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The Effect of Dietary Silicate Minerals Supplementation on Apparent Ileal Digestibility of Energy and Protein in Broiler Chickens

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ABSTRACT

This study examined the effects of kaolin, bentonite and zeolite on energy efficiency ratio (EER), protein efficiency ratio (PER), ileal digestibility of energy, ileal digestibility of protein and carcass yield in broilers. Sexed broiler cockerels Ross 308 were randomly divided into 7 dietary treatments, each comprising 56 chickens. The treatments were: control, 1.5% kaolin, 3% kaolin, 1.5% bentonite, 3% bentonite, 1.5% zeolite and 3% zeolite. PER and EER in diets with 3% kaolin and zeolite in starter phase and 3% kaolin in the overall period showed significant increase compared to control (P<0.05). The protein digestibility in treatments containing 3% kaolin and zeolite showed a significant increase in compared with control (P<0.05). This attribute in other dietary treatments and energy digestibilities in all dietary treatments containing mineral silicate were higher than control, although the differences were not significant (P>0.05). Abdominal fat decreased significantly (P<0.05) in treatments with 1.5% kaolin and bentonite compared to control. The mineral silicate supplementation had a positive effect on the ileal digestibility of energy and protein in broiler chickens. © 2012 Friends Science Publishers

Key Words: Silicate minerals; Ileal digestibility; Energy: protein efficiency ratio; Broiler

INTRODUCTION

In 1965, Japanese researchers reported that the use of mineral silicates in poultry diets improves performance of poultry. Since then, there have been several studies regarding the effects of these mineral silicates on the performance as well as health of poultry. Kaolin, bentonite and zeolite are the most mineral silicates, which are used in poultry diets. Most clays and zeolites are hydrated and composed of mainly aluminum and silica and belong to the group of aluminosilicates. Kaolin and bentonite belong to the group of silicates with the name of phillosilicates (Mumpton, 1999; Trckova *et al.*, 2004). Kaolin is composed of two layers, one of the tetrahedral silica sheet and the other one octahedral sheet that is built by alumin. Difference between different kaolin minerals, is from overlap this layers together. Major constituent mineral of kaolin is kaolinite. It has chemical form of hydrated silicates of aluminum, general structure of this group composed of a sheet of alumin and two sheets of silica (2:1). The chemical formula for the kaolinite group is $Al_2Si_2O_5(OH)_4$ (Adamis *et al.,* 2005). Bentonite is clay that absorbs water rapidly then its volume increase and the main mineral constituent of bentonite is montmorillonite (Serwicka & Bahranowski, 2004).

Zeolites are a group of crystalline aluminosilicates with tiny pores and channels with dimensions of 3 -10 Å, the zeolites have the amount of 10 to 20% of water in their compound, on the basis of weak bund water molecules they reversibly loose water without any change, they can also cation exchange, while absorb and desorb water and exchange their own cations (Tiwari, 2007).

Nowadays, mineral silicates uses as efficacious and useful feed additive at international level because of their influential effect on nutrients of diet. Various studies show that the use of silicate minerals in broiler diets could improve performance (Santurio, 1999; Tauqir *et al.,* 2001; Hesham *et al.*, 2004; Miles & Henry, 2007). Mechanisms of the effects of mineral silicates in improving the poultry performance is not clear enough. There have been various studies, and different reasons have been reported for this subject. Cation exchange and absorption properties of these minerals without major change in its structure cause to increased efficiency in poultry nutrition (Shariatmadari, 2008). In addition to the above properties, Pond (1995) indicated that physiological effects of the zeolites appear to be related to their high cation-exchange capacity that affects tissue uptake and utilization of ammonium ions.

Some researchers believe the silicate minerals by stimulating gastrointestinal tract can improve the digestibility of diet as well as broiler performance. Mechanically stimulated gastrointestinal epithelial cells due to increased mucosal morphology and the level of gastrointestinal absorption of the small intestine improve digestion and absorption of nutrients. Also the presence of montmorillonite in the diet of broilers significantly increased the activities of maltase, aminopeptidase and alkaline phosphatase in small intestinal mucosa (Ma & Guo, 2008). Aluminosilicates are also effective as slow release carriers for many drugs (Cerri *et al.*, 2004). Silicate minerals by a temporary connection with the nutrients reduce gastrointestinal passage rate that nutrients exposure to digestion longer.

The aim of this research was to consider the impacts of using kaolin, bentonite and zeolite in diet and determine energy efficiency ratio (EER), protein efficiency ratio (PER), ileal digestibility of energy and protein and carcass yield of these diets on the performance of broilers.

MATERIALS AND METHODS

Experimental design and diet: A total of 448 1-d-old Ross 308 broiler male chicks were obtained from a commercial hatchery and transported to an environmentally controlled poultry shed at the Gorgan University of Agricultural Sciences and Natural Resources Poultry Research Station (Golestan, Iran). Upon arrival, chicks were weighed and randomly distributed in 28 pens (16 chicks per pen). Temperature kept constant at 32°C from 0 to 7 d and progressively reduced to reach 18°C at 35 d and remained constant until 42 d. Lighting was 24 h/day during the 42 days. The experimental design consisted of 7 dietary treatments. The treatments were: control, 1.5% kaolin, 3% kaolin, 1.5% bentonite, 3% bentonite, 1.5% zeolite and 3% zeolite. Diet was prepared and formulated to contain National Research Council (NRC) (1994) requirements of all nutrients, without antibiotics or growth promoters. The starter (0-21) and grower (21-42) diets were isonitrogenous and isoenergetic and contained the suitable levels of methionine, lysine, vitamins and minerals. The starter diets had 20.85% crude protein, 2900 kcal of ME kg^{-1} and the grower diets had 18.75% crude protein, 3000 kcal of ME per kg of diet, respectively. Birds had ad libitum access to feed and water during the experiment. To maintain accurate and safe control, the diets containing the various treatments were placed in plastic feed containers with lids in the growing house.

Collection and analysis of samples: Before slaughtering at 42 d of age, 8 chickens per treatment were chosen to match the 35 d averages of BW each treatment. At 42 d, all chickens were fasted for 8 h before slaughter and the 56 selected chickens (8 birds from each treatment) were slaughtered to determined carcass, breast, thighs and abdominal fat these organs were immediately dissected and individually weighed. Weights were expressed as a percentage of body weight, thus obtaining the relative weight of organs.

Protein Efficiency Ratio (PER) was gauged according to the method delineated by McDonald *et al.* (1995) (grams of weight gain per gram of protein intake). In order to determine the protein digestibility of diets, on day 28, birds of uniform body weight were chosen and randomly assigned in 28 groups and then, 3 g/kg chromic oxide were added to the diet for 7 days (28-35 d) and on day 35, two birds were randomly selected from each replicate and slaughtered. The contents of the ileum (from Meckel's diverticulum to 1 cm above the ileo-caecal junction) were gently squeezed directly into 250-mL specimen cups. The ileal digesta samples were frozen, freeze dried, ground, and analyzed for energy, nitrogen and chromic oxide to determine energy and protein digestibility (Scott & Boldaji, 1997). Feed and ileal digesta samples were analyzed for chromic oxide by atomic absorption spectrometry as described by Williams *et al.* (1962). Nitrogen was determined by the Kjeldahl method and the protein contents were calculated using the multiplication factor of 6.25. The following equation was used for the calculation of ileal nitrogen digestibility:

Ileal nitrogen digestibility (%) = {1 − [(Cr2O3% diet/Cr2O3% digesta) × (N % digesta/N % diet)]} ×100

Energy efficiency ratio (EER) was also calculated for each phase. EER was calculated as grams of weight gain×100/total ME intake (Kamran *et al.*, 2008). Diets and ileal digesta samples were analyzed for gross energy by bomb calorimetry. The AME values were determined using the following formula (Scott & Boldaji, 1997).

AME (kilocalories per kilogram of diet) = $GE_{diet} - [GE_{excreta/digesta} \times (Marker_{diet}/Marker_{excreta/digesta})]$

Statistical analysis: The experiment was conducted using a completely randomized design. Data were subjected to analysis of variance using GLM procedure of SAS (2003), and when significant differences were obtained, Duncan's multiple range tests (Duncan, 1955) at 5% probability level was used.

RESULTS AND DISCUSSION

The effects of dietary treatments on protein efficiency ratio (PER) and ileal digestibility of protein are presented in Table I. In the starter phase, chickens fed treatments with 3% kaolin and 3% zeolite had a significant (P<0.05) higher PER than chicken fed control diet. There were no significant differences in the grower phase among dietary treatment and control (P>0.05). The PER in treatment with 3% kaolin in overall period was significantly (P<0.05) higher compared to treatment with 3% bentonite and control. The protein digestibility in treatments containing 3% kaolin and zeolite showed a significant increase in comparison with control (P<0.05). In other dietary treatments containing mineral silicate, the protein digestibility was higher than control, but

Table I: Effect of kaolin, bentonite and zeolite on protein efficiency ratio and ileal protein digestibility

Treatments	Protein efficiency ratio (g: g)			Ileal protein digestibility (%)
	Starter (0-21 d)	Grower (21-42 d)	Overall (0-42 d)	35 day
Control	2.80[b]	2.49	2.52[b]	70.22[b]
Kaolin 1.5%	2.92[ab]	2.57	2.60[ab]	75.09[ab]
Kaolin 3%	3.01[a]	2.66	2.69[a]	78.02[a]
Bentonite 1.5%	2.92[ab]	2.50	2.55[ab]	73.85[ab]
Bentonite 3%	2.89[ab]	2.47	2.51[b]	70.95[ab]
Zeolite 1.5%	2.84[b]	2.53	2.55[ab]	74.80[ab]
Zeolite 3%	2.99[a]	2.62	2.65[ab]	77.94[a]
SEM	0.04	0.06	0.04	2.31

Table II: Effect of kaolin, bentonite and zeolite on energy efficiency ratio and ileal energy digestibility

Treatments	Energy efficiency ratio (%)			Ileal energy digestibility (kcal/kg)
	Starter (0-21 d)	Grower (21-42 d)	Overall (0-42 d)	35 day
Control	20.22[b]	15.23	16.72[b]	2716.18
Kaolin 1.5%	20.97[ab]	15.85	17.33[ab]	2742.97
Kaolin 3%	21.70[a]	16.24	17.86[a]	2774.65
Bentonite 1.5%	20.87[ab]	15.55	17.01[ab]	2719.16
Bentonite 3%	20.89[ab]	15.41	16.88[ab]	2730.26
Zeolite 1.5%	20.74[ab]	15.47	17.04[ab]	2737.21
Zeolite 3%	21.56[a]	16.07	17.62[ab]	2761.62
SEM	0.30	0.41	0.31	23.54

Table III: Effect of kaolin, bentonite and zeolite on carcass yield (percentage of live weight)

Treatments	Carcass	Thigh	Breast	Abdominal fat
Control	63.28	17.80[ab]	20.51	1.79[a]
Kaolin 1.5%	64.34	17.96[ab]	20.59	1.53[b]
Kaolin 3%	64.46	17.27[b]	21.42	1.72[ab]
Bentonite 1.5%	63.86	18.33[a]	21.36	1.48[b]
Bentonite 3%	63.95	17.27[b]	20.63	1.63[ab]
Zeolite 1.5%	64.40	18.10[ab]	20.94	1.70[ab]
Zeolite 3%	64.62	17.61[ab]	20.74	1.65[ab]
SEM	0.52	0.28	0.56	0.07

Means within columns with no common superscripts are significantly different (P<0.05)

this difference was numerically not statistically (P>0.05). Acosta *et al*. (2005) reported that the use of 1% zeolite in diet led to decrease in protein intake and increase in body weight. Pasha *et al*. (2008) reported birds fed diets containing sodium bentonite treated with 0.5% or 1.0% acetic acid improved protein efficiency ratio and protein digestibility. The reason for this improvement was the action of silicate minerals in which enhanced digestibility of certain nutrients. Silicate minerals by making temporary connection with the nutrients reduce gastrointestinal passage rate that nutrients exposure to digestion longer.

Mumpton and Fishman (1977) suggested that zeolite can increase digestibility of feeds as well as broilers performance. Tatar *et al.* (2008) observed that the amount of ileal digestibility of protein in diets containing zeolite increased with compared to control and believed zeolite can stimulate small intestine villis. This may be the reason for improved digestibility. Safaeikatouli *et al.* (2011) reported that dietary inclusion of silicate mineral can improve the values of serum total proteins and albumin in broiler chickens. The reason for PER and ileal digestibility of protein improvement was due to the presence of silicate mineral that prolonged feed passage time and improved nutrient metabolism.

The energy efficiency ratio (EER) in diets with 3% kaolin and zeolite in starter phase and 3% kaolin in the overall period showed significant increase compared to control (P<0.05). In the grower phase there were no significant differences between dietary treatments and control (P>0.05). Energy digestibility in all treatments containing mineral silicate was higher compared to control, but this difference was not significant (P>0.05) (Table II). Ly *et al.* (2007) reported ileal digestibility of energy increased when 5% zeolite was added to the pig's diet.

Table III shows the effect of dietary treatments on Carcass yield. The amount of abdominal fat decreased significantly (P<0.05) in treatments with 1.5% kaolin and bentonite compared to control. Diet consisted of 1.5% bentonite significantly (P<0.05) increased thigh percentage compared to the 3% kaolin and bentonite. There were no significant differences (P>0.05) in the carcass and breast percentage among experimental treatments and control. Lon-Wo *et al.* (1993) indicated that adding zeolite to the broiler diet resulted in decrease in abdominal fat compared to control. Lotfollahian *et al.* (2004) reported that using of low level of zeolite (2%) resulted in a decrease in abdominal fat, but with an increase in zeolite level (4% & 6%) resulted in an increase in the amount of abdominal fat. An the other hands, some experiments done by Yalcin *et al*. (1995), Salari *et al.* (2006) and Kermanshahi *et al.* (2009), they found no differences in carcass of broilers fed diets contained either hydrated sodium calcium aluminosilicates or bentonite.

CONCLUSION

The results showed the beneficial effects of kaolin, bentonite and zeolite on broiler's performance. Thus use of these silicate mineral in the broiler diets may improve digestibility of energy and protein as well as protein efficiency ratio.

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