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Economic analysis using silicate minerals in broiler chickens diets

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Abstract. This study investigated a use of different levels of silicate minerals (kaolin, bentonite and zeolite) in broiler diets on economic indicators. Four hundred and forty eight (n 448) day old male broilers (Ross 308 strain) randomly assigned to 1 of 7 treatments, replicated 4 times with 16 broilers in each were reared using completely randomized design for 42 days. Dietary silicate minerals concentrations used were: 0 (control) and 15, 30 g/kg, kaolin, bentonite and zeolite. The feed conversion ratio significantly improved ($P<0.05$) in treatments with 30 g/kg kaolin and zeolite in starter period and 30 g/kg kaolin in the overall study period compared to the control treatment. Treatment with 30 g/kg kaolin in starter and overall periods, and treatments containing two levels of zeolite (15 g/kg and 30 g/kg) in grower and overall periods showed better weight gain value in comparison with 15 g/kg bentonite and control treatments ($P<0.05$). Inclusion of 30 g/kg kaolin in starter, grower and overall periods and 30 g/kg zeolite in overall period in broiler diet significantly ($P<0.05$) decreased meat production cost. In the starter period economic efficiency, profitability and cost benefit ratio were significantly ($P<0.05$) increased in treatment with 30 g/kg kaolin compared to control. In the overall period, diets containing 30 g/kg kaolin and zeolite had a significantly ($P<0.05$) greater profitability than chicken fed control diet. In the starter and overall periods, European production efficiency factor increased significantly ($P<0.05$) in treatments with 30 g/kg kaolin and zeolite compared to the control. Feeding broiler chickens with silicate minerals was effective in the improvement of economic indicators and commercial use of silicates minerals is recommended as an ingredient of broiler diets.
Key Words: Kaolin, bentonite, zeolite, economic analysis, diet, broiler chickens.

Introduction. Poultry industry has been playing a significant role in supplying protein requirements of human beings. Chicken meat with desirable level of protein and essential amino acids has high biological value. Therefore, chicken meat is higher in demand than the other kinds of meat, and its consumption is increasing significantly. During the last century many efforts have been made to increase efficiency in broiler production with improved breeding techniques to produce rapid growing strains with better feed conversion ratio. However, in recent years these methods have been encountered with several limitations. As feed cost of broilers comprises 70 % of raising costs, improving nutritional content of the feed may decrease the cost of production or increase feed efficiency (Louw et al 2011). One solution for improving nutritional value the feed may be use of feed additives such as silicate minerals to improve broiler growth, as well as prevent diseases. Silicate minerals include about 90 % of the ground minerals which due to their physical and chemical properties some kinds of them such as zeolite, bentonite, kaolin, sepiolite, perlite, illite and granite can be used as feed additives in poultry's diet. The most important structural properties of silicate minerals are their ability to lose and gain water reversibly and high cation exchange capacity without much major changes of structure that can be effective in improvement of poultry performance (Shariatmadari 2008; Safaeikatouli et al 2010a).

Several studies have shown that supplementation of broiler chickens diet with silicate minerals could improve broiler performance (Shariatmadari et al 2004; Shi et al 2009;

Eser et al 2011), ileal digestibility of energy and protein (Acosta et al 2005; Pasha et al 2008; Safaeikatouli et al 2012b), bone characteristics (Yalcin et al 1995; Herzig et al 2008; Safaeikatouli et al 2012a), litter quality (Karamanlis et al 2008; Safaeikatouli et al 2011a; Safaeikatouli et al 2014) and reduce adverse effects of aflatoxin (Tomsevic-Canovic et al 2001; Arab-Abousadi et al 2007 ; Oguz et al 2011). Various research have indicated that using silicate minerals in the diet of birds did not have any adverse effects on the birds yield and health (Oguz et al 2000; Safaeikatouli et al 2010b; Eleroglu et al 2011; Safaeikatouli et al 2011b) as well as not harmful effect on human health. Previous findings show that utilize of silicate minerals in diets can be improve health, welfare and performance of broiler chickens. It is expected that using silicate minerals in broiler diets, hence have an effective impact on economic indicators.

The objective of this research was to analyze the effect of different kinds and levels of silicate minerals (kaolin, bentonite and zeolite) in diet of broiler chickens on feed intake (FI), feed conversion ratio (FCR), feed cost (FC), feed intake cost (FIC), weight gain value (WGV), meat production cost (MPC), economic efficiency (EE), european production efficiency factor (EPEF), profitability and cost benefit ratio (CBR).

Material and Method

Four hundred and forty eight day-old Ross 308 male broilers were randomly assigned to 1 of 7 treatments, replicated 4 times with 16 broilers in each. The birds were reared for 42 days in identical size pens (1.5 x 1.5 m, each broiler had approximately 0.14 m^2 spaces) in a deep litter system under completely randomized design. The commercial recommendations were followed for climatic conditions and lighting program. Room temperature during the first week of the experiment was maintained as 32 $^{\circ}$C which was decreased to 18 $^{\circ}$C till the end of the experiment. Relative humidity of the room was about 60 – 70 % and artificial lighting was supplied continuously for 24 hours every day.

Experimental diets. All the experimental diets were formulated to meet the NRC (1994) standards for broiler chicken. The diets were based on corn and soybean meal and were isonitrogenous and isocaloric. The starter diets contained 23 % crude protein and 2900 kcal of metabolizable energy per kg of diet and the grower diets contained 20 % crude protein and 3000 kcal of metabolizable energy per kg of diet. Treatments were (1) control (standard diet without silicate minerals), (2) diet supplemented with 15 g/kg kaolin, (3) diet supplemented with 30 g/kg kaolin, (4) diet supplemented with 15 g/kg bentonite, (5) diet with 30 g/kg bentonite, (6) diet with 15 g/kg zeolite, (7) diet supplemented with 30 g/kg zeolite. The birds were supplied with feed and water *ad-libitum*. They were vaccinated against Gumboro, Bronchitis and Newcastle disease through intra ocular route.

Parameters studied. Body weight and feed consumption of each pen were recorded in starter, grower and overall periods to calculate feed intake (FI), feed conversion ratio (FCR), feed intake cost (FIC), weight gain value (WGV), meat production cost (MPC), economic efficiency (EE), European production efficiency factor (EPEF), profitability and cost benefit ratio (CBR) by using the following formulas:

Feed intake cost ($/kg) = FI (kg) × FC ($)
Weight gain value ($/kg) = weight gain (kg) × price of live broiler ($/kg)
Meat production cost ($/kg) = FIC ($/kg) / weight gain (kg) or = FCR (g/g) × FC ($)
Economic efficiency ($/$) = [(WGV, $/kg – FIC, $) / FIC, $] × 100
European production efficiency factor = [(BW, kg × livability, %) / (FCR × age, days)] × 100
Profitability ($) = WGV ($/kg) – FIC ($/kg)
Cost benefit ratio = Profitability ($) / FIC ($/kg)
Where: FI= Feed intake, FC= Feed cost, FIC= Feed intake cost, WGV= Weight gain value, BW = body weight, FCR = Feed conversion ratio.

Statistical analysis. Statistical analyses were conducted using the general linear model procedure of SAS (2003) to determine if variables differed between groups. Significant effects were further explored using Duncan's multiple range tests (Duncan 1955) to ascertain differences among treatment means at 5 % probability level.

Results and Discussion. The results in respect with dietary treatments on feed intake and feed conversion ratio are given in table 1.

Table 1

Effect of different dietary silicate treatments on feed intake and feed conversion ratio in broilers

Treatments	*Feed Intake (FI) (g)*			*Feed Conversion Ratio (FCR) (g/g)*		
	Starter (0-21 d)	*Grower (21-42 d)*	*Overall (0-42 d)*	*Starter (0-21 d)*	*Grower (21-42 d)*	*Overall (0-42 d)*
Control	1070.86	3047.75[b]	4118.60[b]	1.70[a]	2.12	1.99[a]
Kaolin 15 g/kg	1083.52	3145.27[ab]	4228.78[ab]	1.64[abc]	2.06	1.93[ab]
Kaolin 30 g/kg	1066.41	3040.34[b]	4106.74[b]	1.59[c]	1.99	1.87[b]
Bentonite 15 g/kg	1028.59	3065.41[b]	4094.01[b]	1.64[abc]	2.12	1.98[ab]
Bentonite 30 g/kg	1063.74	3327.78[a]	4391.52[a]	1.66[ab]	2.16	2.01[a]
Zeolite 15 g/kg	1090.70	3265.18[ab]	4355.88[ab]	1.69[a]	2.10	1.98[ab]
Zeolite 30 g/kg	1052.81	3178.35[ab]	4231.16[ab]	1.61[bc]	2.04	1.91[ab]
SEM	22.35	70.33	83.70	0.02	0.05	0.03

Means within columns with different superscripts show significant difference (P<0.05).

The feed conversion ratio in starter period is significantly (P<0.05) improved in treatments with 30 g/kg kaolin and zeolite, compared to the treatments with 15 g/kg zeolite and control. Similarly, feed conversion ratio in treatment with 30 g/kg kaolin was significantly (P<0.05) better as compared to the treatments with 30 g/kg bentonite. Feed conversion ratio did not differ significantly (P>0.05) between treatments in grower period. In the overall period, there were significant differences between 30 g/kg kaolin in compared with 30 g/kg bentonite and control. These results are supported by the previous findings (Pasha et al 2007; Abas et al 2011; Al-Nasser et al 2011) indicating that silicate minerals improved feed conversion ratio in broiler chicks. In contrast, Cabuk et al (2004) and Incharoen et al (2009) observed that adding silicate minerals in diet of broilers did not influenced on feed conversion ratio. The diversity among results of experiments could be due to the structural difference among silicate minerals and also their metal oxide content. Therefore, the structure of silicate minerals and excellent processing should be considered to decrease metal oxide content for better output. There were no significant differences (P>0.05) among dietary treatments in feed intake except treatment containing 30 g/kg bentonite in the grower and the overall period that feed intake was significantly (P<0.05) higher compared to the treatments with 15 g/kg bentonite, 30 g/kg kaolin and control. In agreement, Salari et al (2006) indicated that adding 1 and 2 percent bentonite to broiler diet increased feed intake. Teleb et al (2004) and Abas et al (2011) reported that inclusion of kaolin and zeolite in the diet did not have significant effect on feed intake.

Table 2 shows the effects of experimental treatments on the feed cost and feed intake cost. The feed cost in treatments containing silicate minerals was higher compared to control diet in the starter, grower and overall periods, but these differences were not significant. Feed intake cost was not affected (P>0.05) by dietary treatments in starter period, but in the grower period it was higher in 30 g/kg bentonite and 15 g/kg zeolite treatments compared to the control. Feed intake cost was also found to be significantly (P<0.05) higher in 30 g/kg bentonite treatment compared to the treatments with 15 g/kg bentonite and 30 g/kg kaolin. In overall period, feed intake cost in treatment with 30 g/kg bentonite was significantly (P<0.05) higher compared to the treatments with 15 g/kg bentonite and control. Similar work however did not find any significant differences among experimental treatments (Damiri et al 2010).

Table 2

Effect of different dietary silicate treatments on feed cost and feed intake cost in broilers

Treatments	*Feed Cost (FC) ($)*			*Feed Intake Cost (FIC) ($/kg)*		
	Starter (0-21 d)	*Grower (21-42 d)*	*Overall (0-42 d)*	*Starter (0-21 d)*	*Grower (21-42 d)*	*Overall (0-42 d)*
Control	0.3632	0.3519	0.3548	0.389	1.072^{c}	1.461^{b}
Kaolin 15 g/kg	0.3671	0.3578	0.3602	0.398	1.125^{abc}	1.523^{ab}
Kaolin 30 g/kg	0.3710	0.3596	0.3626	0.396	1.093^{bc}	1.489^{ab}
Bentonite 15 g/kg	0.3660	0.3546	0.3575	0.376	1.087^{bc}	1.464^{b}
Bentonite 30 g/kg	0.3688	0.3554	0.3586	0.392	1.183^{a}	1.575^{a}
Zeolite 15 g/kg	0.3661	0.3548	0.3576	0.399	1.158^{ab}	1.558^{ab}
Zeolite 30 g/kg	0.3690	0.3577	0.3605	0.388	1.137^{bc}	1.525^{ab}
SEM	-	-	-	0.008	0.025	0.030

Means within columns with different superscripts show significant difference (P<0.05).

The effects of dietary treatments on the weight gain value and meat production cost are presented in table 3. In the starter period, weight gain value in treatment with 30 g/kg kaolin was significantly (P<0.05) higher compared with 15 g/kg bentonite and control treatments. The treatments containing two levels of zeolite (15 g/kg and 30 g/kg) showed a significant (P<0.05) increase in weight gain value compared to 15 g/kg bentonite and control treatments in the grower period. In the overall period, treatment containing two levels of zeolite (15 g/kg and 30 g/kg) and 30 g/kg kaolin showed better (P<0.05) results in comparison with 15 g/kg bentonite and control treatments. Inclusion of 30 g/kg kaolin in starter, grower and overall periods and 30 g/kg zeolite in overall period in broiler diet significantly (P<0.05) decreased meat production cost. On the other hand, treatment containing 30 g/kg bentonite showed the highest (P<0.05) meat production cost among dietary treatments in grower and overall periods. Zarin-Kavyani et al (2007) observed that adding 3 to 4 percent zeolite in broiler diets decreased meat production cost. Whereas, Damiri et al (2010) declared that no significant differences (P>0.05) were seen in meat production cost among treatments containing sodium bentonite and control treatments.

Table 3

Effect of different dietary silicate treatments on weight gain value and meat production cost in broilers

Treatments	*Weight Gain Value (WGV) ($/kg)*			*Meat Production Cost (MPC) ($/kg)*		
	Starter (0-21 d)	*Grower (21-42 d)*	*Overall (0-42 d)*	*Starter (0-21 d)*	*Grower (21-42 d)*	*Overall (0-42 d)*
Control	0.949^{b}	2.172^{b}	3.121^{b}	0.617^{a}	0.746^{ab}	0.706^{ab}
Kaolin 15 g/kg	0.997^{ab}	2.302^{ab}	3.299^{ab}	0.602^{ab}	0.737^{bc}	0.695^{bc}
Kaolin 30 g/kg	1.012^{a}	2.307^{ab}	3.319^{a}	0.590^{b}	0.716^{c}	0.678^{d}
Bentonite 15 g/kg	0.947^{b}	2.186^{b}	3.133^{b}	0.600^{ab}	0.752^{ab}	0.708^{ab}
Bentonite 30 g/kg	0.966^{ab}	2.329^{b}	3.295^{ab}	0.612^{ab}	0.768^{a}	0.721^{a}
Zeolite 15 g/kg	0.976^{ab}	2.355^{a}	3.331^{a}	0.619^{a}	0.745^{ab}	0.708^{ab}
Zeolite 30 g/kg	0.990^{ab}	2.355^{a}	3.345^{a}	0.594^{ab}	0.730^{bc}	0.689^{dc}
SEM	0.019	0.051	0.057	0.008	0.008	0.005

Means within columns with different superscripts show significant difference (P<0.05).

Economic efficiency and European production efficiency factor (EPEF) of broilers supplemented with different kinds and levels of silicate minerals in diets are shown in Table 4. In the starter period (0-21 d) economic efficiency was significantly (P<0.05) increased in treatment with 30 g/kg kaolin compared with 15 g/kg zeolite and control. Although, the difference in economic efficiency between experimental treatments and control treatment was not significant (P>0.05) in grower and overall periods, the differences between treatments with 30 g/kg kaolin and 30 g/kg bentonite in overall period was significant (P<0.05). EPEF in starter period increased significantly (P<0.05) in treatments with 30 g/kg kaolin and zeolite compared to control. In the grower period, EPEF in chickens fed kaolin (15, 30 g/kg) and zeolite (15, 30 g/kg) were higher than control, but the differences were not significant (P>0.05). In the overall period (0-42 d), EPEF in treatments containing 30 g/kg kaolin and zeolite were significantly higher compared to treatments with 15 g/kg bentonite and control. Lotfollahian et al (2004) observed an increase in EPEF with the increased level of zeolite in the diet. In contrast, Safari (2009) reported that the inclusion of zeolite in the diet of broilers had no effect on the EPEF.

Table 4

Effect of different dietary silicate treatments on economic efficiency and European production efficiency factor in broilers

Treatments	*Economic Efficiency (EE) ($/$)*			*European Production Efficiency Factor (EPEF)*		
	Starter (0-21 d)	*Grower (21-42 d)*	*Overall (0-42 d)*	*Starter (0-21 d)*	*Grower (21-42 d)*	*Overall (0-42 d)*
Control	144.04^{b}	102.54	113.56^{ab}	175.61^{b}	323.66	247.08^{b}
Kaolin 15 g/kg	150.64^{ab}	104.82	116.74^{ab}	191.77^{ab}	352.16	268.79^{ab}
Kaolin 30 g/kg	155.94^{a}	111.04	122.90^{a}	197.70^{a}	360.43	275.88^{a}
Bentonite 15 g/kg	151.53^{ab}	101.46	114.31^{ab}	182.14^{ab}	316.52	242.96^{b}
Bentonite 30 g/kg	146.49^{ab}	97.02	109.34^{b}	180.85^{ab}	334.98	254.11^{ab}
Zeolite 15 g/kg	144.60^{b}	103.35	113.92^{ab}	182.49^{ab}	350.59	262.60^{ab}
Zeolite 30 g/kg	155.08^{ab}	107.39	119.53^{ab}	194.53^{a}	365.00	276.41^{a}
SEM	3.39	4.89	3.78	5.43	15.48	8.76

Means within columns with different superscripts show significant difference (P<0.05).

Table 5 presents effects of the dietary treatments on profitability and cost benefit ratio.

Table 5

Effect of different dietary silicate treatments on profitability and cost benefit ratio in broilers

Treatments	*Profitability ($)*			*Cost Benefit Ratio (CBR)*		
	Starter (0-21 d)	*Grower (21-42 d)*	*Overall (0-42 d)*	*Starter (0-21 d)*	*Grower (21-42 d)*	*Overall (0-42 d)*
Control	0.56^{b}	1.10	1.66^{c}	1.44^{b}	1.02	1.14^{ab}
Kaolin 15 g/kg	0.60^{ab}	1.17	1.77^{abc}	1.51^{ab}	1.05	1.17^{ab}
Kaolin 30 g/kg	0.62^{a}	1.21	1.83^{a}	1.56^{a}	1.11	1.23^{a}
Bentonite 15 g/kg	0.57^{b}	1.10	1.67^{bc}	1.51^{ab}	1.01	1.14^{ab}
Bentonite 30 g/kg	0.58^{ab}	1.15	1.72^{abc}	1.46^{ab}	0.97	1.09^{b}
Zeolite 15 g/kg	0.58^{ab}	1.20	1.77^{abc}	1.45^{b}	1.03	1.14^{ab}
Zeolite 30 g/kg	0.60^{ab}	1.22	1.82^{ab}	1.55^{ab}	1.07	1.19^{ab}
SEM	0.01	0.05	0.05	0.03	0.05	0.04

Means within columns with different superscripts show significant difference (P<0.05).

In the starter period, treatment containing 30 g/kg kaolin showed significantly (P<0.05) greater profitability compared to 15 g/kg bentonite and control treatments. In the grower period, no significant (P>0.05) differences were observed between dietary treatments and control. In the overall period diets containing 30 g/kg kaolin and zeolite had significantly (P<0.05) greater profitability than the control diet. In the starter period (0-21 d), inclusion of 30 g/kg kaolin in diet significantly (P<0.05) improved cost benefit ratio compared with 15 g/kg zeolite and control diets. Cost benefit ratio did not show any significant (P>0.05) difference between experimental treatments and control in grower and overall periods, but in overall period experimental treatments with 30 g/kg kaolin and 30 g/kg bentonite showed significant differences (P<0.05). These results indicate that inclusion of silicate mineral to broiler diets increased the profitability and cost benefit ratio. Kaolin, bentonite, and zeolite have not been reported to influence profitability and cost benefit ratio.

Conclusions. In conclusion, diets containing kaolin and zeolite showed better result in comparison to diets containing bentonite; also adding 30 g/kg of kaolin and zeolite in diets is more beneficial than 15 g/kg in improving economic indicators in broiler chickens. Based on the results of this study, feeding broiler chickens with silicate minerals was effective in the improvement of economic indicators and commercial use of silicate minerals is recommended as an ingredient in broiler diets.

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