Use of natural zeolite-supplemented litter increased broiler production

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Abstract

The aim of this study was to ascertain the influence of natural zeolite, consisting mainly of clinoptilolite and mordenite, as a component of the litter material in broiler houses on the performance of the broilers and on some litter characteristics. Live weight gain, feed consumption, feed efficiency, viability and leg and body abnormalities of broilers, and litter moisture content were measured during a six-week experimental period. A broiler house was divided into 12 sections using 1 m high duralite partitions that prevented air exchange between sections and stocked with 15 birds/m^2. Natural zeolite was added to wood shavings at levels of 0% (control), 25%, 50% and 75% of total litter volume. Litter thickness was 5 cm in all groups. The addition of zeolite at all levels improved broiler performance significantly above the control. At the end of the six-week trial zeolite did not affect feed consumption significantly, (g), 3547, 3381, 3472 and 3421, but resulted in higher live weights of the broilers of from 1935 g in the control to 1970, 1996 and 1978 g for the respective zeolite treatments. Consequently, feed efficiency improved significantly from 1.83 g feed/g gain in the control to 1.71, 1.74 and 1.73 g feed/g gain in the respective zeolite treatments. No differences between treatments were recorded in vitality or in leg and body abnormalities in the chickens. Litter moisture content decreased from 36.2% in the control to 25.2, 23.6 and 21.8% in the respective zeolite treated litter. It is concluded that the inclusion of zeolitic material to litter positively affected broiler performance, poultry house conditions and litter moisture content. An inclusion rate of up to 25% zeolite is recommended in litter consisting of wood shavings.

Keywords: Clinoptilolite, mordenite, litter, broiler performance
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Introduction

Zeolites are aluminosilicates with framework structures enclosing cavities occupied by large ions and water molecules which have considerable freedom of movement, permitting ion exchange, molecular “sieving”, absorption, diffusion, dehydration, reversible dehydration and catalysis. The physicochemical properties of zeolites encourage the use of these products to large-scale agricultural and industrial utilization such as in fertilizers and soil amendments, as heavy metal traps, in animal nutrition, excrement treatment and for various aquacultural uses (Sand & Mumpton, 1978; Mumpton, 1981; Gottardi & Gali, 1985; Tsitsishvili *et al*., 1992; Bish & Ming, 2001).

Due to some undesirable effects and moral issues encountered in cage-growing of broilers, bedding material, litter, is used in many poultry production systems (Sarıca *et al*., 1996; Amon *et al*., 1997; Sarıca & Çam, 1998; Kelleher *et al*., 2002; McGahan *et al*., 2002; Aktan & Sağdıç, 2004). Many different products have been used as litter depending on availability. Irrespective of their cost, litter may adversely and directly affect the production and health of poultry or, indirectly prevent the maintenance of certain environmental conditions at desirable levels. Type of litter may contribute to body defects and bird mortality, proliferation of microorganisms related to moisture levels of the litter, and to an increase in the gas and dust levels in poultry houses (Moore *et al*., 1996; Sarıca & Çam, 1998).

Wood shavings are commonly used as litter, but because of its other uses, alternative litter material which can be accessed cheaply and easily, is sought (Poyraz *et al*., 1991). Furthermore, in order to bind ammonia in the poultry house with the objective of reducing litter pH and the concentration of microorganisms, and to reduce the generation of ammonia, various chemicals have been applied to litter (Reece *et al*., 1980; Huff *et al*., 1984; Nakaue & Helgestad, 1989).

Wood shavings with various proportions of natural clinoptilolite plus mordenite, an approach not reported in the scientific literature, have been used as litter in this research. Therefore, the present study aimed at elucidating the effects of combinations of these products as litter on poultry production, such as changes in live weight, feed efficiency, vitality, variation in moisture content in litter, body and foot defects.

Materials and Methods

In the study, 180 day-old Ross 208 broiler chicks were obtained from the Ankara-based Öz-Ak company. The birds were divided into four treatment groups. The treatments were based on litter composition (in volume %) in the experimental pens: Group 1: wood shavings as litter (the control group), Group 2: 75% wood shavings + 25% zeolite, Group 3: 50% wood shavings + 50% zeolite and Group 4: 25% wood shavings + 75% zeolite. The inside of the broiler house was separated into 12 sections of 1.2 m² each using 1 m-high panels of duralite. The panels were placed in such a way to prevent air exchange between sections. Fifteen birds – including males and females at random – were allotted to each section. The 180 chicks were used in a 3-repetitive random parcel trial arrangement with a stocking density of 15 birds/m^2.

The zeolite used in this study were collected from well-defined zeolitic stratigraphic units in various measured sections in the Sivas-Yavu region of Turkey, and examined using optical and scanning electron (SEM) microscopes, and by X-ray powder diffraction (XRD). Mineralogical characterizations were carried out on bulk samples by means of a Rigaku DMAX IIIC automated diffractometer at Cumhuriyet University, Sivas. The semi-quantitative abundances of minerals in the bulk samples were calculated from the XRD patterns by using mineral intensity factors from peak intensities based on an external method (Yalçın, 1997) with a relative error of ± 15%. The samples were examined using a JEOL JSM 820 instrument at the General Directorate of Mineral Research and Exploration (Ankara) in order to determine the form, size and textural relations of zeolite minerals. The heulandite/clinoptilolite-mordenite bearing tuffs are generally light-coloured, fairly light, fine-moderate bedded and partly laminated, fine-grained, often conchoidal and hard. The material added to the litter during this investigation was comprised mainly of clinoptilolite (50%), mordenite (40%), quartz (5%), feldspar (5%) and trace amounts of smectitic clay (Figure 1).

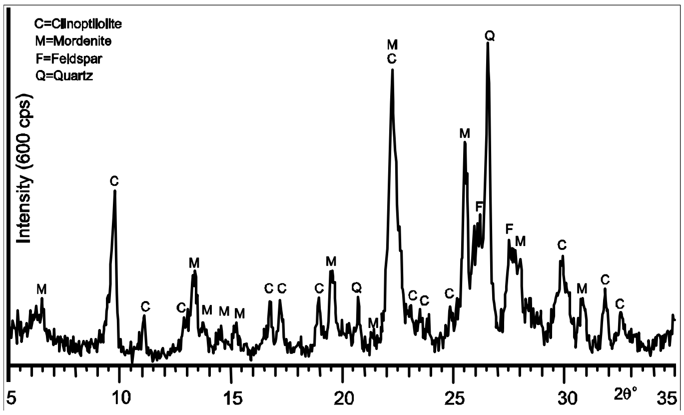


Figure 1 XRD diffractogram of the zeolitic tuffs added to litter

After the floor of a section was covered with zeolite (in the percentages indicated above), wood shavings were added, ensuring an exact blend of shavings and zeolite 5 cm deep. Feed and water containers were placed in each section and fresh water was provided *ad libitum*. Depending on the feed containers, feed was weighed and added when levels dropped. The heights of both the feed and the water containers were adjusted as the chickens grew.

A diet containing 220 g crude protein/kg and 12.6 MJ metabolisable energy/kg was given *ad libitum* until four weeks of age, followed by a diet containing 200 g crude protein/kg and 13.0 MJ metabolisable energy/kg until slaughter age. The specified chemical compositions of the diets obtained from the Kayseri, Turkey feed factory are presented in Table 1.

Table 1 Feed composition according to factory specifications

Contents	1-4 weeks		5-6 weeks	
	Limits	g/kg	Limits	g/kg
Water	Max	120	Max	120
Crude protein	Min	220	Min	200
Crude cellulose	Max	70	Max	70
Crude ash	Max	80	Max	80
Ash dissolved in hydrogen sulphur	Max	10	Max	10
Salt	Max	3.5	Max	3.5
Lysine	Min	12	Min	10
Methionine	Min	5.0	Min	4.0
Cysteine	Min	4.0	Min	3.5
Calcium	Min	6.0	Min	6.0
	Max	15	Max	15
Phosphorus	Min	6.0	Min	6.0
Sodium	Min	1.0	Min	1.0
	Max	30	Max	30
Metabolisable energy (MJ/kg)	Min	12.6	Min	13.0

Broiler house preparation was carried out as specified by Türkoğlu *et al*. (1997) prior to introduction of the chicks. The interior of the broiler house was naturally ventilated. The treatment groups were randomly distributed in the houses and the same airflow was provided, as stated by Türkoğlu *et al*. (1997). Therefore, better or worse areolation for litter was removed so that the effect observed would be due to zeolite. Before the chicks were introduced, the temperature at chick level was maintained at 32 °C with an illumination system containing 150 W cap bulbs, the height of which could be adjusted. As required by Türkoğlu *et al*. (1997), temperature at chick level was decreased every week in line with their growth to reach 20 °C in the fourth week, and was then maintained at this temperature until slaughter. The bulbs on the ceiling were used for illumination when heating was not required. The illumination program supplied light for 24 hours during the first three days of the trial, and then for 23.5 h until slaughter age.

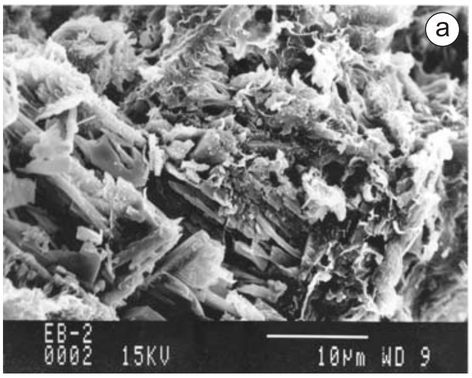
To evaluate the performance effects of zeolite used as a litter supplement, the following parameters were measured: weekly live weights as an average of all birds, weekly feed consumption, feed efficiency and viability in the first to the sixth weeks. Feed intake was corrected for broiler mortalities in calculating feed efficiency. Litter samples were obtained from specific spots in each section to cancel out the influence of distance from feeders and drinkers. The samples were dried for 24 h at 100 °C to measure the moisture level of the litter. After slaughter, carcass appearance and feet defects were recorded.

The compiled data were analyzed using the Minitab statistical program with the random parcels testing pattern.

Results and Discussion

Scanning electron microscopy revealed that 3-10 µm individual crystals had characteristic prismatic monoclinic symmetry in the assemblage clinoptilolite + mordenite + clay + feldspar (Figure 2a). Euhedral clinoptilolites developed in the vitric ash tuffs, and fine smectite particles were present nearby. In another sample, curved fibrous and acicular mordenites were derived from volcanic glass (Figure 2b). Mordenites occurred as parallel bundles in micropores and were associated with clinoptilolite and feldspar; individual fibres were < 1-2 µm in diameter and 10-30 µm long. That this material was comprised mainly of clinoptilolite $(Na,K)_6(Al_6Si_{30}O_{72}).20H_2O$ and mordenite $Na_3KCa_2(Al_8Si_{40}O_{96}).28H_2O$ is corroborated by its chemical composition (major elements in weight %, and trace elements in mg/kg), as follows: SiO_2 = 67.03,

$TiO_2 = 0.31$, $Al_2O_3 = 13.93$, $\Sigma Fe_2O_3 = 1.85$, $MnO = 0.01$, $MgO = 1.49$, $CaO = 3.75$, $Na_2O = 1.50$, $K_2O = 0.48$, $P_2O_5 = 0.06$, loss on ignition = 8.90, Total = 99.31, Cr = 21, Ni = 9, Co = 6, Cu = 24, Pb = 24, Zn = 66, Rb = 39, Ba = 1569, Sr = 3751, Ga = 18, Nb = 16, Zr = 474, Y = 23, Th = 11.



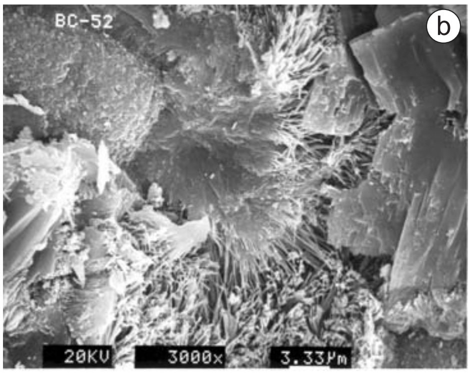


Figure 2 SEM photomicrographs of zeolitic tuffs added to litter: a) Platy clinoptilolites surrounded with smectite flakes, b) Bundles of radiating mordenite needles developed in the matrix, and platy clinoptilolites and prismatic feldspars

During the first three weeks of the trial the mean live weights of the broiler groups reared on the different types of litter did not differ significantly (Table 2). From the fourth week to the end of the trial at six weeks the mean live weight of the group on the litter containing no zeolite was lower ($P > 0.05$) than that of the groups reared on zeolite-supplemented litter (Table2).

Table 2 Mean live weights (g ± s.e.) of broilers during different stages of the trial reared on different types of litter material

	Litter treatments*			
Weeks	Wood shavings 0% zeolite	Wood shavings 25% zeolite	Wood shavings 50% zeolite	Wood shavings 75% zeolite
1	146 ± 7.0	145 ± 3.6	148 ± 2.7	146 ± 3.6
2	378 ± 7.0	378 ± 3.6	385 ± 5.0	382 ± 6.2
3	701 ± 9.5	707 ± 7.2	720 ± 6.9	714 ± 9.9
4	1082 ± 9.6[a]	1110 ± 7.8[b]	1122 ± 10.4[b]	1112 ± 10.5[b]
5	1489 ± 26.1[a]	1540 ± 14.2[b]	1558 ± 11.4[b]	1544 ± 7.9[b]
6	1935 ± 10.0[a]	1970 ± 11.4[b]	1996 ± 10.1[b]	1978 ± 13.1[b]

* Means within the same row with superscripts, a-b, differ significantly at $P > 0.05$

In a study by Sarıca *et al.* (1996) in which clinoptilolitic material was used as litter, a significant difference in live weight in favour of the clinoptilolitic was observed during the first weeks of the study, while in the present study this occurred from the third week onwards. Altan *et al.* (1998) also tested clinoptilolitic as litter material and recorded no statistical differences in the live weight of chickens between treatments. However, in a similar investigation Sarıca & Demir (1998) recorded differences in the live weight of broilers, which agreed with the results of the present study. Apart from the difference between clinoptilolitic used in the studies by Sarıca *et al.* (1996) and Altan *et al.* (1998) and zeolite used in the present study, another major difference was that, in the present study, the experimental subdivisions in the broiler house were separated with 1-m-high barriers which prevented air flow between sections, a factor not controlled in the other two studies. This division of the sections to prevent airflow corresponded to the use of ambient-controlled houses in the study of Sarıca & Demir (1998). This is likely to explain the similarity in response between our study and that of Sarıca & Demir (1998).

The cumulative feed consumption of the treatment groups is given in Table 3. The differences between the groups were insignificant (P > 0.05). The lack of any difference in feed consumption has also been observed by other researchers who carried out similar studies (Sarıca *et al*., 1996; Altan *et al*., 1998). This means that the same quantity of feed consumed by broilers growing on zeolite added litter resulted in higher live weights than that in the broilers growing on litter without zeolite. This, in turn, would affect feed efficiency. The feed efficiency of the broilers is presented in Table 3. Similar to live weights, differences (P < 0.05) in favour of the birds on the zeolite litter compared to the control were observed in feed efficiency during the fourth, fifth and sixth weeks of the trial.

Table 3 Feed consumption and feed efficiency of the broilers reared on litter containing different proportions of wood shavings and zeolite

Weeks	Litter treatments*			
	Wood shavings 0% zeolite	Wood shavings 25% zeolite	Wood shavings 50% zeolite	Wood shavings 75% zeolite
	Cumulative feed consumption (g)			
1	141 ± 4.04	134 ± 6.08	137 ± 5.51	132 ± 5.29
2	497 ± 15.9	506 ± 17.1	508 ± 19.5	505 ± 19.16
3	1060 ± 55.2	1027 ± 28.7	1060 ± 43.7	1044 ± 30.3
4	1846 ± 56.1	1753 ± 52.2	1769 ± 72.6	1734 ± 78.0
5	2695 ± 114.5	2643 ± 15.7	2684 ± 47.9	2619 ± 75.7
6	3547 ± 68.4	3381 ± 67.5	3472 ± 92.0	3421 ± 79.7
	Feed efficiency (g feed/g weight gain)			
1	0.96 ± 0.06	0.92 ± 0.04	0.93 ± 0.02	0.90 ± 0.02
2	1.31 ± 0.03	1.34 ± 0.04	1.32 ± 0.04	1.32 ± 0.03
3	1.51 ± 0.06	1.45 ± 0.03	1.47 ± 0.04	1.46 ± 0.05
4	1.70 ± 0.04[a]	1.58 ± 0.03[b]	1.57 ± 0.05[b]	1.56 ± 0.05[b]
5	1.81 ± 0.04[a]	1.71 ± 0.02[b]	1.72 ± 0.02[b]	1.69 ± 0.04[b]
6	1.83 ± 0.04[a]	1.71 ± 0.04[b]	1.74 ± 0.04[b]	1.73 ± 0.04[b]

* Means within the same row with superscripts, a-b, differ significantly at P > 0.05

It has been reported that zeolites can absorb the nitrogen of some amino acids, thus stabilizing them, they can reduce the energy required for the production of meat and also increase the utilization of calcium in the body (Quarles, 1985; Roland, 1988).

Quarles (1985) reported that some zeolites have a positive effect, up to 2%, on feed efficiency, while others showed no effect. Öztürk *et al*. (1996) for example, reported that zeolite had no effect on feed efficiency. Although the mechanism of these effects is not clear, it could be related to specific characteristics of specific zeolites. There are several major types of zeolite sources on earth, and these are characterized by mineralogical differences (Sand & Mumpton, 1978; Flanigen & Mumpton, 1981; Gottardi & Gali, 1981; Mumpton, 1981; Tsitsishvili, 1992). Such mineralogical differences are thought to be responsible for the difference in results of the present study and previous research with regard to live weight and feed efficiency (Quarles, 1985). A further factor could be the particle size of zeolites used, which is usually not reported. Altan *et al*. (1998) stated that it is possible that the zeolites added to litter might be consumed by the chicks. In the present research, zeolitic tuff with particle sizes < 0.5 mm was used. It is believed that this factor together with others might have contributed to the differences observed in feed efficiency between studies.

High ammonia levels in the poultry house are generated as a result of the fermentation of chicken excreta (Valentine, 1964; Carlile, 1984; Whyte, 1993). This may cause cerato-conjunctivitis of the eyes, reduce the rate and the depth of respiration and increase sensitivity due to irritation of mucus in the respiratory tract (Valentine, 1964; Carlile, 1984; Whyte, 1993). This would reduce the rate of development and decrease feed efficiency (Reece *et al*., 1980) and performance (Homiden *et al*., 1997) of the birds.

Conversely, it is known that the zeolite can absorb ammonia from the air (Dangare & Sabde, 1986). In the progressing weeks of development there will naturally be an increase in excreta in the litter and, therefore, in the ammonia levels of the air within the sections. The fact that separators between the experimental groups limited the ammonia-absorbing effect of the zeolite to within the relevant section in the present study, could have contributed to the statistical differences in performance between the birds on zeolite-supplemented litter and the control group.

Although statistical differences observed in feed efficiency values during the fourth to sixth weeks were similar to the second and fifth weeks in the research of Sarıca *et al*. (1996), the lack of difference in the sixth week of their research is at odds with the present study. Similarly, in the research of Altan *et al.* (1998) there was no difference in feed efficiency between treatments. It is suggested that the reason for previous studies not revealing any statistical differences in live weight and feed utilization with the use of zeolite-supplemented litter, could be the joined ventilation of the houses that might have caused zeolites to indirectly influence the control groups as well. The results of Sarıca & Demir (1998) supported this view.

The viability of the birds in the treatment groups is given in Table 4. No significant difference (P > 0.05) was observed between the average values obtained.

Table 4 The viability (%) of the broilers reared on litter containing different proportions of wood shavings and zeolite

	Litter treatments*			
Weeks	Wood shavings 0% zeolite	Wood shavings 25% zeolite	Wood shavings 50% zeolite	Wood shavings 75% zeolite
1	100	100	100	100
2	100.0 ± 0	97.8 ± 3.85	100.0 ± 0	100.0 ± 0
3	95.6 ± 3.85	97.8 ± 3.85	97.8 ± 3.85	97.8 ± 3.85
4	95.4 ± 3.99	93.3 ± 0	93.0 ± 0.27	93.3 ± 0
5	93.2 ± 0.27	93.2 ± 0.27	93.0± 0.27	93.2 ± 0.27
6	93.2 ± 0.27	93.2 ± 0.27	93.0 ± 0.27	93.0 ± 0.27

* Differences not significant (P > 0.05)

The lack of a statistical difference in viability between experimental groups is in agreement with the findings of other researchers (Sarıca *et al*., 1996; Altan *et al*., 1998; Sarıca & Demir, 1998). Although ambient temperatures (above seasonal averages throughout the country in August 2000 when the research was carried out) caused mass deaths in poultry houses with insufficient ventilation, the birds in the experimental house were not adversely affected by those temperatures. It is thought that this situation is related to the heat-absorbent characteristic of zeolites (Mumpton, 1981).

Table 5 Percentage of moisture (% ± s.e.) at the end of the trial in litter containing different proportions of wood shavings and zeolite

	Litter treatments*			
Week	Wood shavings 0% zeolite	Wood shavings 25% zeolite	Wood shavings 50% zeolite	Wood shavings 75% zeolite
6	36.2 ± 3.91[a]	25.2 ± 5.94[b]	23.6 ± 3.97[b]	21.8 ± 3.99[b]

* Means within the row with superscripts, a-b, differ significantly at P > 0.05

Depending on the type of litter used, various problems may occur in the poultry house because of humidification from excreta. Certain chemicals, such as paraformaldehyde, superphosphate, phosphoric acid, iron sulphate, lime, acetic acid, propionic acid, and antibiotics have been added to litter to prevent bacterial proliferation and generation of gases, particularly of ammonia (Reece *et al*., 1979; Austic &

Nesheim, 1990; North & Bell, 1990; Sarıca *et al*., 1996; Sarıca & Çam, 1998). The mean levels of moisture in the litter measured at the end of the experimental period, are given in Table 5. The differences observed between the control group and the zeolite-supplemented groups were found to be significant ($P < 0.05$). This is in agreement with the results of Sarıca *et al*. (1996), Altan *et al*. (1998), and Sarıca & Demir (1998). These results, which are apparently due to the moisture absorption characteristics of zeolites (Flanigen & Mumpton, 1981), are also in line with earlier reports in the literature. Low litter moisture is indirectly related to the level of ammonia in the broiler house. The lower moisture levels in the research groups with added zeolite, suggest an additional advantage of zeolite-supplemented litter.

The noted absence of body or foot abnormalities in all research groups is in line with the results of other investigations. It is suggested that the particle size of the zeolites used might have a physical influence on body and foot defects. The particle size of the zeolites used in this research was < 5 mm, and even in the treatment group in which 75% zeolite was included in the litter, no body or foot defects were observed. This result is considered noteworthy. It is well-known that zeolites used in litter material have certain structural differences, and fibrous varieties may be carcinogenic (Davis, 1993). Suzuki (1982) determined that mesotheliomas developed in most of the mice receiving erionite and none in mice injected with mordenite. Therefore, the selection of the type of zeolite to be used is also important.

Conclusions

The absence of statistical differences between live weight and feed efficiency during the first weeks, and the observance of differences in later weeks, are meaningful. A stocking density of 15 chicks/m^2 was maintained throughout the study period and, although the area per chick was above the norms in the first weeks, the ideal frequency was reached through development as they aged. It is also expected that the quantity of excreta on the litter and the related ammonia gas density in the sections would be lower during the first weeks compared to later weeks. In these situations, 25% zeolite-supplemented litter will be suitable in broiler houses with high stocking density at the beginning or in houses with low stocking density in the last three weeks, although the addition of 25 to75% zeolite to litter provided the same advantage.

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