Estimation of the bioproductive and economic effect and of the immune response of the amorphous dolomite used as calcium and magnesium source for fattening lambs

Dorica Voicu[1], I. Voicu[1], V. Mihoc[2], Anca Gheorghe[1], Cristina Lazăr[1]

[1]*National Research Development Institute for Animal Biology and Nutrition, Baloteşti;*
[2] *SC Exploatarea Minieră Harghita SA*

SUMMARY

The experiment was conducted on 16 fattening Teleorman Blackead lambs, with an initial average weight of 20 kg, assigned uniformly to two groups of eight lambs each. The groups differed according to the source of dietary calcium as follows: group 1, control, calcium carbonate, and group 2, experimental, amorphous dolomite, both sources being included in a proportion of 2.1% in the feed mixture, next to alfalfa hay, which was the basal diet. The trial showed that the use of dolomite didn't change feed intake and didn't have any adverse effect of diet palatability, the weight gains being comparable with those of the control diet which used calcium carbonate, with no significant ($P \geq 0.05$) differences (220.9 g/lamb/day for the control group and 215 g/lamb/day for the experimental group). The use of dolomite didn't produce significant differences in the feed conversion ratio and in the tibia mineral content, and didn't cause health problems (as shown by blood plasma determinations).

Keywords: diets, amorphous dolomite, intake, weight gain, feeding efficiency, plasma parameters, growing lambs

INTRODUCTION

The minerals (ash) are present both in the forages, and in animal body in different proportions. The amount of minerals, expressed as ash percent, varies with the animal species and with the age of the animals, generally ranging between 3 and 6%. In sheep, the minerals account for about 3.2-3.6% of the whole animal organism, being generally in the same combinations as in plants, but in different proportions. For instance, the animal body ash contains about 80% calcium phosphate, while the plant ash has less than 20% calcium phosphate (Bunicelu, 1984).

The calcium salts of the phosphoric acid account for 65-70% of the total minerals in the body, but related to the weight of the animal, calcium represents 1.3-1.8% (Martin, 1979; Bunicelu, 1984), the phosphorus accounts for 0.1-0.8%, while magnesium represents 0.04-0.05 %. Of the total body content of these minerals, 99% of the calcium, 80% of the phosphorus and 70% of the magnesium concentrate in the bone tissue and on teeth, the rest being spread in different organs and tissues. The Ca/P ratio in the bones is about 2/1 and it generally remains constant.

There are over 70 known interrelations between minerals, in which the excess or deficiency of a mineral element influences the absorption or use of another mineral element (Jacobson et al., 1972). Thus, both role and utilization interrelations exist between Ca, P and Mg; however, since they are mostly involved in growth and development, having thus a plastic role, they need to be supplied in higher levels for the growing and fattening lambs, to assist bone mineralization (Pârvu et al., 1992, 2003), because their deficiency generates rickety-type diseases. On the other hand, the mineral elements are also involved in different vital processes which, besides affecting the health state, also act on the weight gain. The deficit of minerals in the growing lambs mainly disturbs their rate of growing (Pârvu et al., 1992).

Forages, energy feeds (corn, wheat, barley etc.) and protein feeds (meals) are used to feed the ruminant animals. The Ca, P and Mg content of the forages is extremely variable and it depends on the botanic family, species, age of the plant, stage of vegetation and type of soil (Suttle et al., 1996).The cereal grains are generally poor in calcium and rather rich in phosphorus, and several cereal by-products, such as the brans, are rich in phosphorus (Stoica et al., 1999; 2001). The meals are generally rich in phosphorus (0.6-1.2%). The cereal grains and the meals also have sizeable amounts of magnesium, usually between 4 and 7 g/kg DM.

The administration of the different sources of minerals, in the concentrate mixtures, has a favourable influence of animal metabolism and on the use of nutrients. There are many sources of calcium, phosphorus and magnesium for animals, but the forages suitable for a particular species and category of ruminants differ both in the proportion of these elements, and in their biological availability. Among the bulk forages, alfalfa hay is the main provider of calcium (2.05%) three times more than the gramineous plants (0.58%). Calcium carbonate (39% calcium) is the most used source of calcium for the feed concentrates, and its 100% bioavailability is taken as standard. Phosphorus is usually supplied from monocalcium phosphate, with 22% total phosphorus, 16% calcium, with 100% bioavailability

The magnesium oxide (60% Mg) is used as magnesium source for the feed mixture, next to the dolomite $CaMg(CO_3)_2$ which, although has a higher content of magnesium carbonate, is not indicated as source of magnesium for ruminants, because of all farm animals, they have the lowest capacity to use the dietary magnesium (Miloş et al., 1980). Being rich in calcium carbonate, it may be considered a good source of calcium.

Therefore, there are two main sources of minerals for farm animals: the natural forages and the mineral supplements. Even if the plants can supply a large number of minerals, the latter have to be supplemented for an optimal feeding of the animals (Martin et al., 1979).

The purpose of our experiments was to quantify the bioproductive and economic effects and the immune response following the use of amorphous dolomite fed to fattening lambs.

MATERIAL AND METHODS

The experiment was conducted on 16 fattening lambs, males, of about 2 months of age (after weaning), of the local breed Teleorman Blackhead with an initial average weight of 20 kg, assigned uniformly to two groups of eight lambs each.

The two groups received the same type of diet, the difference being the source of calcium included in the feed mixture, as seen in Table 1

Table 1. Experimental design

	C	E
Number of animals	8	8
Experimental days	90	90
Calcium source	Calcium carbonate – 2.1%	Amorphous dolomite – 2.1%

The diets were formulated according to the new system for forages and feeding norms evaluation applied lately in Romania (Burlacu et al., 2002) and contained alfalfa hay as (basal diet) supplemented with a mixture of corn, barley, wheat, rapeseed meal, soybean meal, calcium carbonate or amorphous dolomite, salt and vitamin-mineral premix specific for the growth and fattening period (Table 2). The resulting feed mixture met the energy, protein, vitamin and mineral requirements of the fattening lambs.

The calculation of the feeding (energy and protein) value was done on the basis of the mathematical model for energy and protein metabolism simulation in growing and fattening cattle (Burlacu, 2002), adapted after INRA, 1988.

The protein content was expressed in IDP (intestine digestible protein) with its two forms (adapted after Vérité et al., 1987).

IDPN (intestinal digestible protein derived from nitrogen) where we calculated as reference element Dg (rumen degradability of the nitrogen matter, estimated with the formula of Alderman, 1993);

IDPE (intestinal digestible protein derived from energy) calculated on the basis of the FOM (g/kg DM) which is the fermentescible organic matter, used for the synthesis of 145 g microbial protein.

The net energy was calculated for meat production (NEm) starting from (q) the energy concentration of the forage and from the yield (k) of using the metabolisable energy (ME) as net energy (NE), according to Burlacu et al., 2002 adapted after Vermorel et al., 1987.

Table 2. Feed mixture formulation (%)

	Control	Experimental
Corn	29.6	29.6
Barley	20.4	20.4
Wheat	25.5	25.5
Rapeseed meal	15.4	15.4
Soybean meal	5.0	5.0
Calcium carbonate	2.1	-
Amorphous dolomite	-	2.1
Salt	1.0	1.0
Premix	1.0	1.0
Total	100	100

The calcium carbonate used in the experiment had 38.13% calcium, while the amorphous dolomite contained 20.56% calcium and 12.79% magnesium.

Average samples of the finished compound feeds were collected and assayed for their basic chemical composition, calcium, total phosphorus and magnesium content.

The animals were housed in the same house but in different pens, 8 animals in each pen, with permanent access to a paddock for feeding and watering.

The experiments run for 90 days, including a preparatory period of 14 days for accommodation with the new feeds and an actual experimental period (with determinations) which monitored the following parameters: the average daily feed intake, body weight (weighing at the beginning of the experiment, monthly and at the end of the experiment) which revealed the average daily weight gain and the feed conversion ratio. The health state of the animals has also been monitored permanently.

These data were processed statistically and the differences between groups were analysed with STAT VIEW: Anova and T Test.

At the end of the trial, blood samples were collected from the jugular vein from part of the animals and assayed for glycaemia, triglycerides, albumin, total bilirubin, transaminases (ALAT, ASAT), alkaline phosphatase (ALP), gamma globulin, calcium, phosphorus, magnesium and iron. The biochemical examinations of the plasma parameters were performed on a semiautomatic BS-130 Chemistry analyser (Bio-Medical Electronics Co., LTD, China). Three animals from each group were slaughtered and the tibia level of minerals (ash, Ca, P and Mg) was determined.

RESULTS AND DISCUSSION

The chemical composition of the forages from the basal diet and of the feed mixture with or without amorphous dolomite determined using the improved Weende assay (Criste et al., 2003) has shown the following values (Table 3): the alfalfa hay had 841 g dry matter (DM), 175 g CP, 297 g CF and 17.73 MJ GE/kg DM, parameter evaluated on the basis of the chemical composition and using the equations developed by Burlacu, 1991. The feed mixture with or without amorphous dolomite had rather close values for CP, CF and GE, but the ash content was lower in the experimental diet (56 g/kg DM) compared to the control group (73 g/kg DM).

Table 3. Chemical composition of the dietary forages (g/kg forage and g/1000 g DM)

Item	DM	OM	CP	EE	CF	NFE	Ash	GE(MJ)
Alfalfa hay	841	770	147	8	250	366	71	14.91
	1000	916	175	10	297	435	84	17.73
Feed mixture,	859	796	140	19	60	577	63	15.05
group C	1000	927	163	22	70	672	73	17.52
Feed mixture,	846	799	138	16	54	590	47	15,01
group E	1000	944	163	19	64	697	56	17.74

DM – dry matter; OM – organic matter; CP – crude protein; EE – ether extractives; CF – crude fiber; NFE – nitrogen-free extractives; GE – gross energy

Using the chemical composition results we calculated the feeding value of the feed mixture (with or without amorphous dolomite), expressed in meat feed units (FUm), intestinal digestible protein derived from nitrogen (IDPN), intestinal digestible protein derived from energy (IDPE), calcium (Ca), phosphorus (P) and magnesium (Mg) (Table 4). The energy and protein values of the forages are generally within the limits of the values reported in the literature (Burlacu et al., 2002).

Table 4. Feeding value of the dietary ingredients, g/kg DM

Item	DM	FUm	IDPN	IDPE	Ca	P	Mg
Alfalfa hay	841	0.73	108	85	12.96	2.08	2.70
CF for group C	859	1.32	111	115	11.78	4.92	2.35
CF for group E	846	1.34	111	117	12.06	5.10	2.83

DM – dry matter; FUm - meat feed units; IDPN - intestinal digestible protein derived from nitrogen; IDPE - intestinal digestible protein derived from energy; Ca – calcium; P – phosphorus; Mg – magnesium.

The use of amorphous dolomite as replacer for calcium carbonate increased the amount of minerals in the diet for group E (12.06; 5.10 and 2.83 g/kg DM) compared to the diet for group C (11.78; 4.92 and 2.35 g/kg DM) for Ca, P and Mg, respectively.

The feed intake was recorded on a daily basis and it was quite similar both for the bulk forage (alfalfa hay) and for the concentrate feed (CF), taken as such or on DM basis. Thus, the average total feed intake was 1.508 kg DM (0.897 kg alfalfa hay and 0.611 kg CF) for the control group and 1.520 kg DM (0.916 kg alfalfa hay and 0.604 kg CF) for the experimental group, with amorphous dolomite.

As seen in Table 5, the feed mixture represented 59 % from the diet for the control group and 60 % from the diet for the experimental group.

Table 5. Average feed intake (kg/lamb/day and kg DM/lamb/day)

Item	Control	Experimental
Alfalfa hay – gross	1.067	1.089
Feed mixture – gross	0.711	0.713
Alfalfa hay – SU	0.897	0.916
Feed mixture – SU	0.611	0.604
Total DM	1.508	1.520
Feed mixture from total DM (%)	59	60

The resulting average daily weight gain was quite similar, with slightly higher values for the control group, 220.9 g/lamb, compared to the control group, 215 g/lamb; the difference was not statistically significant ($P \geq 0.05$) (STAT VIEW: Anova and T Test), values which fit the category and genotype of the breed (Table 6). This shows that the use of amorphous dolomite in the diet for the experimental group had similar production and health state effects as the classical calcium carbonate.

Table 6. Body weight evolution and average weight gains*

Item	Control	Experimental
Average initial weight (kg)	20.35±2.86	17.95±2.90
Intermediary average weight	30.48±3.59	27.47±3.65
Average final weight (kg)**	40.45[a]±5.11	37.52[a]±3.19
Total gain (kg/lamb)	20.10	19.57
ADG (g/lamb)**	220.9[a]±32.42	215[a]±18.97

*the average values are accompanied by the standard error

**same letter shows not significant differences between groups ($P \geq 0.05$)

Feed conversion ratio expressed as dry matter (DM), meat feed units (FUm) and intestinal digestible protein (IDP) shows values correlated with the production performance. These values were slightly lower for the production of one kg gain in the control group (6.60 FUm and 704.41 g IDP) compared to the experimental group (6.80 FUm and 731.30 g IDP), about 3% higher, as shown in Table 7.

Table 7. Feed conversion ratio

Item	Control	Experimental
Kg DM/kg gain	6.80	7.07
FUm/kg gain	6.60	6.80
g IDP/kg gain	704.41	731.30

DM – dry matter; FUm - meat feed units; IDP – intestinal digestible protein

In economic terms, the cost of feeding was almost the same irrespective of the source of calcium, the feeds for group E being just 3% more expensive than the feeds for the control group, as shown in Table 8.

Table 8. Feeding cost

Item	Control	Experimental
Lei/animal/day	1.33	1.35
Lei/kg gain	6.00	6.20
Cost lei/kg gain - % compared to the control	100	103

The nutritional state, the physiological state and the pathological state of the animals can be evaluated using the blood parameters (Jain, 1986; Bush, 1991; Awah and Nottidge, 1998), as also proved by our results on the blood mineral, energy, plasma and enzyme profile. These parameters can be influenced by the feeding level, by the age and sex pf the animals, by the type of housing and environment, as well as by other incidental stress factors that may occur both in the tropical and in the temperate regions (Ogunrinade et al., 1981; Bush, 1991; Ogunsanmi et al., 1994).

Plasma mineral profile

Most plasma mineral parameters displayed inconstant variations both in the control group and in the experimental group (irrespective of the calcium source). Thus, for calcium, the values are below the normal physiological values for the age and category of lambs from the experimental group. However, the serum magnesium is higher than the normal physiological values in the same group, considering that the supply of this mineral element from the amorphous dolomite is rather high (12.79%). On the other hand, in the young animals, with more vascularized bones, the mineral exchange is more intense (Pârvu et al., 1992), which makes the values for manganese to increase, as shown in the table below. Phosphorus was higher than the normal physiological limits in the control group, while the blood iron level was within the range of the normal physiological limits (The Merck veterinary manual, 2010) for the age and category of animals, irrespective of the treatment, knowing that iron acts synergistically with the manganese.

Table 9. Plasma mineral profile of the fattening lambs*

Parameters	Control	Experimental	P
Calcium (mg/dL)***	11.25 ± 1.36[a]	8.89 ± 0.79[b]	0.0241
Magnesium (mg/dL)**	2.24 ± 0.40[a]	3.10 ± 2.08[a]	0.4483
Phosphorus (mg/dL)***	11.86 ± 0.84[a]	7.28 ± 2.81[b]	0.0205
Iron (µg/dL)**	840.03 ± 50.34[a]	767.75 ± 260.24[a]	0.6623

*the average values are accompanied by the standard error
**same letter shows not significant differences between groups (P≥0.05)
***different letter shows significant differences between groups (P≤0.05)

The statistical processing of the above data shows that the differences are not statistically significant for magnesium and iron (P≥0.05), but that they are statistically significant for calcium and phosphorus (P≤0.05), with higher values in the control group than in the experimental group.

The dynamics of the blood energy profile (concentrations of glucose and triglycerides) was not significantly influenced by the treatment with amorphous dolomite. The determination of serum triglycerides are indicators of the evolution of the different processes of the lipid metabolism such as: retention, mobilisation from tissues, lipolysis or lipogenesis; they account for 95% of the adipose tissue lipids, as also reported by Şogorescu et al., 2008. These values were within the range of the normal physiological limits for the age and category of lambs, with no significant differences from the control group (Table 10).

Table 10. Plasma energy profile of the fattening lambs *

Parameters	Control	Experimental	P
Glycaemia (mg/dL)**	46.23 ± 5.66[a]	44.58 ± 6.67[a]	0.7189
Triglycerides (mg/dL)**	22.65±3.93[a]	19.53 ± 5.96[a]	0.4523

*the average values are accompanied by the standard error
**same letter shows not significant differences between groups (P≥0.05)

The plasma protein profile (total bilirubin and albumin) displayed a configuration within the range of the normal physiological limits for the age and category of lambs, values comparable with those reported by Kaneko et al., 1997. The plasma protein profile was not significantly influenced by the different treatments (calcium carbonate or amorphous dolomite), as shown in Table 11. However, a trend to influence the reference values (P>0.05 to 0.10) was noted for bilirubin.

Table 11. Plasma protein profile of the fattening lambs *

Parameters	Control	Experimental	P
Albumin (g/dL)**	3.17 ± 0.49[a]	2.71 ± 0.11[a]	0.1184
Total bilirubin (mg/dL)**	0.06 ± 0.04[a]	0.02 ± 0.01[a]	0.0710***

*the average values are accompanied by the standard error
**same letter shows not significant differences between groups (P≥0.05)
***P>0.05 to 0.10 = tendency to be influenced.

Although the common characteristics of the enzyme compounds are rather variable because of the instability of the blood biochemical indicators, as also reported by Şogorescu et al., 2008, in our experiment, the concentrations of (ALAT, ASAT, alkaline phosphatase, Gama GT), markers of liver functions, which describe the plasma enzyme profile, were within the normal limits for the age and category of lambs used in the experiment. Only the concentration of alkaline phosphatase displayed a non-significant increase in the experimental group compared to the control group (Table 12).

Table 12. Plasma enzyme profile of the fattening lambs *

Parameters	Control	Experimental	P
ALAT (U/L)**	23.98 ± 24.31[a]	15.77 ± 2.45[a]	0.5941
ASAT(U/L)**	110.23 ± 27.44[a]	106.53 ± 29.16[a]	0.8806
Alkaline phosphatase (U/L)**	118.50 ± 50.71[a]	137.63 ± 74.06[a]	0.6849
Gama GT (U/L)**	37.43 ± 6.54[a]	32.13 ± 6.65[a]	0.3407

*the average values are accompanied by the standard error
**same letter shows not significant differences between groups (P≥0.05)

Table 13 shows the mineral concentration in the tibia of the slaughtered fattened lambs. The data show that the level of minerals was not significantly influenced (P≥0.05) by the calcium source, the calcium, phosphorus and magnesium concentrations being rather close in the experimental and control groups. These results show that the bioavailability of calcium was rather similar for both sources, improving phosphorus metabolism, which favoured the increased consistency of the bones.

Table 13. Mineral concentration in the tibia of the fattening lambs*

Group	Chemical composition of the tibia (%)					
	DM 103ºC	G	Ash**	Ca**	F**	Mg**
C	78.93±1.68	14.27±2.91	61.08±0.45	17.90±0.45	10.04±0.52	0.40±0.41
E	79.39±0.84	11.47±0.39	59.32±2.28	17.05±0.22	10.01±0.18	0.42±0.04
P	-	-	0.5787	0.0890***	0.9464	0.7247

*the average values are accompanied by the standard error
**same letter shows not significant differences between groups (P≥0.05)
***P>0.05 to 0.10 = tendency to be influenced.

Ca/P ratio of the bones varies with the age, and it was also within the normal physiological limits for the category of experimental animals, irrespective of the treatment (1.78/1 for the control group and 1.70/1 for the experimental group), which allowed the optimal use of each individual element. A higher ratio would have decreased the absorption of phosphorus and would consequently delay de growth and calcification of bones.

CONCLUSIONS

The use of amorphous dolomite in the feed mixture for fattening lambs didn’t change feed intake and didn’t have an adverse influence on feed palatability, while allowing weight gains comparable with those of the control group which used calcium carbonate, with no statistically significant differences ($P \geq 0.05$) (220.9 g/lamb/day for the control group and 215 g/ lamb/day for the group treated with 2.1% amorphous dolomite).

The replacement of calcium carbonate by amorphous dolomite in the feed mixture for the fattening lambs didn’t cause significant changes in feed conversion ratio, in the mineral level of the tibia, and didn’t cause health problems for the experimental animals, as shown by the blood plasma profile.

REFERENCES

Alderman G. (1993) – Energy and protein requirements of ruminants. CAB International Wallingsford, UK.

Awah J. N., Nottidge H. O. (1998) - Serum biochemical parameters in clinically healthy dogs in Ibadan. Trop. Vet. 16, 123.

Burlacu Gheorghe (1991) – Metode şi tehnici pentru măsurarea valorii nutritive a nutreţurilor. Editura Ceres, Bucureşti.

Burlacu Gh., Cavache A., Burlacu R. (2002) – Potenţialul productiv al nutreţurilor şi utilizarea lor. Editura Ceres, Bucureşti.

Bush B. M. (1991) - Interpretation of laboratory results for small animal clinicians. Blackwell scientific publication London.

Criste Rodica Diana, Veronica Hebean, Doina Grossu Valentina, Margareta Olteanu, C. Dragomir, Anca Bercaru (2003) – Metode analitice specifice studiului nutreţurilor. Vol. I, Colecţia Cărţile Centrului de Excelenţă „Nutriţia şi Alimentaţia Animalelor”, pag. 21 – 51.

Jacobson, D. R., R. W. Hemken, F. S. Button and R. H. Hatton (1972) – Mineral nutrition. Calcium, Phosphorus, Magnesium and Potasium Interrelationships. J. Dairy Sci., 55, 7. 935-944.

Jain N. C. (1986) - Schalm Veterinary Haematology. 4th ed. Lea and Febiger, Philadelphia, U.S.A.

Kaneko J. J., Harvey J. W., Bruss M. L., 1997. Clinical biochemistry of domestic animals. 5ed San Diego Academy Press, San Diego, CA, USA.

Martin V., Mihai D. (1979) – Dismineralozele la animale. Editura CERES, Bucureşti.
Miloş M., Drînceanu D. (1980) – Nutriţia minerală a animalelor. Editura CERES, Bucureşti.
Ogunrinade A., Fajimi J., Adenike A. (1981) - Biochemical indices in the White Fulani (Zebu) cattle in Nigeria. Rev. Elev. Med. Vet. Pays. Trop., 34 (4): 41.
Ogunsanmi A.O:, Akpavie S. O., Anosa V. O. (1994) - Serum biochemical changes in West African Dwarf sheep experimentally infected with Trypanosoma brucei. Rev. Elev. Med. Vet. Pays. Trop., 47 (2): 195.
Pârvu Gheorghe (1992) - Supravegherea nutriţional metabolică a animalelor.Editura CERES, Bucureşti.
Pârvu Gheorghe, Mihaela Costea, M. Pârvu, B. Nicolae (2003) – Tratat de nutriţia animalelor. Editura Coral Sanivet, Bucureşti.
Popa O., M. Miloş, P. Halga, Elena Bunicelu (1984) – Alimentaţia animalelor domestice. Editura Didactică şi Pedagogică, Bucureşti.
Stoica Ioan (1997) – Nutriţia şi alimentaţia animalelor. Editura Coral Sanivet, Bucureşti.
Stoica Ioan şi Liliana Stoica (2001) – Bazele nutriţiei şi alimentaţiei animalelor. Editura Coral Sanivet, Bucureşti.
Suttle Neville, Bush Loan (1996) – Mineral nutrition of livestock 4th Edition. www.cabi.org.
Şogorescu Elena, Stela Zamfirescu, Andreea Hortanse Anghel, (2008) - Influenţa rasei asupra profilului biochimic al serului recoltat de la ovine. Analele SNCB Vol. XIII, pag. 137-141.
Vérité R., Michalet-Doreau Brigitte, Chapoutot P., Peyraud J. L. et Poncet C. (1987) – Bull. techn., No. 70, INRA, p. 19 – 35.
Vermorel M., Coulon J. B. et M. Journet (1987) – Bull. Techn. No. 70, 9 – 19. INRA.
XXX INRA (1988) - Alimentation des bovins, ovins et caprins. Ed. R. Jarrige.
XXX The Merck veterinary manual. Tenth edition, 2010.