

The solubility and availability of magnesium from calcium-magnesium carbonate and magnesium carbonate

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ABSTRACT

Solubility in water, 2% citric acid, and 0.4% hydrochloric acid of calcium-magnesium carbonate (dolomite) and magnesium carbonate (magnesite) from deposits in Poland, and of magnesium oxide and magnesium sulphate, were studied. The magnesium content in the compounds was 136.2, 277.6, 484.0, and 122.7 g Mg/kg DM, respectively. The solubility of magnesium from dolomite and magnesite in water was low and equaled 2.50 and 2.44 %, respectively. The solubility of magnesium in 2% citric acid was 78.73, 67.01, 79.52, and 76.09%, respectively, whereas in 0.4% hydrochloric acid is equaled 77.57, 80.68, 68.04, and 90.22%.

The availability of magnesium was studied in a feeding experiment on 25 growing wethers, 5 animals per group, with a body weight of 30.2±1.8 kg, housed in balance cages. The wethers were fed a synthetic maintenance diet composed of (%): glucose (29), potato starch (28), cellulose (30), urea (4), sunflower oil (4) and minerals (5). The mineral mixture contained the studied magnesium salts. Magnesium intake equaled 800-1000 mg/animal/day. Apparent and true absorption of magnesium and its retention were studied assuming that the amount of endogenous magnesium excreted daily in faeces is 2.33 mg kg⁻¹ BW/day.

Apparent retention of magnesium in wethers receiving dolomite, magnesite, magnesium oxide, and magnesium sulphate was 32.1, 16.3, 31.2, and 17.0% of magnesium intake. Apparent absorption of magnesium from the mineral salts equaled 32.6, 17.4, 37.6, and 21.0% of magnesium intake, respectively. True absorption equaled 38.8, 23.8, 44.9, and 29.9% of magnesium intake, respectively. Apparent retention, apparent absorption and true absorption in wethers receiving dolomite did not differ significantly from retention and absorption in animals receiving magnesium oxide, but were significantly higher than the respective values when magnesite and magnesium sulphate were fed.

The magnesium level in the serum of wethers equaled 2.40 mg/100 ml in the control group, which did not receive magnesium. It was significantly higher ($P < 0.01$) in the groups receiving dolomite, magnesite, magnesium oxide, and magnesium sulphate, and equaled 2.82, 2.63, 2.96, and 2.89 mg Mg/100 ml, respectively. The highest increase in the serum magnesium concentration was found in the wethers fed magnesium oxide, followed by magnesium sulphate and dolomite ($P \leq 0.01$). Administering magnesium oxide to wethers significantly lowered calcium absorption ($P \leq 0.01$).

KEY WORDS: magnesium, solubility, availability, dolomite limestone, magnesium oxide, magnesium sulphate, wethers, absorption, retention

INTRODUCTION

Magnesium is one of the most important essential trace elements for both animals and humans. In ruminants the most common symptom of magnesium deficiency is tetany (Kemp, 1960). Similarly as calcium or phosphorous deficiency, chronic, subclinical magnesium deficiency has an adverse effect on the health of animals and their productivity. Most animal nutritional requirements (MAFF, 1984; NRC, 1988; INRA 1989; IZ, 1993) include magnesium. The magnesium content of bulk feeds, grass and maize forages and silages, is usually very low and equals about 1.2-2.5 g/kg DM (IZ, 1993). Magnesium availability from bulky feeds is also very low, especially from meadow grass, and equals from 7 to 33% of magnesium intake (Kemp and Geurink, 1978). The availability of magnesium from minerals depends on their source, the chemical and physical form of the magnesium, and on antagonistic and synergic factors in the diet. Naturally occurring magnesium minerals include calcium-magnesium carbonate ($\text{CaCO}_3 \cdot x\text{MgCO}_3$) called dolomite limestone, and magnesium carbonate, magnesite. In animal nutrition, natural forms of magnesium such as magnesium oxide are used most often. Magnesium oxide is usually decarbonized magnesite. Other types of magnesium used in animal nutrition include such chemical forms as magnesium sulphate and magnesium hydroxide. Studies to date on the availability of magnesium from various compounds have focused on sulphates, carbonates, citrates, silicates, acetates, chlorides and oxides (Stewart and Moodie, 1956; Gerken and Fontenot, 1967; Rahnema and Fontenot, 1983; Davenport et al., 1990; Hurley et al., 1990). It was shown that although the availability of magnesium from magnesium carbonate is good, it is inferior to that from magnesium oxide and chloride. Because calcium-magnesium salts release the carbonate ion in the rumen, they can buffer hydrogen ions, which is beneficial for microbial protein synthesis and counteracts acidification of rumen contents.

Poland is rich in calcium-magnesium carbonate deposits, some of which are interlaced by deposits of magnesium carbonate, which is decarbonized

to magnesium oxide for use in metal processing. Wierny (1986) showed that dolomite deposits have negligible radioactive radiation, comparable to background levels, and that their heavy metal content does not exceed admissible levels or concentrations found in feed grains. In laboratory and physiological tests, dolomite was shown to dissolve well in rumen fluid. Solubility after two hours equaled 31.3%, rising to 82.1% after 48 h. Studies on the use of dolomite in mineral mixes for cows gave positive results (Brzóška et al., 1996).

Magnesium oxide used in mineral mixes is obtained through energy-consuming, thermal decarbonization of magnesium carbonate. It is therefore a very expensive carrier of this element. Poland's relatively rich resources of dolomite limestone and magnesite may be an attractive alternative source of magnesium for the feed industry and in animal nutrition.

Given the lack of data on the availability of magnesium from dolomite and magnesite obtained from Polish deposits, we undertook a study to compare the solubility and availability of magnesium from these sources in ruminant nutrition in comparison with magnesium oxide and magnesium sulphate.

MATERIAL AND METHODS

Animals and diets

The dolomite used in this study was extracted from the deposit in Siewierz (Poland), magnesite from Wiry near Bytom (Poland); magnesium oxide and magnesium sulphate (a mixture of mono- and septahydrates) were obtained from the Institute of Fireproof Materials in Gliwice (Poland). Grain size was determined using a mechanical laboratory sifter from Fritsch to sift a 50 g sample through sieve meshes of 1.400; 0.710; 0.355; 0.250; 0.180; 0.125; 0.063, and 0.040 mm in 15 min. The solubility of the magnesium raw materials was determined using the method described by Watson et al. (1979) and three solvents: triple-distilled water, 2% citric acid and 0.4% hydrochloric acid.

The availability of magnesium from rations was determined *in vivo* using the direct balance method. The experiment was carried out on growing wethers of the submountain long-wool sheep assigned randomly to 5 groups of 5 animals each. The animals whose average body weight was 30.2 ± 1.8 kg were fed a synthetic diet prepared using the components listed in Table 1, similarly as in earlier studies by Chicco et al. (1972). Moreover, the animals received 4400 IU, 1100 IU and 11 mg/animal/day of vitamins A, D and E, respectively. The experiment proper was preceded by a 30-day adaptation period during which the wethers were accustomed to the synthetic diet. The animals were kept in individual metabolic cages and were fed at the maintenance level. The ration

TABLE 1

Composition of the diet for sheep

Ingredient	g/kg DM of the diet
Glucose	290
Potato starch	280
Cellulose	300
Urea	40
Sunflower oil	40
Minerals ^a	25.0
NaH ₂ PO ₄	9.2
Vitamins ^b	+
Mg additive ^c	15.8

^a buffer components and trace minerals contain, %: K₂CO₃ 28,30; Na₂SO₄ 35,00; NaCl 34,88; FeSO₄ 1,10; CuCl₂ x 2H₂O 0,08; MnCO₃ 0,21; CoCO₃ 0,02; ZnCO₃ 0,38; KI 0,03.

^b vitamins added per kilogram of diet: α-tocopherol 11 mg, vit. A 4,400 IU and vit. D₃ 1,100 IU

^c variable levels of magnesium plus potato starch to adjust to 15.8 g/kg DM

was offered twice daily, in the morning and afternoon, similarly as the mineral supplements. The latter were administered *per os*, which guaranteed their intake in full. The wethers had free access to water. The mineral supplements contained: disodium hydrogen phosphate (9.2 g/kg DM), buffering agents and trace elements (25.0 g/kg DM) and the investigated magnesium salt (15.8 g/kg DM). To balance the calcium level in the rations, a small amount of calcium carbonate and potato starch was added. The wethers received:

- Group I – experimental feed without added magnesium salt,
- Group II – experimental feed + 5.21 g dolomite,
- Group III – experimental feed + 2.72 g magnesite,
- Group IV – experimental feed + 1.17 magnesium oxide,
- Group V – experimental feed + 3.49 magnesium sulphate.

Magnesium intake in the groups was similar, 800-1000 mg/day, and fulfilled the maintenance requirements of wethers according the animal nutritional requirements. The initial period of the experiment lasted 21 days, the experiment proper that included the collection of faeces and urine, lasted 7 days. Every morning, a 5% of sample 24 h collections of urine and faeces was taken. The dry matter content was determined in fresh samples of faeces and the remainder was frozen until further chemical analysis. Before the experiment and after its completion blood was sampled from the jugular vein into heparinized tubes. The blood was centrifuged and the serum was frozen until laboratory analysis.

Analyses and calculations

Samples of feeds, faeces, urine and blood were mineralized in a mixture of nitric and perchloric acids in a MLS 1200 Mega microwave oven. Magnesium, sodium and potassium were assayed in the samples by atomic absorption spectrometry using a Philips PU 9100 spectrometer. Calcium was determined by titration with EDTA (Directive, 1971) and phosphorous colorimetrically with ammonium molybdate (Directive, 1971a). Magnesium availability was expressed as apparent retention, apparent absorption and true absorption, calculated using the formulas below:

$$\begin{aligned} \text{Apparent retention, mg} &= P - (W_k - W_m) \\ \text{Apparent retention, \%} &= [P - (W_k - W_m)] / P \cdot 100 \\ \text{Apparent absorption, mg} &= P - W_k \\ \text{Apparent absorption, \%} &= (P - W_k) / P \cdot 100 \\ \text{True absorption, mg} &= P - W_k + E \\ \text{True absorption, \%} &= (P - W_k + E) / P \cdot 100 \end{aligned}$$

where:

P – the amount of the element taken up, mg/day,

W_k – the amount of the element excreted in faeces, mg/day,

W_m – the amount of the element excreted in urine, mg/day,

E – the amount of endogenous element, mg/day.

In calculating the true absorption of magnesium, the value of endogenous magnesium in sheep given by Chicco et al. (1972), 2.33 mg kg⁻¹ body weight /day, was used.

The results were subjected to statistical analysis using one-way analysis of variance. The averages of groups were compared using the multiple ranks test.

RESULTS

The share of particles smaller than 0.25 mm exceeded 50% in all of the examined raw materials. This fraction made up 69.62% of dolomite, 52.16% of magnesite, 69.34% of magnesium sulphate, and 89.18% of magnesium oxide.

The magnesium content of dolomite, magnesite, magnesium oxide and sulphate varied and equaled: 136.2, 277.6, 484.0 and 122.7 g Mg/kg DM, respectively. Dolomite also contained 226.9 g Ca/kg DM (Table 2).

Magnesium sulphate was most soluble in water. The solubility of magnesium from dolomite and magnesite in this medium was low and equaled 2.50 and 2.44%, respectively, which is significantly lower than the other sources of magnesium

(Table 2). The solubility of magnesium in 2% citric acid was 78.73, 67.01, 79.52 and 76.09%, respectively, and was significantly lower for magnesite ($P \leq 0.05$). The solubility of magnesium in 0.4% hydrochloric acid was 77.57, 80.68, 68.04 and 90.22%, respectively. The solubility of magnesium in magnesium sulphate was significantly higher than in the remaining sources, whereas that in dolomite and magnesite was significantly higher than in magnesium oxide ($P \leq 0.01$).

TABLE 2

Mineral content and solubility of dolomite limestone, magnesite, sodium oxide and magnesium sulphate

Item	Dolomite limestone	Magnesite	Magnesium oxide	Magnesium sulphate	SEM±
Mineral content, g/kg DM					
magnesium	136.21	277.75	484.03	122.72	
calcium	226.90	2.82	n.d.	n.d.	
phosphorus	0.35	0.14	0.44	0.10	
sodium	0.43	0.63	3.92	1.57	
potassium	0.33	0.18	0.03	0.03	
Solubility, %					
destilated water	2.50 ^a	2.44 ^a	8.22 ^c	62.42 ^b	0.3
2% cytric acid	78.73 ^a	67.01 ^b	79.52 ^a	76.09 ^{ab}	1.2
0.4% sodium hydroxide	77.57 ^a	80.68 ^a	68.04 ^b	90.22 ^c	2.2

^{a,b} - $P \leq 0.05$; ^{A,B,C} - $P \leq 0.01$

n.d. - not detected

In the balance experiment, the wethers in the experimental groups consumed on average about 1000 mg Mg/day, whereas in the control, unsupplemented group, about 400 mg Mg/day. The amount of magnesium excreted by the animals was highly varied. Aside from the control animals, the animals receiving magnesium oxide excreted the least magnesium in faeces; those given magnesite excreted the most. The average amount of magnesium excreted in urine was also the lowest in the control and dolomite groups, and the highest in the animals receiving magnesium oxide. Apparent retention of magnesium calculated for animals in the particular groups was higher in the groups given dolomite and magnesium oxide, and lowest in those fed magnesite and magnesium sulphate. Apparent retention expressed as the percentage of magnesium consumed from dolomite, magnesite, magnesium oxide and sulphate equaled 32.10, 16.32, 31.16, and 16.96%, respectively (Table 3). It was significantly higher for magnesium from dolomite and magnesium oxide ($P \leq 0.05$).

Apparent absorption expressed in percent of magnesium intake equaled: 32.62, 17.42, 37.57, and 21.03%, respectively. It was significantly higher in

animals receiving dolomite and magnesium oxide ($P \leq 0.01$). True absorption followed a similar pattern after taking into account excretion of endogenous magnesium in faeces. True absorption equaled: 38.79, 23.80, 44.91, and 29.87 % of Mg intake.

TABLE 3
Faecal, urinary, and plasma magnesium of wethers fed different of dietary magnesium minerals

Item	Group					SEM±
	Control	Dolomite limestone	Magnesium site	Magnesium oxide	Magnesium sulphate	
Magnesium intake, mg/d	386.4	1054.2	1053.5	925.8	806.4	301
Magnesium excreted, mg/d						
faeces	279.8 ^A	710.3 ^B	870.0 ^C	578.0 ^B	636.8 ^B	24.4
urine	5.6 ^A	5.5 ^A	11.6 ^{AB}	59.3 ^C	32.8 ^B	3.4
total	285.4 ^A	715.8 ^B	881.6 ^C	637.3 ^B	669.6 ^B	24.2
Apparent retention, mg/d	101.0 ^A	338.4 ^C	171.9 ^{AB}	288.5 ^{BC}	136.8 ^A	23.6
% of intake	26.14 ^{ab}	32.10 ^b	16.32 ^a	31.16 ^b	16.96 ^a	2.59
Apparent absorption	106.6 ^A	343.9 ^B	183.05 ^A	347.8 ^B	169.6 ^A	23.9
% of intake	27.59 ^{AB}	32.62 ^{AB}	17.42 ^B	37.57 ^A	21.03 ^{AB}	2.63
True absorption, mg/d	172.6 ^A	408.9 ^B	250.5 ^A	415.8 ^B	240.9 ^A	23.7
% of intake	44.68 ^A	38.79 ^{AB}	23.80 ^B	44.91 ^A	29.87 ^{AB}	2.59
mg/kgBW ^{0.75} /d	14.2 ^A	32.4 ^{BC}	20.1 ^{AB}	33.3 ^C	18.5 ^A	1.9
Magnesium content in blood serum, mg/100 ml						
before experiment	2.24	2.50	2.44	2.46	2.45	0.07
after experiment	2.40 ^A	2.82 ^B	2.63 ^{AB}	2.96 ^B	2.89 ^B	0.07
differences	+0.16 ^A	+0.32 ^B	+0.19 ^A	+0.50 ^B	+0.44 ^B	0.05

^{a,b} - $P \leq 0.05$; ^{A, B, C} - $P \leq 0.01$

The serum magnesium level in control wethers equaled 2.40 mg/100 ml, whereas in the experimental groups it was higher and significantly dependent on the magnesium source (Table 3). The highest increase in the magnesium concentration occurred in wethers given magnesium oxide, followed by magnesium sulphate and dolomite ($P \leq 0.01$).

Calcium intake in the experimental groups ranged from 2200 to 3800 mg Ca/day (Table 4). The high intake of this element by wethers fed dolomite results from its presence in this mineral. This group also had the highest apparent absorption of calcium. The lowest retention of this element was found when magnesium sulphate was supplemented.

TABLE 4

Intake and apparent absorption of calcium, phosphorus, potassium and sodium of the wethers fed different of dietary magnesium minerals

Item	Group					SEM ₁
	Control	Dolomite limestone	Magne-site	Magne-sium oxide	Magne-sium sulphate	
Calcium intake, mg/d	2585	3797	2469	2194	2854	21
Apparent absorption						
% of intake	21.3 ^{AB}	37.0 ^B	39.2 ^B	4.9 ^A	39.0 ^A	3.1
mg/kgBW ^{0.75} /d	45.1 ^{AB}	111.1 ^C	77.6 ^{BC}	8.6 ^A	85.6 ^{BC}	6.3
Phosphorus intake, mg/d	1704	1754	1770	1765	1788	22
Apparent absorption						
% of intake	39.8	41.6	34.7	38.4	34.1	3.7
mg/kgBW ^{0.75} /d	55.6	57.8	49.2	52.2	48.6	5.3
Potassium intake, mg/d	2373	2193	2173	2203	2008	26
Apparent absorption						
% of intake	89.9 ^{AB}	92.8 ^{AB}	87.5 ^A	90.0 ^{AB}	88.2 ^A	0.7
mg/kgBW ^{0.75} /d	175.2 ^A	161.5 ^{AB}	152.4 ^{BC}	152.6 ^{BC}	141.3 ^C	3.0
Sodium intake, mg/d	3831	4235	4764	4106	4129	73
Apparent absorption						
% of intake	94.0 ^A	97.6 ^C	95.5 ^B	97.9 ^C	96.3 ^B	0.2
mg/kgBW ^{0.75} /d	295.3 ^B	237.8 ^A	364.8 ^C	309.4 ^B	317.4 ^B	6.7

^{A,B,C} - $P \leq 0.01$

The apparent absorption of phosphorus was similar in all groups, whereas its retention was negative in wethers fed dolomite (-0.69 mg P/day) and magnesite (-125 mg P/day); animals given magnesium oxide showed a positive phosphorus balance.

The supply of potassium in the diet ranged from 2000 to 2200 mg K/day, and apparent absorption of potassium expressed as a percentage of phosphorus intake was: 92.8, 87.5, 90.0, and 88.2%, respectively. In the experimental groups, with the exception of the animals fed magnesium oxide, the retention of this element was negative.

Sodium intake ranged from 4100 to 4800 mg Na/day and its apparent absorption was high; in relation to intake, it equaled 97.6, 95.5, 97.9, and 96.3%, respectively.

DISCUSSION

Grain size and solubility are basic characteristics of mineral raw materials that enable a preliminary assessment of their potential use in mineral mixes for animals. The studies carried out by Thomas et al. (1984), Jensen et al. (1986) and Noller et al. (1986) showed that minerals with finer grains have superior availability. In our experiment, the fraction of dolomite and magnesite grains smaller than 0.25 mm made up about 90%.

Bouwman (1978) showed that the availability of magnesium is most highly correlated with the solubility of minerals in 0.4% hydrochloric acid, whereas according to Van Ravenswaay et al. (1989) the best medium for studying the solubility of minerals is 2% citric acid. In our experiments the solubility of dolomite and magnesite in water was low and did not exceed 3%, but magnesium sulphate was over 62% soluble. The solubility of dolomite and magnesite in 2% citric acid and 0.4% hydrochloric acid was substantially higher and equaled from 67 to over 80%. In comparison with magnesium sulphate, assuming the solubility of magnesium sulphate as 100%, the solubility of dolomite and magnesite in 0.4% hydrochloric acid was 85.9% and 89.4%, respectively, whereas that in 2% citric acid was 100.0 and 88.1%.

Rahnema and Fontenot (1983) in studies on sheep showed a significantly lower absorption of magnesium from dolomite than magnesium oxide. At relatively high doses of magnesium equaling 2210 mg and magnesium oxide 2100 mg/animal/day, the absorption of this element equaled 510 and 890 mg/day, respectively, which is the equivalent of 23.08 and 42.38% of the magnesium taken up by the animal, whereas in the group receiving magnesium oxide, 890 mg/day, i.e. 42.38% of magnesium intake. Retention of magnesium from these compounds equaled, respectively, 9.95% and 17.14% of their magnesium intake. In the studies of Ammerman et al. (1972) on the availability of magnesium from various inorganic compounds to sheep, it was also shown that the availability of magnesium from magnesite was relatively low. The apparent absorption of magnesium from a ration containing 800 ppm Mg/kg was 9.38% in comparison with the 52% absorption of magnesium from magnesium oxide. In the same experiment, the availability of magnesium from hydrated magnesium carbonate equaled 56.43% of the amount provided in the ration. Despite such major differences in magnesium absorption, the level of this element in the blood of wethers in all of the experimental groups was similar and ranged from 2.18 mg/100 ml in the group receiving magnesite to 2.41 mg/100 ml in the group given hydrated magnesium carbonate.

The results obtained in the present experiment are much better than those cited above. The availability of magnesium from dolomite expressed as apparent absorption was 32% of magnesium intake, retention, 338.4 mg Mg/day, which

was 32.1% of Mg intake. True absorption of this element from dolomite was also high and equaled 38.8% of Mg intake, but was slightly worse than from magnesium oxide. The results of our study are similar to those of Kinal et al. (1994) who studied dolomites from Silesia (Poland) on growing rams weighing 45.6 kg. In that study, the apparent absorption of magnesium from 4 dolomite deposits ranged from 25.8 to 50.7%, whereas magnesium retention from 24.4% to 49.3% of Mg intake.

In our study, magnesite was found to be an inferior source of magnesium for animals, as indicated by its low absorption (17.4%) and retention (16.3%). These values were similar to the absorption and retention of magnesium from magnesium sulphate, but were significantly lower than the values found for dolomite and magnesium oxide.

Despite such varied availability of magnesium from the studied magnesium compounds, the level of this element in the serum of sheep in the experimental groups ranged from 2.82 (dolomite), 2.63 (magnesite), 2.96 (magnesium oxide) and 2.89 mg/100 ml (magnesium sulphate), which is somewhat higher than the 2.50 mg/100 ml accepted as the normal physiological value for sheep. In the control group this level equaled 2.40 mg/100 ml and was lower than the accepted normal values (Pinkiewicz, 1971).

The differences between the values obtained in our study for dolomite and magnesite are difficult to explain. They may be a consequence of differences in the chemical properties of the two substances from different deposits. The degree of crystallization and dolomitization of minerals, their porosity and other characteristics resulting from geological differences during the formation of the deposits may significantly affect both physical characteristics such as solubility and biological value manifested as the availability of the magnesium contained in them.

In our study the amount of available calcium for wethers depended on its level in the rations. A similar tendency was found for the retention of calcium. A deficit of available calcium appeared in the group of animals receiving magnesium oxide, i.e. in the group in which magnesium availability was highest. It may be assumed that in this case antagonism developed between the two elements, as discussed by Georgievski et al. in their monograph (1982). Interestingly, despite a relative high calcium deficiency (young sheep require more than 5000 mg daily; INRA, 1989) in animals receiving dolomite, magnesite and magnesium sulphate, the apparent retention of calcium ranged from 946 mg (magnesite) to 1387 mg Ca/day (dolomite) and exceeded the value of this parameter found in the studies of Rahnema and Fontenot (1983). These authors reported that lambs in the dolomite group received an average of 5400 mg Ca/day, the group given magnesium oxide, 4930 mg Ca/day. The apparent retention of this element equaled, respectively, 780 mg and 1114 mg Ca/day. Also the level of calcium absorption in the study cited above was lower than in our experiment.

The addition of magnesium to the diet did not cause significant differences in the phosphorus metabolism of the experimental animals. The amount of absorbed phosphorus equaled from 609 to 730 mg P/day and was higher than in the studies of Rahnema and Fontenot (1983), but the calculated absorption was within the range determined for absorption of this element from feed phosphorus (Brzóska et al., 1992). Despite the negative retention, the concentration of total phosphorus in the serum of wethers was double the physiological value (Pinkiewicz, 1971).

The inclusion of magnesium substances in the diet had a negative effect on potassium retention in the animals. In comparison with the control group, K retention was distinctly lower and in most experimental groups, it assumed negative values despite the relatively high absorption of this element. Similarly in the case of sodium, despite its relatively high absorption from the gastrointestinal tract, the retention of this element was very low or negative. Similar behaviour of both of these elements was found in studies on sheep and cattle (Chester-Jones et al., 1989, 1990). Despite the negative retention of these elements, the serum potassium concentration was within physiological normal limits, but the sodium concentration was slightly below accepted normal values (Pinkiewicz, 1971).

CONCLUSIONS

In conclusion it can be said that the availability of magnesium from calcium-magnesium carbonate in sheep nutrition, expressed by the level of true absorption and retention, is high and similar to the availability of magnesium from magnesium oxide and higher than the availability of magnesium from magnesium carbonate (magnesite), as well as hydrated magnesium sulphate. The dolomite and magnesite used in this study were characterized by higher magnesium availability than described in the literature for dolomites and magnesites from North American deposits. Both forms of magnesium are characterized by high solubility in 2% citric acid and 0.4% hydrochloric acid. The results of this study suggest that dolomite in particular from these deposits may be a valuable source of magnesium for ruminants.

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STRESZCZENIE

Rozpuszczalność i przyswajalność magnezu z węglanu wapniowo-magnezowego i węglanu magnezowego

Badano rozpuszczalność węglanu wapniowo-magnezowego (dolomit) oraz węglanu magnezowego (magnezyt) ze złóż krajowych, tlenku magnezowego i siarczanu magnezowego w wodzie, 2% kwasie cytrynowym i 0,4% kwasie solnym. Zawartość magnezu w surowcach magnezowych wynosiła odpowiednio: 136,2; 277,6; 484,0 i 122,7 g Mg/kg s.m. Rozpuszczalność magnezu z dolomitu i magnezytu w wodzie była niska i wynosiła odpowiednio 2,50 oraz 2,44%. Rozpuszczalność magnezu w 2% kwasie cytrynowym wynosiła odpowiednio 78,73; 67,01; 79,52 i 76,09%, w roztworze 4% kwasu solnego 77,57; 80,68; 68,04 i 90,22%.

Przyswajalność magnezu badano w doświadczeniu żywieniowym wykonanym na 25 rosnących skopach, po 5 sztuk w każdej grupie, o masie ciała $30,2 \pm 1,8$ kg, trzymany w klatkach bilansowych. Skopy żywiono dietą syntetyczną składającą się z, %: glukozy (29), skrobi ziemniaczanej (28), celulozy (30), mocznika (4), oleju słonecznikowego (4) i składników mineralnych (5). Składniki mineralne zawierały badane sole magnezu. Pobranie magnezu wynosiło 800-1000 mg/szt/d. Badano retencję, absorpcję pozorną i rzeczywistą magnezu u skopów, przyjmując za Chicco i in. (1972), że ilość magnezu endogennego wydalana codziennie z kałem wynosi 2,33 mg Mg kg⁻¹ m.c./doba.

Retencja pozorna magnezu u skopów otrzymujących poszczególne sole wynosiła: 26,5; 13,9; 23,2 i 10,5 mg Mg/kg m.c.^{0.75}/doba i była istotnie wyższa u zwierząt otrzymujących tlenek magnezowy i dolomit ($P \leq 0.01$). Absorpcja pozorna magnezu z poszczególnych soli mineralnych wynosiła odpowiednio: 27,0; 14,7; 27,9 i 15,1 mg Mg/kg m.c.^{0.75}/doba i była istotnie wyższa dla tych samych soli magnezu ($P \leq 0.01$). Absorpcja rzeczywista wynosiła odpowiednio: 32,4; 20,2; 33,3 i 18,5 mg Mg/kg m.c.^{0.75}/doba. Retencja pozorna oraz absorpcja pozorna i rzeczywista u skopów otrzymujących dodatek dolomitu nie różniła się istotnie od retencji i absorpcji u zwierząt otrzymujących tlenek magnezowy.

Surowce mineralne zawierające magnez, zastosowane w żywieniu skopów, różnicowały istotnie poziom magnezu w surowicy krwi; wynosił on w grupie kontrolnej 2,40 mg/100 ml, a w grupach doświadczalnych odpowiednio: 2,82; 2,63; 2,96 i 2,89 mg Mg/100 ml. Najwyższy wzrost koncentracji magnezu w krwi stwierdzono u skopów otrzymujących tlenek magnezowy, a w dalszej kolejności otrzymujących siarczanu magnezowy i dolomit ($P \leq 0,01$).