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The Effect of a Natural Zeolite (Clinoptilolite) on the Performance of Broiler Chickens and the Quality of Their Litter*

X. Karamanlis, P. Fortomaris, G. Arsenos, I. Dosis, D. Papaioannou, C. Batzios and A. Kamarianos**
Department of Animal Production, Ichthyology, Ecology and Protection of Environment,
Faculty of Veterinary Medicine, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

ABSTRACT : The objective of this study was to assess the effect of clinoptilolite (a natural zeolite) on growth and performance of broilers as well as on the quality of their litter. A total of 5,200 one-day old broiler chickens (Cobb 500) were used in two consecutive rounds lasting 42 days each. The broilers were given free and continuous access to a nutritionally non-limiting diet (in meal form) that was either a basal diet (B) or a 'zeolite diet' (Z; the basal diet supplemented with clinoptilolite at a level of 2%). A 2×2 factorial design consisted of two feeding treatments (B and Z) and two bedding types, sawdust (S) and sawdust with zeolite (Sz, which was the result of adding 2 kg zeolite/m^2), was used. In each round the broilers were randomly assigned to one of four (n = 650), treatment groups: two fed on the basal diet (B) and had bedding of either sawdust (group BS) or sawdust and zeolite (group BSz) and two fed on the Z diet and had as bedding either sawdust (ZS) or sawdust and zeolite (ZSz). Average growth rates were significantly ($p<0.05$) different between broilers of different groups; broilers that were fed on the 'zeolite diet' (Z) and were placed either in a compartment with sawdust bedding or sawdust bedding and zeolite (ZS and ZSz) as well those that were fed on the basal diet in a compartment with sawdust bedding and zeolite (BSz) grew at a faster rate ($p<0.05$) compared with those of the control group (BS). The incorporation of NZ in broilers diets and in their bedding material decreased the organic content in litter samples throughout the experimental period. The lowest organic content was recorded in group ZSz where NZ was added in both feed and litter. Mean ammonia concentration (ppm) was significantly higher in group ZS in comparison to groups BSz and ZSz (27.00 vs. 20.55 and 21.71 respectively). The results of this study showed that the incorporation of the clinoptilolite both in feed and into the litter had a positive effect on broiler growth and also on the quality of their litter. (**Key Words :** Broilers, Clinoptilolite, Performance, Litter Quality)

INTRODUCTION

In practice, one of the priorities of today's industrialized poultry production is the control of excreta/litter moisture and quality, which implies reduction of their amount and content as well as their utilization and disposal (Francesch and Brufau, 2004; Kim et al., 2006). The notion is that excreta, feed, feathers and bedding material are all components of poultry litter (Nahm, 2005a). The evidence in the literature suggests that excreta/litter moisture and quality are associated with health, performance and welfare of broilers and hens whereas they may be the source of environmental and management problems in commercial poultry industry (Blair et al., 1999; Al-Homidan et al., 2003; Islam et al., 2003).

There is also evidence of intense research efforts towards various methods to reduce the pollutants released from poultry farms. The need of alternative approaches to address the aforementioned problems is particularly relevant in the case of nutritional aspects that could modify the moisture and quality of poultry excreta/litter (Francesch and Brufau, 2004) and the use of chemicals as litter and manure additives (McCrory and Hobbs, 2001; Nahm, 2005a). But the effectiveness of such approaches has been debated (Nahm, 2005b). The need to establish management practices to reduce or to eliminate the pollutants from poultry farms necessitates the research on natural alternatives for safe use in poultry production. Such alternatives are natural zeolites, which have favorable effects on the growth and performance of different species of animals including poultry (Mumpton and Fishman, 1977;

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** Corresponding Author: X. Karamanlis. Tel: +30-2310-99966, Fax: +30-2310-999986, E-mail: karamanl@vet.auth.gr
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Table 1. Physical composition and chemical analysis of the experimental feeds

Physical composition (g/kg)	Starter (days 0 to 14)		Grower (days 14 to 28)		Finisher (days 29 to 42)	
	B	Z	B	Z	B	Z
Wheat	617.9	580.9	614.4	576.9	624.4	583.4
Soyabean meal	289	290	287	287	273	275
Soya oil	20	31	24.5	32	28	32
Animal fat	0	0	10	15	20	30
Fish meal	30	35	20	25	10	15
Natural zeolite	0	20	0	20	0	20
Vitamin and trace mineral premix*	25	25	25	25	25	25
Limestone	13.5	13.5	14.5	14.5	15	15
Biotronic	3	3	3	3	3	3
Monocalc. phosphate	1	1	1	1	1	1
Anticoccidial	0.5	0.5	0.5	0.5	0.5	0.5
Phytase	0.1	0.1	0.1	0.1	0.1	0.1
Chemical analysis (%)						
Crude protein	23.2	23.2	22.3	22.3	21.1	21.1
Fat	3.9	5.0	5.3	6.5	6.5	7.9
Ca	0.97	0.97	0.98	0.98	0.95	0.95
Avail. P	0.49	0.49	0.48	0.48	0.47	0.47
ME (kcal/kg)	3,074	3,074	3,148	3,148	3,223	3,223

* Providing per kg of diet: 14,000 IU vitamin A, 5,000 IU vitamin D_3, 80 mg vitamin E, 13 mg vitamin K, 26 mg thiamin, 8 mg riboflavin, 3 mg pyridoxine, 0.02 vitamin B_{12}, 85 mg niacin, 22 mg pantothenic acid, 2 mg folic acid, 0.15 mg biotin, 10 mg vitamin C and 450 mg choline chloride, 100 mg zinc, 120 mg manganese, 30 mg iron, 15 mg copper, 0.20 mg cobalt, 1 mg iodine and 0.3 mg selenium.

Pond, 1984; Ramos and Hernandez, 1997; McCrory and Hobbs, 2001).

In the case of poultry, particularly, there has been recently a new interest in the use natural zeolites as a means of reducing odor and ammonia emissions from broiler houses (Amon et al., 1997; McCrory and Hobbs, 2001), as feed additive (Christaki et al., 2001; Christaki et al., 2006; Suchy et al., 2006) and as supplement in bedding materials (Ullman et al., 2004; Eleroglu and Yalcin, 2005). There is less new information, however, on the impact of clinoptilolite on growth and performance of broilers when it is used both as supplement in the diet and into bedding material. The question is whether such approach is reasonable in relation to broiler production and whether can sufficiently account for problems associated with broiler performance and excreta/litter quality. Hence, the objective here was to address the latter question by assessing the effect of a natural material (clinoptilolite) on growth and performance of broilers as well as in the quality of excreta/litter in broiler houses.

MATERIALS AND METHODS

Animals and housing

A total of five thousand and two hundred (5,200) day old broiler chickens from a commercial strain (Cobb 500), were used. The experiment consisted of two consecutive rounds, lasting 42 days each and involving 2,600 broilers, respectively. It took place in a designated area of a commercial poultry house, which was divided in four independent, but identical compartments. Upon arrival (day 0) the broilers were randomly assigned to one of four groups (n = 650), and were equally allocated (stocking density 615 cm^2/bird) to each compartment, which had sawdust for bedding (litter material). Each compartment measured 5.00×8.00 m and was equipped with six (6) feed troughs and five (5) adjustable drinkers for food and water provision, respectively. A light: dark pattern of 23 L:l D was provided. The interior of the poultry house was naturally ventilated by the use of side openings.

Feeds and feeding

The broilers were given free and continuous access to a nutritionally non-limiting concentrate diet (in meal form) that was either a basal diet (B) or a ‘zeolite diet’ (Z). The latter (diet Z) was formulated by supplementing diet B with clinoptilolite (a natural zeolite) at the level of 2%. For the first 14 days a starter ration, was offered. Subsequently, from day 15 to 28 and day 29 to day 42, a grower and a finisher ration were offered, respectively. Both diets were formulated to be relatively high in protein and energy content in order to support the potential growth of broilers according to their physiological state; they were also non-limiting in mineral and vitamin contents. The physical and chemical composition of the diets is shown in Table 1.

Natural zeolite (NZ)

The zeolitic material used was a Clinoptilolite-rich tuff that was obtained from the Palaeogene zeolite-rich tuffs of Evros area, North-Eastern Greece. It contained almost 88% calcium rich clinoptilolite (Kassoli-Fournaraki et al., 2000; Kantiranis et al., 2002). Clinoptilolite is a naturally

Table 2. Semi-quantitative mineralogical composition and chemical microanalysis of the natural zeolite, which was added either in the diet or in the bedding material

Component	% wt
Mineralogical composition	
Clinoptilolite	87
Swelling clays	2
Non swelling clays	1
Micas	4
Quartz	4
Feldspars	2
Chemical microanalysis of the clinoptilolite	
SiO_2	67.54
Al_2O_3	11.92
MnO	0.04
Fe_2O_{3T}	0.06
MgO	0.90
CaO	3.52
SrO	0.51
Na_2O	0.50
K_2O	1.67
LOI	13.23
Total	99.89

occurring zeolite in Greece, which, in common with the other natural or synthetic zeolites belongs to a family of crystalline aluminosilicate minerals. They have a three-dimensional, porous structure consisting of SiO_4 and AlO_4 tetrahedra joined by shared oxygen atoms that are responsible for specific cation exchange capacity (Perraki and Orfanoudaki, 2004). The later, combined with the porosity of clinoptilolite, provide many of its very useful properties (Kantiranis et al., 2002). The tuff was crushed in an industrial crusher and the 0.8 mm fraction was homogenized. Mineralogical composition of the natural zeolite (92% microporous materials) was determined by means of X-ray powder diffraction analysis using a Philips diffractometer, Ni filtered CuK_a radiation. Chemical microanalysis of the zeolite was determined from polished thin sections using a Jeol JSM-840 scanning electron microscope equipped with a LINK-An 10000 Energy Dispersive System microanalyzer. Table 2 shows the semi-quantitative mineralogical composition and the chemical microanalysis of the zeolite material used.

Experimental design

A 2×2 factorial design consisted of two feeding treatments (B and Z) and two bedding types, sawdust bedding (S) and sawdust bedding with zeolite (Sz) which was the result of the incorporation of 2 kg zeolite material per square meter of bedding, was used. The first two groups comprised of broilers that were fed on the basal diet (B) and were either placed in a compartment with sawdust bedding or sawdust bedding and zeolite, hence called BS and BSz, respectively. The other two groups comprised of broilers that were fed on the 'zeolite diet' (Z) and were placed either in a compartment with sawdust bedding or sawdust bedding and zeolite, hence called ZS and ZSz, respectively.

Measurements of broiler performance indicators and litter quality

A random sample of sixty- five (65) birds for each group was weighed individually upon arrival (day 0). Thereafter, a random sample of 65 individual birds in every group was individually weighed at 14, 28 and 42 days of age. Hence, at every measurement of BW the birds were not the same. Feeds refusals of each group were also recorded at the same periods. Based on feed refusals, the average feed consumption as well as feed conversion ratios were calculated for each group. Mortality in each group was also recorded when occurred.

Litter sampling took place also at 14, 28 and 42 days, respectively. Litter quality was assessed in a series of samples that were obtained from five different points located at the edges and in the centre in each compartment. A designated cylindrical sampler, which was 30 cm long and had 8cm diameters, was used to obtain vertical core samples of litter. Each sample was put in polyethylene bag, which was sealed and temporary kept in a portable refrigerator until it was transferred to the laboratory for analyses. All analyses of litter samples were performed immediately when the samples arrived at the laboratory of Ecology and Protection of Environment of Veterinary School of Aristotle University of Thessaloniki. Following the APHA Standard Methods (APHA, 1989), moisture, organic solids, total Kjeldahl nitrogen, nitrogen ammonia and the BOD_5 content were determined for each individual sample. Moisture content (% ww) of samples was determined by drying them up to a constant weight in 105°C. Organic content (% Total Solids) was determined by sample combustion in 550°C, after drying them up to constant weight in 105°C. Total Kjeldalh Nitrogen was determined by the Macro-Kjeldahl Method (APHA, 1989). Litter nitrogen ammonia was determined by the titrimetric method on samples that have been carried through preliminary distillation without NaOH addition to prevent ammonia release from zeolite. BOD_5 was determined by the use of a YSI oxygen meter after the incubation (Forma Scientific Incubator) of the gradually diluted, homogenized original samples up to 1:20,000.

Furthermore, in the second round of the experiment, ammonia concentration in broiler compartments atmosphere was measured by the use of electro chemical sensors (DrägerSensor XS EC NH_3) using a Dräger Pac III S gas monitoring system (Dräger Safety AG Co). Four samples were collected daily on days 29 to 42. Sampling was made by the adjustment of the portable device at a height of 50

Table 3. Growth of broilers according to treatment and age

Age (days)	Treatment groups (Live weight (g))[1]				SEM	p value	Overall effect
	BS (n = 130)	ZS (n = 130)	BSz (n = 130)	ZSz (n = 130)			
0	39.8	39.8	39.3	39.7	0.28	0.448	NS
14	399.4[a,b]	405.3[a]	390.9[b,c]	384.4[c]	3.21	<0.001	***
28	1,283.3[a]	1,334.1[b]	1,333.5[b]	1,325.5[b]	9.62	<0.001	***
42	2,317.5[a]	2,474.1[b]	2,468.1[b]	2,482.2[b]	16.5	<0.001	***

[1] Treatment groups: BS = Basal diet and sawdust, ZS = 2% clinoptilolite diet and sawdust, BSz = Basal diet and sawdust with 2 kg/m^2 clinoptilolite. ZSz = 2% clinoptilolite diet and sawdust with 2 kg/m^2 clinoptilolite.

[a, b, c] Means in the same row with different superscript differ significantly (p<0.05).

* p<0.05, ** p<0.01, *** p<0.001.

cm above the litter in the center of each compartment.

In each compartment air temperature (°C) and relative humidity (%) were determined by the use of HOBO H8 RH/ Temp (Onset Computer Corporation) sensors that were installed next to ammonia electrochemical sensors. Data (10 min mean values of 10 sec sampling rate) was electronically transferred by the use of a HOBO Shuttle Logger (Onset Computer Corporation).

Statistical analysis

All statistical analyses were performed using MINITAB version 11 (Minitab corporation, 1993). Data of broiler growth (live weight gain) as well of the litter quality and ammonia emissions were initially analyzed separately by a two-way analysis of variance. Subsequently, the same model of two-way ANOVA with two levels of feeding (basal and zeolite) and two levels of bedding type (sawdust and sawdust with zeolite) was used to test for the effects of feeding treatment, bedding type and their interaction. Data concerning the other performance traits (feed consumption, feed conversion ratios and broilers mortality level) were analyzed using the t-test procedure for independent samples.

RESULTS

Growth and performance of broilers

Table 3 shows the average growth of broilers, during the two rounds of the experiment, according to treatment groups and age. Average growth rates were significantly (p<0.05) different between broilers of different groups; broilers that were fed on the 'zeolite diet' (Z) and were placed either in a compartment with sawdust bedding or sawdust bedding and zeolite (ZS and ZSz) as well those that were fed on the basal diet were the compartment with sawdust bedding and zeolite (BSz) were growing to a faster rate (p<0.05) compared with those of the control group (BS). However, such differences were more evident after day 28 in each of the three rounds of the experiment. There was a significant interaction between feeding and bedding treatments on days 28 and 42; p<0.05 and p<0.001, respectively.

The results also showed that there was a significant

Table 4. Feed consumption, Feed conversion ratios and Mortality of broilers according to treatment and age

Traits	Period (days)	Treatment groups[1]			
		BS (n = 2)	ZS (n = 2)	BSz (n = 2)	ZSz (n = 2)
Feed consumption (g)	0-14	472.2	484.6	498.8	486.5
	15-28	1,416.9	1,489.3	1,401.4	1,527.5
	28-42	2,034.6	2,294.9	2,046.5	2,420.8
	Overall	3,923.7[a]	4,268.8[a,b]	3,946.6[a]	4,434.8[b]
Average daily feed consumption (g)	0-14	33.7	34.6	35.6	34.8
	15-28	101.2	106.4	100.1	109.1
	28-42	145.3	163.9	146.2	172.9
	Overall	93.4[a]	101.6[a,b]	94.0[a]	105.6[b]
Feed conversion ratio	0-14	1.3	1.3	1.4	1.4
	15-28	1.6	1.6	1.5	1.6
	28-42	2.0	2.0	1.8	2.1
	Overall	1.7	1.8	1.6	1.8
Mortality (%)	0-14	1.5	1.7	3.3	3.1
	15-28	1.1	0.9	1.3	1.4
	29-42	5.2	4.6	4.4	4.8
	Overall	7.7	7.1	8.8	9.1

[1] Treatment groups: BS = Basal diet and sawdust, ZS = 2% clinoptilolite diet and sawdust, BSz = Basal diet and sawdust with 2 kg/m^2 clinoptilolite, ZSz = 2% clinoptilolite diet and sawdust with 2 kg/m^2 clinoptilolite.

[a, b] Means in the same row with different superscript differ significantly (p<0.05) when compared using the t-test procedure for independent samples.

interaction between feeding and bedding for day 42. Broilers fed the zeolite diet (treatment groups ZS and ZSz) were significantly heavier from those fed the basal diet (treatment groups BS and BSz) at the age of 42 days (2,475 g vs. 2,393 g, s.e.d. 23 g, p<0.001, respectively). Similarly, broilers raised on zeolite bedding (treatment groups BSz and ZSz) were heavier from those raised on sawdust bedding (treatment groups BS and ZS) at the age of 42 days (2,472 g vs. 2,393 g, s.e.d. 23 g, p<0.001, respectively).

Data of average feed consumption (g fresh feed per fourteen days) of broilers are presented in Table 4. The data are presented in relation to the four treatment groups of broilers. Moreover, Table 4 shows the overall means of the feed consumed by each group of broilers during the two rounds of the experiment as well as feed conversion ratio (FCR) and broilers mortality (%) within the same periods. As shown in Table 4, the broilers of ZS and ZSz groups consumed higher amounts of feed across the whole experiment. However performing the t-test significant differences were only found for group ZSz when compared to groups BS and BSz. FCR and mortality in broilers were not affected by the use of the natural zeolite.

For the data regarding litter quality the statistical analysis were performed separately for different ages but also using age as a covariate. The results in the first case showed significant interactions in most of the examined parameters whereas when age was used as a covariance the results showed a significant (p<0.001), interaction between feeding and bedding only in the organic content. More analytically, the organic content (% of total solids) in compartments where broilers were fed zeolite (ZS and ZSz) was 80.47% while in those where broilers were fed the basal diet (BS and BSz) was 84.90% (s.e.d. 0.99, p<0.001). Similarly, the organic content (% of total solids) in compartments where broilers were raised on zeolite and sawdust bedding (BSz and ZSz) was 79.21% while in those where broilers were raised on sawdust bedding was 86.16% (s.e.d. 0.99, p<0.001). However, for all the other parameters there were significant main effects.

Data of the quality parameters that were determined in litter samples obtained from each of the compartments where the broilers were kept are presented in Table 5.

As expected, there was an increase (p<0.001) in moisture content in litter samples for all treatment groups with time (average values were 29.57%, 42.05% and 47.99% for days 14, 28 and 42 respectively) due to the continuous accumulation of broilers excreta. Within the same sampling day, the moisture content was decreased in treatment groups were NZ was involved however such differences were not significant. The incorporation of NZ in broilers diets and in their bedding material decreased the organic content in litter samples throughout the experimental period. The lowest organic content was recorded in group ZSz where NZ was added both in feed and in litter. Furthermore, significant differences were recorded between treatments groups ZS and BSz in comparison to the control group (BS) in days 28 and 42. Total Kjeldahl Nitrogen concentration showed a tendency to increase with time (average values 15.50, 22.84 and 23.55 g/kg, p<0.001). A significant difference was recorded in group ZSz only in day 14 when compared to groups BS and ZS (12.68 g/kg vs. 17.11 and 17.72 g/kg, respectively). Nitrogen ammonia concentration, which represents the nitrogen ammonia forms in litter and is not bided by the NZ,

Table 5. Quality parameters in litter samples according to treatment and sampling day

Parameters	Sampling day	Treatment groups[1]				SEM	p value	Overall effect
		BS (n = 10)	ZS (n = 10)	BSz (n = 10)	ZSz (n = 10)			
Moisture (% ww)	14	32.25	31.67	27.09	27.28	3.45	0.643	NS
	28	46.02	39.07	42.14	40.97	4.49	0.769	NS
	42	51.74	49.41	46.02	44.59	3.01	0.381	NS
Organics (% TS)	14	94.46[a]	91.80[a,b]	85.82[b]	78.98[c]	1.81	0.002	***
	28	86.03[a]	83.00[b]	78.98[c]	75.91[d]	0.91	<0.001	***
	42	83.29[a]	78.39[b]	80.50[a,b]	74.75[c]	1.08	0.003	***
Kjeldahl nitrogen (g/kg ww)	14	17.11[a]	17.72[a]	14.49[a,b]	12.68[b]	1.40	0.075	NS
	28	22.88	23.55	23.03	21.91	2.01	0.958	NS
	42	24.80	23.24	23.46	22.50	1.90	0.897	NS
Nitrogen ammonia (g/kg ww)	14	0.90[a]	0.54[b]	0.46[b]	0.62[b]	0.07	0.014	*
	28	3.28[a]	2.82[a]	2.75[a]	2.52[b]	0.19	0.124	NS
	42	6.16[a]	5.20[a,b]	5.34[a,b]	4.56[b]	0.57	0.392	NS
BOD_5 (g/kg ww)	14	134.00[a]	113.20[a]	83.60[b]	70.80[b]	8.32	0.105	NS
	28	129.60[a]	110.60[a,b]	100.85[b]	86.70[b]	7.83	0.009	**
	42	132.00[a]	115.40[a,b]	110.56[a,b]	105.70[b]	8.55	0.198	NS

[1] Treatment groups: BS = Basal diet and sawdust, ZS = 2% clinoptilolite diet and sawdust, BSz = Basal diet and sawdust with 2 kg/m^2 clinoptilolite. ZSz = 2% clinoptilolite diet and sawdust with 2 kg/m^2 clinoptilolite.

[a, b, c, d] Means in the same row with different superscript differ significantly (p<0.05).

* p<0.05, ** p<0.01, *** p<0.001.

Table 6. Overall ammonia emission of compartments according to treatment

	Period (days)	Treatment groups[1]				SEM	p value	Overall effect
		BS (n = 56)	ZS (n = 56)	BSz (n = 56)	ZSz (n = 56)			
Ammonia emission (ppm)	29-42	23.64[a,b]	27.00[b]	20.55[a]	21.71[a]	1.20	0.002	**

[1] Treatment groups: BS = Basal diet and sawdust, ZS = 2% clinoptilolite diet and sawdust, BSz = Basal diet and sawdust with 2 kg/m^2 clinoptilolite. ZSz = 2% clinoptilolite diet and sawdust with 2 kg/m^2 clinoptilolite.

[a, b] Means in the same row with different superscript differ significantly ($p<0.05$). ** $p<0.01$.

increased with time ($p<0.001$) in all treatment groups (average values 0.63, 2.81 and 5.47 g/kg for days 14, 28 and 42, respectively). Again, the lowest value was recorded in group ZSz for days 28 and 42 when compared to the control one (2.52 and 4.56 g/kg vs. 3.28 and 6.16 g/kg, respectively). The addition of NZ in broilers feed and into their bedding material resulted in a significant reduction of the BOD_5 value in litter samples. The respective values for group ZSz compared to the control one (BS) were 70.80, 86.70 and 105.70 g/kg *vs.* 134.00, 129.60 and 132.00 g/kg for days 14, 28 and 42.

Table 6 shows the overall ammonia emission in all treatment groups for the period of 29 to 42 days during the second experimental round. Mean ammonia concentration (ppm) was significantly higher in group ZS in comparison to groups BSz and ZSz (27.00 vs. 20.55 and 21.71 respectively). Interestingly, mean ammonia concentration in group BS (control) was lower when compared to the one of group ZS (23.64 vs. 27.00 p = 0.052, respectively). A similar tendency was revealed between groups BS and BSz comparison (23.64 vs. 20.55 p = 0.073, respectively).

As shown in Figure 1, air temperature and relative humidity were kept similar in all compartments ensuring the same environmental conditions throughout the experimental period.

DISCUSSION

Intensive broiler farming has resulted in the production and accumulation of enormous amounts of poultry manure (litter and faeces). In terms of environmental pollution, disposal of this manure is of major concern. Therefore, alternative management strategies to control and/or reduce the pollutants from poultry production systems are of increasing importance. Natural materials, such as zeolites, are used as alternatives in poultry production systems due to their favorable effects upon growth and performance of broilers (Christaki et al., 2001). Furthermore natural zeolites have been used with varying success as means of reducing odor and ammonia emissions from broiler houses (Al Homidan et al., 2003). However, there is less new information on the use of these compounds both as

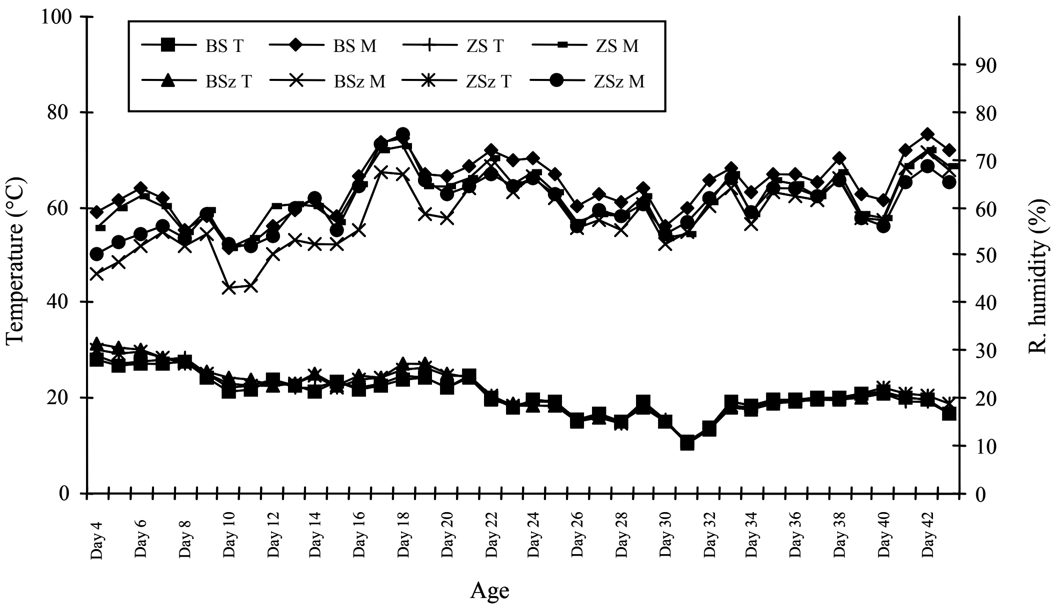

Figure 1. Air temperature (T) and relative humidity (M) in treatment groups (BS = Basal diet and sawdust, ZS = 2% clinoptilolite diet and sawdust, BSz = Basal diet and sawdust with 2 kg/m^2 clinoptilolite, ZSz = 2% clinoptilolite diet and sawdust with 2 kg/m^2 clinoptilolite) according to age.

supplement in the broilers diet and into bedding material. We questioned here whether the use of a natural zeolite (clinoptilolite rich tuff) could affect the performance of broilers and the quality of the litter in the broiler houses when used both as feed additive and as supplement into the bedding material.

The use of natural zeolites in animal rations has been a research subject since mid- 1960s and the early work in this area originates from Japan (for a review see Mumpton and Fishman, 1977). There is a numerous studies in the literature that suggest improvement on performance traits of various animal species by the use of natural zeolites, which was attributed to the type of the material used, its purity and physicochemical properties as well as the levels of its supplementation (Papaioannou et al., 2005). There are two prevailing views about the underlying mechanisms of zeolites; (i) the ammonia binding effect which leads to the elimination of the toxic effects of NH_4^+ produced by intestinal microbial activity (Shurson et al., 1984; Pond et al., 1988) and (ii) the retarding effect on digesta transit which leads to more efficient use of nutrients (Mumpton and Fishman, 1977; Olver, 1997).

In the current experiment the incorporation of NZ in the feed affected feed consumption. Birds fed diets containing NZ (treatment groups ZS and ZSz) consumed higher amounts of fed in comparison to those fed diets not containing NZ (groups BS and BSz). Feed efficiency was not affected by the dietary inclusion of NZ and, therefore, the observed differences in broilers growth should be partially ascribed to the elevated feed consumption. A possible explanation of this effect lies to the differences regarding feed formulation of broilers rations. As all diets were maintained isonitrogenous and isoenergetic the addition of NZ led to differences in the dietary fat level between rations (3.9% vs. 5.0% for the starter rations, 5.3% vs. 6.5% for the grower rations and 6.5% vs. 7.9% for the finisher rations). The latter might have been responsible for differences in feed consumption observed here, however this effect cannot be readily explained. It was evident in this study that the addition of NZ in broilers diets affected birds growth. Broilers in groups ZS and ZSz were significantly heavier from those in the control group (BS) at the age of 28 and 42 days. In agreement to these results Christaki et al. (2001) demonstrated a beneficial effect of a natural zeolite (containing 67% clinoptilolite) on broilers growth when added at the levels of 2% in their rations. Another interesting finding in the present study was the positive effect on broilers growth of the inclusion of the NZ in the bedding material. Broilers in group BSz were significantly heavier from the control ones in days 28 and 42, while no differences in growth were observed between this group and groups ZS and ZSz. Similar to our findings were also the results of Eleroğlu and Yalçin (2005) who reported differences in broilers growth in favor of the natural zeolitic material (50% clinoptilolite plus 40% mordenite) when added to the bedding material in broiler houses.

One of the most important challenges in poultry production is the control of litter quality. The latter has been seen as a priority in modern poultry industry to avoid environmental and birds welfare problems and also to reduce productivity losses (Francesch and Brufau, 2004). Over the last few years several strategies have been suggested for the control of litter quality including nutritional manipulation (Francesch and Brufau, 2004) or management practices (McCrory and Hobbs, 2001; Patterson and Adrizal, 2005). In this study litter quality was assessed in terms of litter moisture, organic solids, total Kjeldahl nitrogen, nitrogen ammonia, BOD_5 content and aerial ammonia concentration. The incorporation of NZ in broilers litter and feed resulted in the reduction of the litter moisture content; however, this reduction was not statistically significant. In a recent study Eleroğlu and Yalçin (2005) measured lower mean levels of moisture in zeolite- supplemented litter (25%, 50% and 75% of the total litter volume) in broilers. Similarly, Öztürk et al. (1998) reported lower moisture faecal content in hens fed diets containing natural zeolite, which has been ascribed to the higher water absorbing capacity of the clinoptilolite. Litter organic content (organic solids) was significantly lower in groups where NZ was added as feed additive compared to the control group. These findings suggest that the zeolite incorporation in feed had a positive effect in broiler feed efficiency in terms of feed organic matter utilization and can be supported by the significant differences in broilers growth that have been recorded here. Further supporting to these results, BOD_5 data showed that using NZ both as feed and litter additive contributes to litter production of a less pollution potential. Although, litter's total Kjeldhal nitrogen content was similar in all groups, ammonia nitrogen concentration (not bided by the zeolite, thus more easily available to be converted to free atmospheric ammonia) was lower in groups where NZ was used. This effect was more pronounced in group ZSz where NZ was used both in feed and in litter. Furthermore, according to the findings of this study, aerial ammonia concentration was higher in group ZS in comparison to groups BSz and ZSz. These results suggest that the use of NZ as feed additive contributes to the increase of ammonia emission probably due to the ammonia biding effect of NZ that occurs in broilers digestive tract. Another possible explanation of this effect could be ascribed to the positive effect of NZ in nutrients utilization in terms of the absorption of higher amounts of protein nitrogen. The addition of NZ in broilers rations most probably resulted in a higher protein intake that subsequently affected the ammonia emission. In agreement to this finding, Robertson et al. (2002) demonstrated an observable correspondence between ammonia emission concentration and total protein intake in broilers when fed different protein levels. In the present study the use of NZ as broilers litter additive resulted in lower aerial ammonia concentration. Natural zeolites have been used with varying success for the control of ammonia production (for a review see Al Homidan et al., 2003) depending of the physical properties of the materials used. Earlier studies on the use of clinoptilolite as broiler litter- additive had demonstrated a positive effect on ammonia concentration. For example, Nakaue et al. (1981) showed that an application rate of 5 kg/m^2 clinoptilolite reduced ammonia concentration up to 35%. Contrary to these results Amon et al. (1997) measured higher ammonia concentrations in a room treated with clinoptilolite, however, the ventilation rate was lower and the moisture level was higher in the zeolite treated rooms. That confirms that the housing conditions and in specific ventilation rate and moisture content along to the dietary factors are the most important factors affecting ammonia emission.

The results of this study showed that the use of NZ both as feed and litter additive had a beneficial effect on broilers growth and also led to the improvement of their litter quality. Hence, it is concluded that the use of alternative management strategies can include natural zeolites, however, other factors such as the type of the natural zeolite or its inclusion ratio, need further investigation.

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