ARE THERE ECONOMIC BENEFITS TO ADDING ZEOLITES TO POULTRY DIETS ?

M. EVANS AND D.J. FARRELL

SUMMARY

The use of the synthetic zeolite, sodium zeolite A (SZA), and the natural zeolites Z1 and Z3 was examined in poultry diets in a series of experiments to test commercial claims made for these feed additives and to investigate their possible mode of action. Experiments were also conducted to investigate some special applications of zeolites in poultry diets.

The commercial use of **SZA** in diets for poultry is questionable. For laying hens, despite the overseas findings that **SZA** improved egg specific gravity, none of the experiments presented in these studies showed any improvements in egg shell quality as measured by conventional methods or the incidence of shell defects from the use of **SZA** in diets. One of the major claims for **SZA** was its ability to alleviate the adverse effects of heat stress. Again, there was no evidence from this study to support these claims. A number of adverse effects of **SZA** on egg production, egg weight and feed consumption have been reported. These adverse effects were not apparent in any of these studies using dietary inclusions of up to 1.5%. In contrast, the use of SZA in diets for broilers was detrimental to their performance and is not recommended for use commercially. Growth rate and feed consumption were reduced and feed efficiency impaired in broilers fed diets containing **SZA.**

The commercial use of natural zeolites in diets for poultry is not recommended on a routine basis. There is very little evidence from these studies that natural zeolites are anything more than good dietary fillers or diluents, or act differently from other natural aluminium silicates (kaolin, sodium bentonite). Their ability to consistently improve poultry performance is questionable. The water adsorption ability of the intact structure of the natural and synthetic zeolites does appear to have some practical role when blended with grain and poultry feed with moisture levels up to 20% in delaying the onset of mould growth. This same adsorption ability helps to reduce the excreta moisture content in birds fed diets containing natural zeolites.

Zeolites do not appear to modify the toxic effects of cadmium and methyl mercury as reflected in reduced broiler performance. However, the use of the cation exchange capability to reduce the uptake, and influence the distribution of these heavy metals in poultry tissues is promising.

It is concluded that the use of synthetic and natural zeolites have limited economic benefit or application for improving the performance and egg shell quality in poultry and that many of the commercial claims made for the use of zeolites in poultry diets could not be fully substantiated by the literature reviewed nor by the experiments conducted in these studies.

INTRODUCTION

Many claims have been made concerning the usefulness of zeolites in diets for poultry. Whilst there is some truth to these claims, in some instances the evidence is inconclusive and at times conflicting and based on scanty or incomplete information. A list of these commercial claims is as follows :

Department of Biochemistry, Microbiology and Nutrition, University of New England, Armidale, **N.S.W. 2351**

(1) Improvements in egg production (layers, broiler breeders).
(2) Improvements in egg size (layers, broiler breeders).
(3) Improvements in feed efficiency (layers and broilers).
(4) Resistance to heat stress (layers and broilers).
(5) Improvement in egg shell quality as measured by specific gravity (older layers).
(6) Reduced incidence of cracked eggs (older layers).
(7) Reduced non collectable eggs (older layers).
(8) Reduced incidence of egg body checks (older layers).
(9) Reduced mortality (layers, broilers)
(10) Improved fertility (breeders).
(11) Improved feather quality (layers and broilers).
(12) Improved bone structure (layers).
(13) Increased weight gain (broilers).
(14) Improved utilisation of calcium (Ca) and other nutrients in the diet (layers).
(15) Heavier hatched chicks (broiler breeders).
(16) Reduced malodour of manure and improved value of the manure (layers, broilers).

Of particular interest in this list of claims is the ability of zeolites to improve egg shell quality. The Australian egg industry is currently (1989/90) worth 317.1 million dollars (Smith 1991). Each year up to 20% of all eggs laid, fail to meet the consumer's table due to shell defects and shell breakage (Balnave, personal communication). Every one percent improvement in egg shell quality, would mean a saving of 3 million dollars to the egg industry each year. Whilst this author believes the long term solution to egg shell quality problems is through genetic improvement, any short term remedies are economically worthwhile pursuing.

There is increasing concern in the community from environmental contamination with heavy metals in both human and animal health, and methods to minimise them entering the human food chain is of interest. There is some evidence (Pond and Yen 1984) that when zeolites are included in animal feed, they provide a means by which animals may be protected from the adverse effects of toxic heavy metals and may reduce their uptake in animal tissues. This is worthy of further investigation.

Similarly, there is also increased interest in the presence and effect of naturally occurring mycotoxins on animal and human health, and methods to reduce their effects. There is some evidence (Smith 1980; Carson and Smith 1983; Scheideler 1989) that some aluminium silicates can provide some protection against the adverse effects of these mycotoxins.

The purpose of this paper is to summarise the results of four years research that has been conducted at this University into the practical applications of zeolites in diets for poultry. The aims of the research were; 1) to test some of the commercial claims outlined above; 2) to investigate the possible mode of action of zeolites when included in diets for poultry, and; 3) to investigate further possible applications for the use of zeolites in diets for poultry, including their use in protecting against the adverse effects of heavy metals and mycotoxins.

USE OF SODIUM ZEOLITE A IN DIETS FOR POULTRY

Tables 1 and 2 summarise the literature on the positive, negative and non effects of synthetic zeolites on laying hens and broilers respectively. The most consistent positive response of synthetic zeolites in laying hens was on egg shell quality and in broilers on the reduction of leg problems. There were some significant negative effects of synthetic zeolites on layer and broiler performance, including reduced growth rate, body weight, egg production, egg weight and feed consumption. Manure moisture was also increased on synthetic zeolites in contrast to natural zeolites where manure moisture was reduced. Effects on blood parameters and nutrient retention were conflicting.

Table 1 Review on the use of synthetic zeolites in diets for laying hens

Parameter	Number of[1] experiments	Increased Improved Positive effects	No effect	Reduced Impaired Negative effects
Growth rate	1	-	1	-
Body weight	14	2	11	1
Egg production	45	2	26	17
Egg weight	39	1	29	9
Egg mass	1	-	1	-
Egg quality	1	-	1	-
Feed consumption	34	-	21	13
Feed efficiency	10	4	5	1
Water consumption	3	3	-	-
Mortality	3	-	-	3
Shell quality	48	44	4	-
Manure moisture	6	6	-	-
Fertility and hatchability	2	1	1	-
Plasma calcium	13	1	12	-
Plasma phosphorus	10		10	-
Plasma vitamin D	3	-	3	-
Plasma sodium	3	-	3	-
Plasma potassium	3	-	3	-
Calcium retention	4	-	4	-
Phosphorus retention	2	-	1	1
Bone breaking strength	5	3	2	-
Tibia bone ash	1	-	1	-

[1]A total of 57 experiments were cited.

From our studies and from the work presented in the literature review (Tables 1 and 2) the commercial use of SZA in diets for poultry is questionable. For laying hens, despite the overseas findings that SZA improved egg specific gravity (44 experiments out 48 experiments showed a favourable response to egg specific gravity), none of the experiments presented in our studies showed any improvement in shell quality, as measured by conventional methods, or the incidence of shell defects, from the use of SZA in diets (Evans and Farrell 1990 1991a, Evans 1993). It is interesting to note that in an experiment by Christmas et al. (1989), using seven strains of layers, only one strain showed a significant improvement in egg specific gravity due to SZA. There was a significant strain x level SZA interaction for major shell defects in one experiment (Evans and Farrell 1991a, experiment 1; Evans 1993, layer experiment 1, Chapter 8) which tends to indicate that different strains respond differently to SZA. However, subsequent studies

Table 2 Review on the use of synthetic zeolites in diets for broilers

Parameter	Number of[1] experiments	Increased Improved Positive effects	No effect	Reduced Impaired Negative effects
Growth rate	10	2	3	5
Body weight	17	4	6	7
Feed consumption	5	-	2	3
Feed efficiency	24	3	16	5
Water consumption	1	1	-	-
Mortality	9	-	4	5
Manure moisture	1	1	-	-
Carcass yield	5	4	-	1
Carcass fat	3	-	1	2
Tibial dyschondroplasia	11	-	1	10
Leg problems (turkeys)	3	-	-	3
Tibia bone ash	15	4	5	6
Bone breaking strength	4	4	-	-
Calcium retention	7	2	2	3
Phosphorus retention	7	-	1	6
Plasma calcium	1	1	-	-
Plasma phosphorus	3	1	-	2
Plasma zinc	2	1	1	-

[1]A total of 34 experiments were cited.

on the egg ultra-structure variations of these eggs showed the interaction between the level of **SZA** and strain of bird was more due to chance than real (Evans 1993, Chapter 8, part 2). One of the major commercial claims for **SZA** is its ability to alleviate the adverse effects of heat stress. There was no evidence from our studies to support these claims (Evans et al. 1990; Evans 1993, layer experiment, Chapter 4). **A** number of adverse effects of **SZA** on egg production, egg weight and feed consumption have been reported in the literature (Table 1). These adverse effects were not apparent in any of the experiments reported in our studies (Evans and Farrell 1990, 1991a; Evans 1993), with the exception that feed consumption declined linearly as the level of **SZA** increased in one layer experiment (Evans 1993, layer experiment, Chapter 5). It should be pointed out, however, that this was a short term experiment and time may be needed for the birds to adjust to the presence of **SZA.** The **SZA** levels in this experiment were also higher (up to 3%) than normally recommended in practice (0.75%). In the longer term experiments feed consumption was not affected (Evans and Farrell 1990, 1991a; Evans 1993, layer experiments 1, 2 and 3, Chapter 8).

In contrast, the use of **SZA** in diets for broilers was detrimental to their performance and is not recommended for use commercially. Growth rate and feed consumption were reduced and feed efficiency impaired in broilers fed diets containing **SZA** (Table 4) (Evans and Farrell 1991b; Evans 1993, broiler experiment 1, Chapter 5; broiler experiments 1 and 4, Chapter 10). These findings agree with the literature (Table 2). It is suggested that these adverse effects are due to the residual hydroxyl ions and the possible toxic effects of aluminium (Al) released on breakdown of the zeolite structure.

USE OF NATURAL ZEOLITES IN DIETS FOR POULTRY

Tables 3 and 4 summarises the literature on the positive, negative and non effects of natural zeolites on laying hens and broilers respectively. The most consistent positive response of natural zeolites in laying hens and broilers was on feed efficiency, nutrient utilisation, manure characteristics and reduced mortality. There were no significant negative effects of natural zeolites on layers or broilers, except at the 10% inclusion level where egg production was adversely affected, mainly through reduced feed consumption. This 10% level is not normally included in poultry diets under practical conditions. Also, in broilers, growth rates tended to improve with the inclusion of natural zeolites.

Table 3 Review on the use of natural zeolites in diets for laying hens

Parameter	Number of[1] experiments	Increased Improved Positive effects	No effect	Reduced Impaired Negative effects
Growth rate	3	2	1	-
Body weight	5	-	5	-
Egg production	9	2	5	2
Egg weight	6	-	6	-
Egg mass	1	-	1	-
Egg quality	4	-	4	-
Feed consumption	6	2	3	1
Feed efficiency	8	6	1	1
Mortality	5	1	2	2
Shell quality	8	2	5	1
Manure moisture	3	-	-	3
Manure NH_3 retention	1	1	-	-
GIT microflora counts	1	-	-	1

[1]A total of 11 experiments were cited.

From our studies and from the work presented in the literature review (Tables 3 and 4) the commercial use of natural zeolites in diets for poultry is not recommended on a routine basis. There is very little evidence from our studies to suggest that natural zeolites are anything more than good dietary fillers or diluents, or act differently from other natural aluminium silicates (kaolin, sodium bentonite). Their ability to consistently improve poultry performance is questionable. There was some indication that natural zeolites can improve feed efficiency, but in laying hens this appears to be more at the expense of body weight than a true improvement in feed or nutrient utilisation (Evans 1991a; Evans 1993, layer experiment 2, Chapter 8), despite the fact that the natural zeolite Z3 did reduce the rate of passage of digesta (Evans 1993, layer experiment, Chapter 9). These results may have some value for the inclusion of zeolites in diets for layers towards

Table 4 Review on the use of natural zeolites in diets for broilers

Parameter	Number of[1] experiments	Increased Improved Positive effects	No effect	Reduced Impaired Negative effects
Growth rate	4	4	-	-
Body weight	18	7	8	3
Feed consumption	7	3	2	2
Feed efficiency	19	12	6	1
Nutrient utilisation	5	4	1	-
Water consumption	2	-	-	2
Mortality	11	-	4	7
Manure moisture	5	-	3	2
Tibial dyschondroplasia	1	-	1	-
Tibia bone ash	1	-	1	-

[1]A total of 26 experiments were cited.

the end of lay where body weight is usually excessive and in breeders where control of body weight is critical. The findings of our studies are very much in agreement with those found in the literature (Tables 3 and 4). There was no evidence to support the suggestion that the inclusion of natural zeolites in diets deficient in protein can spare protein (Evans 1993, layer experiment, Chapter 7). The inclusion of natural zeolites at levels above 2.5% in broiler diets would appear to be detrimental to growth rate, probably due to dietary dilution effects (Evans 1993, broiler experiment 1, Chapter 6).

The particle size of the natural zeolites did influence their response in poultry diets. However, the zeolite particle size had no effect on layer performance up to 2000µm (Evans 1993, layer experiment, Chapter 6) or broilers up to 500µm (Evans 1993, broiler experiment 1, Chapter 6). Zeolite particle size did influence gizzard and proventriculus development of broilers, but this did not translate into improved performance.

MODE OF ACTION OF ZEOLITES

It is very clear that the mode of action of synthetic zeolites and natural zeolites are very different. The major difference relates to the stability of the zeolite structure as it moves through the gastrointestinal tract (GIT) of the bird, and the presence of detrimental contaminants. It is clear that the structure of SZA breaks down under the influence of the acidic gastric environment, releasing Al and silicon (Si) into the system (Elliot and Edwards 1991b; Moshtaghian et al. 1991; Wiegand et al. 1991). Wiegand et al. (1991) demonstrated the release of $Si(OH)_4$ in an experiment under simulated gastric conditions. They concluded that the ability of SZA to provide high levels of $Si(OH)_4$ on acid hydrolysis is believed to be due to its unique structure consisting solely of monomeric SiO_4^- units The implications of such a breakdown in the SZA structure, poses the question of what happens to the Al and Si that is released into the GIT. Results from our studies (Evans 1993, broiler experiment 2, Chapter 5) show that Al was retained by the bird and that this retention increased as the level of SZA included in the feed increased (Table 5).

Table 5 The effect of treated and untreated sodium zeolite A on the retention of aluminium (%) of 3-week old broiler chickens

Level of SZA	Treated SZA (%)	Untreated SZA (%)	Mean (%)
1%	1.6	12.4	7.0[a]
2%	26.1	21.5	23.8[b]
3%	42.3	64.9	53.6[c]
Mean	23.3	32.9	
LSD (P<0.05)	12.8		15.7

[a,b,c]Values in the same column with different superscripts are significantly different (P<0.05).

This retention of Al has implications, not only in terms of Al toxicity and subsequent adverse effects on bird performance (Elliot and Edwards 1991a; Hussein et al. 1989), but also for the human food chain. It appears from many experiments (Edwards 1988; Elliot and Edwards 1991b; Moshtaghian et al. 1991), that some of the Al does combine with dietary phosphorus (P) and influence P utilisation. However, the extent to which this influences performance, is very much dependent on the level of P in the diet and is supported by the work of Watkins and Southern (1992). At high levels of P in the diet (> 0.5%), SZA appears not to modify the response to P and has led some researchers to conclude that the mechanism of SZA on improving egg shell quality may be independent of dietary P level (Moshtaghian et al. 1991; Roland 1990). Roland (1990) suggested the beneficial effect of SZA on egg specific gravity may be related to its affinity for Ca and to its high capability for ion exchange. This suggested mode of action has also been proposed by Breck (1974) and Mumpton and Fishman (1977). Moshtaghian et al. (1991) also came to the same conclusion since dietary supplementation with SZA increased egg specific gravity in both low and high P diets and there was no interaction between the P level and SZA. A similar result was shown by our studies Evans 1993, layer experiment 3, Chapter 8), where the P level at 1.2% reduced egg specific gravity but SZA did not influence the response. The expectation was that SZA would assist by alleviating the adverse effects of the high P level on egg specific gravity. In contrast, birds fed diets with lower levels of dietary total P (< 0.3%) with 1% SZA, experienced a more rapid and greater decline in egg production than those fed 0.3% total P without supplementary SZA (Roland 1990). The influence of SZA on P utilisation is further supported by the work in broilers, where six of the seven experiments cited showed a reduction in P retention (Table 2). In our studies (Evans 1993, broiler experiment 2, Chapter 5), there was no such effect on total P retention. However, again this may be explained by differences in the total amount of P in the diet. In our studies (Evans 1993, broiler experiment 2), the P level was 1% whilst in the other broiler experiments cited, the total P level was below 0.65%.

Other consequences of the breakdown of the zeolite structure are that these specialised characteristics of SZA of adsorption and cation exchange ability no longer apply. This tends to go against the hypothesis suggested by Breck (1974), Mumpton and Fishman (1977) and Roland (1990), that the improvement in egg specific gravity is due to SZA high cation exchange capacity. If the special characteristics of SZA were operating, one would have expected some consistent effects on acid-base balance. In our studies (Evans 1993, 1ayer experiment, Chapter 4; broiler experiment 1, Chapter 5), effects on blood sodium (Na) and potassium (K) cations did not occur or were inconsistent. The lack of an effect of SZA on blood Na and K cations is in agreement with Daly et al. (1992). The effects on plasma ionised Ca were more a result of adverse changes in the pH of the anterior GIT, than to the SZA cation exchange capacity. One possible explanation for the significant reduction in blood plasma Ca of birds fed untreated and treated SZA again relates to the pH of the GIT and the site of Ca absorption. Hurwitz (1976) showed that at the exit of the gizzard over 90% of the Ca was in an ultrafilterable form in a fluid of pH 1 to 2. The digesta entering the duodenum increases to a pH above 6. Ca concentration then rapidly decreases in the ultrafilterable fraction, probably due to precipitation. The ultrafilterable Ca concentration and activity are lower in the ileum than the duodenum and jejunum, due to the high pH in the ileum. The main site of Ca absorption is the duodenum and jejunum. This is usually a passive process with birds maintained on Ca-sufficient diets, but when low Ca diets are fed, an active transport of Ca may be needed. Although the nature of the passive mechanism remains unclear, it is suggested it is a result of an increased permeability to Ca (Hurwitz et al. 1973). Since these diets were adequate in Ca the passive process of Ca absorption is likely to be operating, and changes to the ultrafilterable form and activity of Ca due to pH prior to entering the duodenum may be responsible for a change in the ability of Ca to permeate the intestinal tract and influence the level of plasma ionised Ca. The evidence from experiments in our studies would tend to support the former hypothesis that the mode of action of SZA is through the structure breaking down.

There is little explanation in the literature as to why, in many instances SZA, particularly when included in diets at levels above 1%, has been detrimental to both layer and broiler performance. As outlined in Tables 1 and 2 a significant number of experiments showed a reduction in egg production, egg weight, feed consumption, body weight and growth rate when SZA was fed. The presence of high levels of residual hydroxyl ions in SZA, is proposed as one factor contributing to the lowered performances of layers and broilers, mediated through an increase in the pH of the anterior segments of the GIT, particularly at dietary inclusion levels above 1% (Evans 1993, broiler and layer experiments, Chapter 5). Table 6 shows the relationship between the level of treated and untreated SZA in diets and their effect on the pH of the proventriculus and gizzard and Table 7 shows the relationship between the level of treated and untreated SZA in diets and their effect on growth rate and corrected feed efficiency of 3-week old broiler chickens. Whilst these residual hydroxyl ions may be necessary to maintain the stability of the zeolite structure for industrial purposes, this has detrimental implications when SZA is included in diets for monogastric livestock. These effects are of course confounded with the other adverse effects due to the breakdown in the SZA structure, associated with Al retention (Table 5) and subsequent effects on P utilisation.

Table 6 The relationship between the level (X;%) of treated and untreated SZA in diets and their effect on the pH of the proventriculus (Y) and gizzard (Y) of 3-week old broiler chickens

		Equation	R^2	n	Probability
Proventriculus	Treated	Y = 2.88 + 0.208X	0.73	4	0.145
	Untreated	Y = 2.97 + 0.446X	0.84	4	0.086
Gizzard	Treated	Y = 3.13 + 0.070X	0.27	4	0.486
	Untreated	Y = 3.15 + 0.305X	0.97	4	0.017

Table 7 The relationship between the level (X;%) of treated and untreated SZA in diets and their effect on growth rate (Y;g) and corrected feed efficiency (Y;g feed/g growth) of 3-week old broiler chickens

		Equation	R^2	n	Probability
Growth rate	Treated	Y = 517 - 31.1X	0.83	4	0.090
	Untreated	Y = 504 - 26.4X	0.95	4	0.024
Corrected feed efficiency	Treated	Y = 1.80 + 0.094X	0.74	4	0.138
	Untreated	Y = 1.86 + 0.077X	0.99	4	0.007

The effects of the acidic gastric environment on the structure of natural zeolites are more likely to be less severe. This is because of the greater ratio of Si to Al atoms in the zeolite structure. This more stable structure of the natural zeolites seems to be supported by the work of Hayhurst and Willard (1980) who measured the Al content in lung, brain, skeletal muscle, liver and kidney but found no difference between zeolite (clinoptilolite) diets and controls. This would suggest that the Al is remaining within the zeolite structure. Negative retention data for Al reported by us (Evans 1993, broiler experiment 2, Chapter 6), indicates a net excretion of Al in one-week-old broilers fed the natural zeolite Z3 (Table 8). This would suggest that the zeolite structure is remaining intact; Al is being held by the zeolite structure, and is therefore not available for absorption. Despite the zeolite structure remaining intact however, the cation exchange capability does not appear to play a major role in enhancing poultry performance, or improvements in egg shell quality, as suggested by Hayhurst and Willard (1980). If this were the case, then one might expect a much more positive effect on egg shell quality with natural zeolites. As previously indicated in eight experiments which reported information on shell quality with natural zeolites, five did not show a response to clinoptilolite (Table 3). Similarly, in the six experiments reported by us (Evans and Farrell 1990, 1991; Evans 1993, layer experiment, Chapter 6; layer experiment Chapter 7; layer experiments 2 and 3, Chapter 8; layer experiments 1 and 2, Chapter 11) which measured shell quality in birds fed the natural zeolite Z3; none reported an improvement in shell quality or a reduction in the incidence of shell defects. Since there are a number of conflicting reports in the literature on the effect of natural zeolites on poultry performance and shell quality (Tables 3 and 4), it may be that the different composition and structure of the various zeolites are

Table 8 The effect of two levels of natural zeolites on the retention of aluminium in one-week old broiler chickens

Dietary filler and level	Aluminium retention (%)
Commercial control	76.6
Kaolin control 2.5%	17.0
Kaolin control 5.0%	-53.1
Natural zeolite 2.5%	-157.0
Natural zeolite 5.0%	-118.2
Mean ± SEM[1]	-96.4 ± 32.8

[1]SEM = Standard error of the mean

responsible for some of these conflicting reports This would suggest that individual natural zeolites should be evaluated individually.

Particle size appears to influence the mode of action of natural zeolites. This was demonstrated in our studies (Evans 1993, broiler experiment 2, Chapter 6) where at the larger particle size 1000µm, the retention of the cations, Na, K, magnesium, manganese and zinc was significantly higher than at smaller particle sizes. Table 9 shows the significant ($P<0.05$) relationships between the zeolite particle size and retention of potassium, magnesium, manganese and zinc. It would appear that some active cation exchange has taken place as reflected in the significant positive relationship between the particle size of the zeolite and the retention of some of the minerals. The use of natural zeolites of low particle size has implications for mineral retention due to cation exchange with the zeolite structure, particularly in diets which may be marginally deficient in minerals. Again, this gives further evidence to support the suggestion that the structure of natural zeolites remains intact as it moves through the GIT of the bird.

Table 9 The relationship between the zeolite particle size (X;µm) and mineral retention (Y) of one-week old broiler chickens

Mineral	Equation	R^2	n	Probability
Potassium	$Y = 18.5 + 13.1 \log_{10}X$	0.90	4	0.033
Magnesium	$Y = -9.1 + 0.024 X$	0.93	4	0.025
Manganese	$Y = -19.2 + 0.030 X$	0.93	4	0.025
Zinc	$Y = -26.2 + 0.031 X$	0.95	4	0.015

Table 10 The effect of sodium zeolite A on the rate of passage of digesta of l-week old broiler chickens

Dietary Treatment Name	Zeolite Level %	Mean Retention Time Red particles (hours)
Commercial	0	7.33[a]
Kaolin control	0	8.39[b]
Level SZA	1%	8.27[b]
	2%	8.37[b]
	3%	9.18[b]
Mean ± SEM[1]		8.41 ± 0.258
LSD ($P<0.05$)		1.17

[1]SEM = Standard error of the mean
[a,b]Values for the same variable within treatments with different superscripts are significantly different ($P<0.05$)

One mode of action that cannot be discounted as having some influence, is the effect of zeolites on the rate of passage of digesta. Lon-Wo et al. (1987) alluded to the possibility that natural zeolites may slow the rate of passage through the GIT and therefore be responsible for the improvements in feed efficiency. In our studies (Evans 1993, broiler and layer experiments, Chapter 9), SZA at 3% inclusion significantly increased the mean retention time of digesta for l-week old broilers (Table 10) and the natural zeolite Z3 and kaolin significantly increased the mean retention time of digesta for layers (Table 11). However, there was not a corresponding improvement in feed efficiency in any of these experiments. In other experiments in our studies, however, corrected feed efficiency was improved with the inclusion of natural zeolites and other aluminium silicates (Evans 1993, layer experiment 2, Chapter 8). This mode of action on rate of passage of digesta appears to be a general attribute of aluminium silicates.

Table 11 The effect of natural zeolite on the time of first appearance of the marker in excreta (T_1) and mean retention time (Tm) in laying hens

Dietary Filler	T_1 (hours)	T_m (hours)
Commercial control	2.31[a]	4.72[b]
Kaolin control	2.89[b]	5.51[b]
Zeolite	2.75[b]	5.91[b]
Mean ± SEM[1]	2.64 ± 0.087	5.78 ± 0.154
LSD (P < 0.05)	0.363	0.637

[1]SEM = Standard error of the mean
[a,b]Values for the same variable within treatments with different superscripts are significantly different(P<0.05)

The water adsorption ability of the intact structure of the natural and synthetic zeolites does appear to have a practical role in delaying the onset of mould growth, when blended with grain and poultry feed having moisture levels up to 20% (Evans 1993, mould growth experiments 1 and 2 Chapter 11). Table 12 shows the effect of various levels of SZA in feed containing 20% moisture on the day of first appearance of mould growth and Table 13 shows the effect of three aluminium silicates at 2.5% and 5.0% inclusion in layer feed containing 20% moisture on the day of first appearance of mould growth. Commercially, this is a very useful attribute of zeolites and other aluminium silicates that can be exploited in the absence of alternative methods of reducing the moisture content in grain intended for storage. This same adsorption ability helps to reduce the excreta moisture content in birds fed diets containing natural zeolites, and results from our studies are in agreement with those in the literature. Zeolites and other aluminium silicates were not effective in reducing the adverse effects of the mycotoxin cyclopiazonic acid (CPA) on laying hens or reducing the uptake of CPA in egg albumen (Evans 1993, layer experiments 1 and 2, Chapter 11).

Table 12 The effect of various levels of SZA in feed containing 20% moisture on the day of first appearance of mould growth

Level of SZA (%)	Mean first appearance of mould growth[1] (days)
0.0	5.00[a]
0.75	5.75[a]
1.125	5.50[a]
1.5	9.00[b]
LSD (P<0.05)	2.139

[1]Mean of 4 replicates
[a,b]Values for the same variable within treatments with different superscripts are significantly different (P<0.05)

Table 13 The effect of three aluminium silicates at 2.5% and 5.0% inclusion in layer feed containing 20% moisture on the day of first appearance of mould growth

Dietary Treatment		Mean first appearance of mould growth[1] (days)
Control (No zeolite)		4.00[a]
Natural zeolite Z3	2.5%	9.25[b]
Sodium bentonite	2.5%	11.25[b]
Kaolin	2.5%	16.25[c]
Natural zeolite Z3	5.0%	12.75[bc]
Sodium bentonite	5.0%	13.75[bc]
Kaolin	5.0%	16.50[c]
LSD (P<0.05)		4.79

[1]Mean of 4 replicates
[a,b,c]Values for the same variable within treatments with different supercripts are significantly different (P<0.05)

Whilst zeolites do not appear to cope with the toxicity effects of cadmium and methyl mercury as reflected in broiler performance, the use of the cation exchange capability to reduce the uptake and influence the distribution of these heavy metals in poultry tissues is promising (Evans 1993, broiler experiments, Chapter 10), and is worthy of further investigation. Table 14 shows the effect of feeding high mercury fish meal in conjunction with zeolites on mercury retention and mercury levels in breast, liver and feather tissue.

Table 14 The effect of feeding high mercury fish meal in conjunction with zeolites on mercury retention and mercury levels in breast, liver and feather tissue

Treatment		Mercury retention (%)	Breast tissue (ug/kg)	Liver tissue (ug/kg)	Feather tissue (ug/g)
Zeolite	No zeolite	84.6[a]	66.5[a]	152.1[a]	1.106
	SZA	83.2[a]	59.7[ab]	95.7[b]	1.197
	Z3	91.6[b]	48.4[b]	110.5[b]	1.218
LSD (P<0.05)		6.05	12.06	36.4	0.3395
Fish meal level	0%	81.4[a]	19.0[a]	21.1[a]	0.271[a]
	5%	84.8[a]	55.8[b]	121.2[b]	0.935[b]
	10%	93.2[b]	99.7[c]	216.0[c]	2.314[c]
LSD (P<0.05)		6.05	12.06	36.4	0.3395

[a,b,c]Values for the same variable within treatments with different supercripts are significantly different (P<0.05)

CONCLUSIONS

Our studies have demonstrated that the use of synthetic and natural zeolites have limited economic benefit or application for improving the performance and egg shell quality in poultry. The experiments conducted in these studies have been unable to substantiate many of the commercial claims made for the use of zeolites in poultry diets. The inclusion of zeolites in poultry diets have no economic advantage, and even if they were included in the diet at no cost, their use is questionable.

In many instances, the use of the synthetic zeolite, SZA, can be detrimental to poultry performance and therefore its use is not recommended.

Natural zeolites and other aluminium silicates, however, appear to be useful diluents for poultry diets, and may be useful in controlling mould growth in feed, and to assist in controlling body weight in older layers and breeders.

The use of zeolites to limit the uptake of heavy metals in poultry tissues is promising and certainly worthy of further study.

The use of zeolites to alleviate the adverse effects of mycotoxicoses is very much dependent on the type of aluminium silicate, and the type and level of the mycotoxin present. Each zeolite, with each mycotoxin, needs to be evaluated in its own right. From a commercial perspective, this is certainly worthy of further study.

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