of drip and thawing loss reduction.

Table 3
Effects of dietary rice hull silicon (RHS) on meat quality of broilers at 45 d of age.

Item	Control	Dietary RHS, mg/kg				*P*-value
		2.5	5.0	7.5	10.0	
Breast meat quality						
Drip loss, %	14.13	13.80	13.25	9.09	13.32	0.092
Thawing loss, %	14.24[bc]	11.09[ab]	11.69[ab]	8.08[a]	17.81[c]	0.050
Shear force, kg	5.35[b]	6.43[b]	6.49[b]	9.13[a]	6.19[b]	0.030
Thigh meat quality						
Drip loss, %	12.38[ab]	13.31[ab]	13.51[ab]	8.46[a]	14.22[b]	0.050
Thawing loss, %	14.77	11.07	11.60	7.25	14.21	0.058
Shear force, kg	8.86	7.04	8.88	9.26	8.56	0.328

[a, b, c] Within a row, means with different superscripts are significantly different ($P < 0.05$).

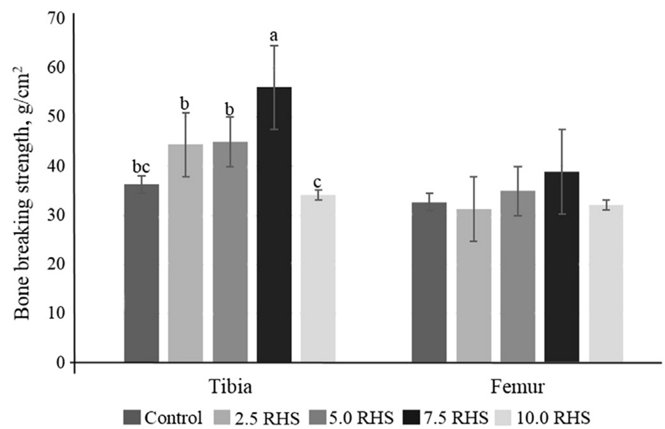

Fig. 1. Effects of dietary rice hull silicon (RHS) on the bone-breaking strength of broilers at 45 d of age. The data represent the means ± SE of 4 replicates. [a, b] Each bar with different letters denotes a significant difference ($P < 0.05$).

Bone-breaking strength results are presented in Fig. 1. The breaking strength of femur was highest in the group supplemented with 7.5 mg RHS/kg diet, followed by the 5.0 mg RHS/kg diet, control, 10.0 mg RHS/kg diet, and 2.5 mg RHS/kg diet. Although data for the breaking strength of the femur showed variability among the groups, no significant difference was found among groups. Regarding the breaking strength of tibia, a significant difference was found in the 7.5 mg/kg RHS group ($P < 0.05$), followed by the 5.0, 2.5, and 10.0 mg/kg RHS groups, but no significant difference was found in the control group. The results of the present study are also comparable with that of Short et al. (2011), who demonstrated that dietary silicon supplementation has the ability to reduce lameness in broiler chickens. Boonrungsiman et al. (2013) noted that silicon supplementation plays an important role in skeleton development and bone formation. Silicon might be also involved in the collagen and connective tissue development (Jugdaohsingh, 2007; Reffitt et al., 2003). Recently, Jugdaohsingh et al. (2015) confirmed that silicon showed an equal distribution in the collagen and mineral fractions at the early stages of bone mineralization. These results correlated with those of Jugdaohsingh et al. (2004), who noted that a higher silicon concentration is related to production and bone and cartilage strength.

4. Conclusion

The present study concludes that dietary RHS has no adverse influence on broiler performance during the grower and finisher periods. Moreover, RHS plays a key role in improving bone-breaking strength and reducing drip and thawing loss of broiler chickens' breast and thigh muscles. On the basis of the presented results, dietary RHS can be used as an important trace mineral in broiler diets, especially at a concentration of 7.5 mg/kg.

Conflict of interest

We declare that we have no financial and personal relationships with other people or organizations that might inappropriately influence our work, and that there is no professional or other personal interest of any nature in any product, service, and/or company that could be construed as influencing the content of this paper.

Acknowledgements

The current research was financially supported by the Faculty of Agriculture, Natural Resources and Environment, Naresuan University. The authors and co-authors thank all members of Center of Excellence for Agricultural and Livestock Innovation for their cooperation, help, and collaboration.

References

Bintas E, Bozkurt M, Kucukyılmaz K, Konak R, Cinar M, Aksit H, et al. Efficacy of supplemental natural zeolite in broiler chickens subjected to dietary calcium deficiency. Ital J Anim Sci 2014;1:275–83.
Boguszewska-Czubara A, Pasternak K. Silicon in medicine and therapy. J Elem 2011;16:489–97.
Boonrungsiman S, Fearn S, Gentleman E, Spillane L, Carzaniga R, McComb DW, et al. Correlative spectroscopy of silicates in mineralised nodules formed from osteoblasts. Nanoscale 2013;5:7544–51.
Incharoen T, Tartrakoon W, Nakhon S, Treetan S. Effects of dietary silicon derived from rice hull ash on the meat quality and bone breaking strength of broiler chickens. Asian J Anim Vet Adv 2016;11:417–22.
Jugdaohsingh R, Tucker KL, Qiao N, Cupples LA, Kiel DP, Powell JJ. Dietary silicon intake is positively associated with bone mineral density in men and premenopausal women of the Framingham Offspring cohort. J Bone Miner Res 2004;19:297–307.
Jugdaohsingh R. Silicon and bone health. J Nutr Health Aging 2007;11:99–110.
Jugdaohsingh R, Pedro LD, Watson A, Powell JJ. Silicon and boron differ in their localization and loading in bone. Bone Rep 2015;1:9–15.
Kim MH, Bae YJ, Choi MK, Chung YS. Silicon supplementation improves the bone mineral density of calcium-deficient ovariectomized rats by reducing bone resorption. Biol Trace Elem Res 2009;128:239–47.
Maehira F, Miyagi I, Eguchi Y. Effects of calcium sources and soluble silicate on bone metabolism and the related gene expression in mice. Nutrition 2009;25:581–9.
Papaioannou DS, Kyriakis CS, Alexopoulos C, Tzika ED, Polizopoulou ZS, Kyriakis SC. A field study on the effect of the dietary use of a clinoptilolite-rich tuff, alone or in combination with certain antimicrobials, on the health status and performance of weaned, growing and finishing pigs. Res Vet Sci 2004;76:19–29.
Pietak AM, Reid JW, Stott MJ, Sayer M. Silicon substitution in the calcium phosphate bioceramics. Biomaterials 2007;28:4023–32.
Reffitt DM, Ogston N, Jugdaohsingh R, Cheung HF, Evans BA, Thompson RP, et al. Orthosilicic acid stimulates collagen type 1 synthesis and osteoblastic differentiation in human osteoblast-like cells in vitro. Bone 2003;32:127–35.
Shim MY, Karnuah AB, Mitchell AD, Anthony NB, Pesti GM, Aggrey SE. The effects of growth rate on leg morphology and tibia breaking strength, mineral density, mineral content and bone ash in broilers. Poultry Sci 2012;91:1790–5.
Short FE, Belton D, Mann G, Perry C. Efficacy of a novel form of dietary silicon supplement in reducing lameness in poultry. Br Poult Abstr 2011;7:1–2.
Tran ST, Bowman ME, Smith TK. Effects of a silica-based feed supplement on performance, health and litter quality of growing turkeys. Poultry Sci 2015;94:1902–8.
Wu QJ, Wang LC, Zhou YM, Zhang JF, Wang T. Effects of clinoptilolite and modified clinoptilolite on the growth performance, intestinal microflora, and gut parameters of broilers. Poultry Sci 2013;92:684–92.
Yan L, Han DL, Meng QW, Lee JH, Park CJ, Kim IH. Effects of anion supplementation on growth performance, nutrient digestibility, meat quality and fecal noxious gas content in growing-finishing pigs. Asian Australas J Anim Sci 2010;23:1073–9.