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Availability of manganese from different manganese oxides and their effect on performance of broiler chickens

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ABSTRACT

An experiment was conducted to investigate the influence of manganese (Mn) oxide added to mixed feeds on the performance of broiler chickens and Mn retention in the tibia bone. Six hundred broiler chickens were divided into 5 groups, and fed on maize-based diets without supplemental Mn (group I) or with a supplement of 50 mg/kg Mn as sulphate (group II) or 3 different feed grade manganese oxides (groups III, IV, V).

The greatest mean body weight of 2146 g was found in group II. Mean body weights in the other groups were from 4.3 to 2.7% lower ($P<0.05$). Body weights and feed conversion rates of chickens fed diets supplemented with Mn oxides were similar to control birds fed a diet without supplemental Mn. Chickens of group II utilized mixed feeds most effectively ($P<0.01$).

Addition of Mn to diets at a level of 50 mg/kg as sulphate or oxides resulted in a tendency to increase the Mn concentration in the tibia of broiler chickens. Mn availability from the investigated manganese oxides ranged from 61 to 74% and was lower than that from the sulphate, taken as 100%.

KEY WORDS: manganese oxide, manganese retention, broiler chicken

INTRODUCTION

Manganese (Mn) is an essential element in animal nutrition. Its deficiency in young birds, especially chickens and turkeys, results in perosis and slipped tendon; in laying and breeding birds it leads to lowered egg production, reduced egg shell strength, poor hatchability and reduced fertility (NRC, 1994).

The Mn requirement in broiler chickens according to NRC (1994) is 60 mg/kg of diet. Raw materials commonly used in broiler diets contain low amounts of Mn: maize (5 mg/kg), wheat (26 mg/kg), soyabean meal (38 mg/kg) (Nutrient Requirements of Poultry, 1993). Furthermore, the bioavailability of Mn from cereals and oil meals is 50-70%. In order to increase the Mn content in broiler diets, salts of this element, especially Mn sulphate, are added as a supplement at a level of 50 mg/kg. In addition to Mn sulphate, Mn oxides in the form of fine-grained powders, which are easier to mix, are often used.

Mn as a sulphate or chloride is more available than carbonate or oxide (Black et al., 1984). But these investigations on Mn availability were conducted at high levels of this element, from 1000 to 4000 mg/kg, not used in animal nutrition. In availability research, high doses of Mn could be questioned because a non-linear increase in the tissue content of this element was found as the Mn level in feed rose (Henry et al., 1986). Moreover, a high level of Mn in the diet can reduce absorption of other elements.

The following experiment was conducted to study the influence of Mn oxides added at near requirement levels to mixed feeds on the performance of chickens and Mn retention in their tibias.

MATERIAL AND METHODS

The experiment was performed on 600 Shaver Minibro sexed broiler chickens reared to 42 days. The birds were divided into 5 groups. Treatment groups were replicated six times (20 birds in each replication – 10 males and 10 females).

The birds were kept in thermostatically controlled and electrically heated batteries placed in an air-conditioned room and were allowed *ad libitum* access to feed and water. For the first 3 weeks broilers were fed on starter, from 4 to 6 weeks on grower diets (Table 1). Broilers of the control group were fed on the basal diets without Mn supplementation (Treatment I) or with the addition of 50 mg Mn/kg of feed as sulphate (Treatment II). Birds of the experimental groups were fed the same basal diet with different Mn oxide preparations: Agrimax P-70 (Treatment III) and Agrimax S-68 (Treatment IV) supplied by Elkem Materials (Norwey) and reference feed grade (FG) Mn oxide (Treatment V).

The main constituent of the Elkem product, Agrimax, is Mn_3O_4. Both Agrimax preparations contain 31% MnO and 69% Mn_2O_3. The reference Mn oxide supplied by Elkem is made by Sedema: Alma feed grade, Belgium. Mn oxides were added in an amount to supply 50 mg Mn/kg of feed. The content of Mn in oxide preparations is presented in Table 2.

During the experiment, bird health and mortality were constantly monitored. After 3 and 6 weeks chick body weight and feed consumption were recorded and feed conversion calculated.

TABLE 1

Composition of basal diets, %

Indices	Diets	
	starter	grower
Maize	54.23	15.99
Wheat	–	53.68
Wheat bran	0.66	–
Soyabean oilmeal	33.60	17.29
Meat meal	3.00	6.00
Rapeseed oil	4.86	4.80
Limestone	0.54	0.60
Dicalcium phosphate	1.34	0.63
Premix L-Lysine 50%	0.54	0.15
Premix DL-Methionine 50%	0.32	0.26
NaCl	0.41	0.10
Mineral-vitamin premix*	0.50	0.50
Calculated AME_N, kcal/kg	3040	3080
Chemical analysis, g/kg		
dry matter	884	886
ash	64	48
crude protein	221	190
ether extract	70	64
crude fibre	31	28

* Premix provides per kilogram of diet: vitamin A, 12000 IU; vitamin D_3, 3000 IU; vitamin E, 20 mg; vitamin K, 3 mg; vitamin B_1, 2 mg; vitamin B_2, 6 mg; vitamin B_6, 2 mg; vitamin B_{12}, 15 ug; biotin, 0.05 mg; folic acid, 1.0 mg; niacin, 20 mg; calcium pantothenate, 12 mg; choline, 200 mg; dl-methionine, 1 g; manganese, 0.0 mg; zinc, 50 mg; copper, 6 mg; iron, 20 mg; iodine, 0.5 mg; selenium, 0.1 mg; cobalt, 0.2 mg

TABLE 2

Manganese concentration and heavy metal residue in preparations

Indices	Mn %	Cd mg/kg	Pb mg/kg
Manganese sulphate	31.7	8	17
Agrimax P-70 $MnO \cdot Mn_2O_3$	70.1	3	320
Agrimax S-68 $MnO \cdot Mn_2O_3$	68.9	4	928
Reference feed grade Mn oxide	62.0	8	140

At the end of the experiment 6 chickens from each treatment (3 males and 3 females) were killed, the tibias were excised, cleaned and kept frozen in plastic bags for Mn analysis. After ashing the tibia at 550^{0}C and digesting the ash, the resulting solutions were analyzed for Mn using atomic absorption spectrometry (Unicam, Model 9100 X). The same method was used for determination of Mn in mixed feeds and Cd as well as Pb in preparations. The Mn content in preparations was analyzed by potentiometric titration. Basal nutrients in mixed feeds were determined by conventional methods.

The data were submitted to analysis of variance and the differences between means were determined by Duncan's multiple range test.

RESULTS AND DISCUSSION

Treatment diets and chemical composition of mixed feeds are shown in Tables 1 and 2. Protein, fibre and metabolizable energy contents corresponded with the requirements of Nutrient Requirements of Poultry (1993). Differences between treatments resulted from Mn supplementation and type of Mn compound. The difference in Mn levels for Treatments II - V was in the range of acceptable deviation.

The Mn content of the studied preparations (Table 2) was 1.1 to 3.4% lower than the declared levels, which is in the range of permissible deviation. Heavy metal contents varied. The Cd concentration was low, from 3 to 8 mg/kg, and did not create a risk of toxic residue in animal products. The Pb concentration was highest in the Agrimax S-68 preparation and amounted to 928 mg/kg. Although Agrimax S-68 contained a higher level of Pb than the other preparations, the use of this source at the recommended dietary level of 50 mg Mn/kg would contribute only 0.071 mg Pb/kg of the mixed feed. This amount is much below the maximal tolerable level in poultry mixed feeds, i.e. 10 mg Pb/kg (Feeding Stuffs Regulations, Agriculture No 386, 1988; Wong-Valle et al., 1989).

The performance of broiler chickens is presented in Table 3. There were no differences in body weight (from 672 to 693 g) of 3-week chickens due to treatments. After 6 weeks the average chicken body weight amounted to 2096 g. The highest body weight, 2146 g, was found in Treatment II in which broiler chickens were fed mixed feed supplemented with Mn sulphate. The mean body weight was lower in the remaining treatments, from 4.3 to 2.7% ($P<0.05$).

The final body weight of chickens in the control Treatment I did not significantly differ from that found in Treatments III-V. This data corresponds with the findings of Kirchgessner et al. (1989), who observed that Mn supplementation of diets at levels from 8 to 60 mg/kg did not influence body weight gain, feed conversion or mortality of birds.

TABLE 3

Live body weight (LBW), feed conversion ratio (FCR) and mortality

Indices	Treatment					
	I	II	III	IV	V	SEM
LBW, g:						
– 3 week	693	695	685	672	689	24.08
– 6 week	2108[ab]	2146[a]	2053[b]	2085[b]	2089[b]	35.77
FCR, kg/kg:						
– 3 week	1.57	1.55	1.56	1.70	1.63	0.104
– 6 week	2.18[AB]	2.11[A]	2.38[B]	2.41[B]	2.40[B]	0.093
Mortality, %	5.8	0.8	4.2	8.3	6.7	4.16

a, b – $P<0.05$
A, B – $P<0.01$

Feed conversion in all periods resulted from the rate of bird growth. Chickens from Treatment II utilized mixed feeds most effectively ($P<0.01$). Among others, better feed conversion in this treatment was the effect of low mortality (0.8%). Protein conversion was similar to feed conversion and was lowest in Treatment II in which broiler chickens were fed on mixed feed with supplemental Mn sulphate.

Mean mortality of broiler chickens in the experiment amounted to 5.2%. Leg abnormalities were not recorded.

The Mn concentration in the tibia bone of broiler chickens averaged 7.08 mg/kg, with no significant differences. However, a tendency for the Mn concentration to increase above the value for group I in Mn– supplemented groups II – V was observed. On the basis of differences in Mn concentration of control group I and the remaining groups, it was assumed that Mn availability from sulphate equaled 100%, and the relative bioavailability of Mn from the investigated oxides was calculated. Mn availability from Agrimax P-70, Agrimax S-68 and reference FG Mn oxide preparations was 74, 61 and 72%, respectively (Table 4).

The availability of Mn from Agrimax preparations determined in this experiment was similar to that from reference FG Mn oxide. Black et al.(1984) found that the availability of Mn from MnO, calculated on the basis of Mn retention in chicken bone, was about 60%. Mn availability from sulphate was double that from the carbonate salt. Wong-Valle et al. (1989) noted that the bioavailability of Mn from oxides of different origin, determined in the same manner, equaled 70 to 93% of Mn bioavailability from sulphate salt. Black et al. (1984) and Wong-Valle et al. (1989) investigated Mn availability at high levels of Mn oxide supplementation, from 1000 to 4000 mg/kg. However, Henry et al.

TABLE 4

Manganese concentration in mixed feed and tibia bones of broiler chickens and relative bioavailability of manganese

Indices	Manganese preparation added					
	I no added	II sulphate	III oxide Agrimax P-70	IV oxide Agrimax S-68	V Ref. FG Mn oxide	SEM
Mn in diet, mg/kg						
– starter	53	102	99	105	106	–
– grower	40	99	90	88	87	–
Mn in tibia ash, mg/kg	6.62	7.38	7.18	7.08	7.17	1.243
Mn in tibia bone, mg/kg DM	2.98	3.25	3.19	3.15	3.19	0.554
Relative bioavailability, %	–	100	74	61	72	–

(1986) obtained similar availability of Mn from oxides, equal to 66%, at Mn supplementation from 40 to 120 mg/kg, comparable to that used in this experiment.

CONCLUSIONS

The addition of Mn to diets at a level of 50 mg/kg of feed as oxides resulted in a tendency to increase the Mn concentration in the tibia of broiler chickens. Chickens fed diets with supplemental Mn oxides attained body weights and feed conversion similar to control birds fed diets without supplemental Mn. Chickens from group with supplemental Mn sulpfate attained favourable performance parameters. The results of the retention study indicated that the availability of Mn from $MnO \cdot Mn_2O_3$ was comparable to availability from reference FG Mn oxide.

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STRESZCZENIE

Dostępność manganu z różnych tlenków manganu i ich wpływ na wyniki odchowu kurcząt

W doświadczeniu badano wpływ tlenków manganu (Mn) dodanych do mieszanek paszowych na wyniki odchowu i retencję Mn w kości piszczelowej kurcząt brojlerów. Sześćset brojlerów podzielonych na 5 grup żywiono natłuszczonymi mieszankami paszowymi z udziałem kukurydzy, pszenicy i śruty sojowej bez dodatku Mn (I) lub z dodatkiem 50 mg Mn/kg paszy w postaci siarczanu (II), preparatów zawierających mieszaninę tlenków MnO : Mn_2O_3 (Agrimax P-70; III), (Agrimax S-68; IV) i paszowego tlenku Mn (V).

Największą masę ciała, równą 2146 g, osiągnęły kurczęta z grupy II. Masa ciała kurcząt w pozostałych grupach była niższa o 4,3 do 2,7% ($P<0,05$). Masa ciała i wykorzystanie paszy przez ptaki żywione mieszankami z dodatkiem tlenków były podobne jak ptaków z grupy kontrolnej, żywionych paszą bez dodatku Mn. Kurczęta z grupy II lepiej wykorzystywały paszę niż kurczęta z grup IV i V ($P<0,01$).

Przy dodatku Mn w postaci siarczanu lub tlenków wystąpiła tendencja zwiększenia odkładania Mn w kości piszczelowej ptaków. Przy przyjęciu przyswajalności Mn z siarczanu za 100%, przyswajalność Mn z preparatu Agrimax S-68 wyniosła 61, paszowego tlenku Mn – 72, a Agrimax P-70 – 74%.