Mineral requirements of dairy sheep

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ABSTRACT

This paper reviews the major (Calcium, Phosphorus, Potassium, Sodium, Chlorine, Sulphur, Magnesium) and the trace elements (Iron, Copper, Cobalt, Iodine, Manganese, Zync, Molybdenum, Selenium) that play an essential role in animal metabolism. For each one the authors indicate not only the function, but also the more recent advances in terms of daily requirements for dairy sheep.

Key words: Major elements, Trace elements, Dairy sheep.

RIASSUNTO

FABBISOGNI MINERALI DEGLI OVINI DA LATTE

Il lavoro passa in rassegna i macro (Calcio, Fosforo, Potassio, Sodio, Cloro, Zolfo, Magnesio) e microelementi minerali (Ferro, Rame, Cobalto, Iodio, Manganese, Zinco, Molibdeno, Selenio) che svolgono un ruolo essenziale nel metabolismo animale. Per ciascuno di essi gli autori indicano non solo la funzione svolta, ma anche le più recenti acquisizioni in materia di fabbisogni giornalieri per gli ovini da latte.

Parole chiave: *Macroelementi, Microelementi, Ovini da latte.*

Introduction

Many minerals make up the body composition of animals; they play many fundamental roles and many of them are essential to the normal vital functions of animals. The roles played by each inorganic component are not always completely known and in some cases it is not clear whether or not they are really essential. In fact, the privation of some minerals (even when found in each animal organism) does not result in any effect (Underwood, 1977). Depending on the amount of minerals found in the organism they are classified as either major elements (or macrominerals) or trace elements (or microminerals). In the animal body, major minerals constitute more than 100 mg/kg (Ca, P, Mg, Na, K, Cl, S), while microminerals or trace elements (Fe, Zn, Cu, Mb, Se, I, Mn, F, Co, Cr, Al, As, Si, V, Ni, Sn) are present in lower amounts (Underwood, 1977). The average content of some minerals in the animal body is reported in the Table 1 (ARC, 1980; Grace, 1983; Underwood, 1977) and that of ash and the main mineral elements in sheep milk is shown in Table 2 (NRC, 1985). Nearly 40 minerals play an essential role in the metabolic processes of animals; their functions are numerous and heterogeneous. They participate in the regulation of the osmotic pressure and in the acid-base balance of liquids within the body.

Table 1. Major elements and nutritionally important trace elements and their approximate concentration in the animal body.

Macrominerals		Microminerals	
Element (g/kg):		Element (mg/kg):	
Calcium	15	Iron	20-80
Phosphorus	10	Zinc	10-50
Potassium	2	Copper	1-5
Sodium	1.6	Molybdenum	1-4
Chlorine	1.1	Selenium	1-2
Sulphur	1.5	Iodine	0.3-0.6
Magnesium	0.4	Manganese	0.2-0.5
		Cobalt	0.02-0.1

Table 2. Average content of ash and of the main minerals in sheep milk.

Total ash	g/100g	0.85
Macrominerals	(g/100g):	
Sodium		0.04
Potassium		0.15
Chlorine		0.075
Calcium		0.20
Phosphorus		0.15
Sulphur		0.05
Magnesium		0.016
Microminerals (mg/l):		
Iron		0.60 - 0.70
Copper		0.05 - 0.15
Manganese		0.06
Aluminium		1.70
Zinc		2.00 - 3.00

Minerals play fundamental roles in the permeability and polarisation of the cellular membrane and determine the transmission of the nervous impulses and the contraction of muscles. In many cases minerals are essential constituents of co-enzymes, factors or cofactors participating in chemical reactions in the organism. Moreover, some minerals have plastic functions in several organs and tissues: first of all, they are constituents of bones, representing half of their weight. The deficiency of many trace mineral elements can be obtained only under experimental conditions because they are required in such minute quantities, and are so widely distributed in foods, that deficiencies are unlikely or even impossible under normal practical conditions (Suttle, 1983c; Underwood, 1977). Moreover, some elements (copper, selenium, molybdenum, fluorine, vanadium, arsenic), although essential, when ingested in excessive quantities can become toxic (Table 3). Therefore,

Table 3. Micromineral requirements of sheep and maximum tolerable levels in the diet.

Element	Requirement (mg/kg DM)	Maximum tolerable level (mg/kg DM)
Iodine	0.10-0.80	50
Iron	30-50	500
Copper	7-11	25
Molybdenum	0.5	10
Cobalt	0.1-0.2	10
Manganese	20-40	1000
Zinc	20-33	750
Selenium	0.1-0.2	2
Fluorine	-	60-150

the supplementation of these elements must be carefully evaluated, taking into account the real food allowances (NRC, 1980). For many aspects the mineral requirements of ovines in different physiological situations are not completely clear as respects many elements (ARC, 1980; INRA, 1978, 1988; NRC, 1975, 1985). Studies on mineral requirements of sheep often refer to breeds which are specialised in meat production. Requirements may be different in dairy sheep, especially because of their long milking period. In addition, the content of each mineral in milk can change as the lactation advances (Braithwaite, 1983a, 1983b). The range of macromineral requirements (mg/kg DM of diet), except for chlorine (which is always associated with sodium), is reported in Table 4 (NRC, 1985).

Table 4. Range of macromineral requirements in sheep.

Element	Requirement (mg/kg DM of diet)
Sodium	0.09-0.18
Calcium	0.20-0.82
Phosphorus	0.16-0.38
Magnesium	0.12-0.18
Potassium	0.50-0.80
Sulphur	0.14-0.26

Major elements

Calcium

Calcium is the most abundant mineral element in the animal body and it is fundamental for the activity of many enzyme systems, coagulation of blood, transmission of nerve impulses, contraction of muscles, flocculation of casein in the stomach and many others (ARC, 1980; INRA, 1978; 1988; NRC, 1975; 1985). About 99% of the total body calcium is localised in the skeleton and teeth as basic phosphate, $3Ca2(PO4)_2$. $Ca(OH)_2$ in association with magnesium salts. Bone ash contains approximately 36% calcium, 17% phosphorus and 10% magnesium. Calcium (together with phosphorus) in bones is in a constant state of flux and is available to offset any deficiency due to the lack of intake and/or an increase in requirements (e.g. during some phases of the lactation). The turnover of calcium and phosphorus in bones is under the control of calcitonin and parathormone (Farningham, 1988). The absorption of calcium in the intestine increases with the requirements of the animals and when the content of the element decreases in the diet (Braithwaite, 1982). At maintenance level in adult animals the absorption of calcium is around 40%; in pregnant animals it is about 50% and it reaches 60% in lactating ewes and in growing lambs. The optimal calcium/phosphorus ratio is 1:1 or 2:1, but larger ratios (up to 7:1) do not determine any problems. The content of calcium in ewe milk is 0.18-0.20% on average (Table 2). In milk calcium and inorganic phosphate are present in excess of their solubility and - as a result of their interactions with casein - are not precipitated as calcium phosphate. Calcium phosphate in casein micelles, which is associated with casein, is called colloidal calcium phosphate or micellar calcium phosphate. Casein micelles are the carriers of calcium phosphate and colloidal calcium phosphate plays an important role in maintaining the structure of casein micelles (Takayoshi, 1992). The allowance of calcium can vary depending on the category of animal and the physiologic condition; with respect to the maintenance phase, during the flushing period the allowance is higher and increases slightly during the first 15 weeks of gestation (Table 5). In the subsequent period of gestation the requirements of the element increase (Braithwaite, 1983a) depending on the distance from the delivery and the estimable litter weight at lambing (Table 6). The requirements of calcium for milk production increase (Braithwaite, 1983a; INRA, 1988; NRC, 1985) as lactation advances and they are in rela-

Table 5. Daily requirements of Ca and P for sheep at maintenance level, during the breeding period and in the first 15 weeks of gestation.

	Live weight (kg)	Daily gain (g)	Ca (g)	P (g)
Maintenance	40	10	3.0	2.0
	50	10	3.5	2.5
	60	10	4.0	3.0
	70	10	4.5	3.5
Flushing	50	100	5.3	2.6
	60	100	5.5	2.9
	70	100	5.7	3.2
First 15 weeks of gestation	40	30	3.9	2.3
	50	30	4.4	2.9
	60	30	4.9	3.4
	70	30	5.4	4.0

Table 6. Daily requirements of Ca and P in late pregnancy according to the ewes live weight and to the litter weight.

Ewes live weight (kg)	Litter weight (kg)	Ca (g)	P (g)
6-5 weeks before lambing			
55	4	5.7	3.2
55	5	6.2	3.3
55	7	7.2	3.6
60	5	6.4	3.6
60	6	6.9	3.7
60	7	7.4	3.8
60	8	7.9	3.9
70	5	7.0	4.1
70	7	8.0	4.4
70	9	9.0	4.7
70	11	10.0	4.9
Ewes live weight (kg)	Litter weight (kg)	Ca (g)	P (g)
4-3 weeks before lambing			
55	4	6.9	3.5
55	5	7.7	3.7
55	7	9.1	4.1
60	5	7.9	4.0
60	6	8.6	4.2
60	7	9.3	4.4
60	8	10.0	4.6
70	5	8.5	4.5
70	7	10.1	4.9
70	9	11.7	5.3
70	11	13.3	5.7
Ewes live weight (kg)	Litter weight (kg)	Ca (g)	P (g)
2-1 weeks before lambing			
55	4	9.0	4.0
55	5	10.3	4.4
55	7	13.0	5.0
60	5	10.5	4.6
60	6	11.8	4.9
60	7	13.2	5.3
60	8	14.5	5.7
70	5	11.1	5.2
70	7	13.8	5.8
70	9	16.5	6.5
70	11	19.1	7.1

tion to the weight gain of lambs as well as the fat and protein content of milk (Tables 7 and 8). The calcium requirements of growing replacement lambs in relation to the main factors of variation (live weight, weight gain, gestation, lactation, and sex) are reported in the Tables 9-11 (Braithwaite,1983a, 1983b; INRA, 1988; NRC, 1985; Pond, 1983).

Phosphorus
This mineral is of vital importance in the energy metabolism; in fact, it participates in the formation of sugar-phosphates and adenosine di- and tri- phosphates. It is a component of phosphoproteins, nucleic acids and phospholipids. The content of phosphorus in the animal body is lower than that of calcium (Table 1). The relationship between phosphorus and calcium in the inorganic matter of bone tissue have been already described. About 80% of the total phosphorus of the organism is localised in the skeleton along with calcium. In many feeds, especially in cereal grains, the element is in the form of undigestible phytates. In ruminants, because of the presence of bacterial phytase in the rumen, this form of phosphorus can be efficiently utilised (ARC, 1980; Field *et al.*, 1982; Field, 1983; INRA, 1978, 1988; NRC, 1975, 1985; Suttle, 1983b). The content of this element in ewe milk is on average 0.14-0.15% (Table 2). In milk this element is in part present as calcium phosphate in casein micelles, as described for calcium. The adsorption of phosphorus in the intestine is 60% in adult animals at maintenance level and in the first 15 weeks of gestation, 70% in the subsequent period of gestation, in lactating ewes and in growing animals (NRC, 1985). The phosphorus requirements in the different categories of animals (Tables 5-11) change together with those of calcium (ARC, 1980; Braithwaite,1984a, 1984b; Field *et al.*, 1982; Field, 1983; INRA, 1978, 1988; NRC, 1975, 1985; Suttle, 1983b).

Potassium
Potassium is fundamental (along with sodium, chlorine and bicarbonate ions) in the osmotic regulation of body fluids and in the acid-base balance in the organism. It is the main intracellular cation and plays a role of primary importance in nerve and muscle excitability (Campbell *et al.*,1965; INRA, 1988; NRC, 1985; Suttle, 1983b). Vegetable foods always contain large amounts of potassium, consequently potassium deficiency is rare in herbivores (Calhoun *et al.* 1983). The content of potassium in ewe milk (NRC, 1985) is on average 0.15% (Table 2).

Sodium
Sodium is the main extra-cellular cation; most of it is present in the soft tissues, body fluids and haematic plasma. It participates in the maintenance the acid-base balance and in osmotic regulation. It plays a fundamental role in the absorption of sugars and amino-acids from the intestine and in the transmission of nerve impulses (ARC, 1980; INRA, 1978, 1988; NRC, 1975, 1985; Suttle, 1983b). Much of this element is ingested in the form of sodium chloride. This latter is commonly added to the concentrates (1%), but it is possible to offer it in blocks left available for free choice licking. The content of sodium in ewe milk is on average 0.04% (Table 2). This value can increase together with chlorine in the case of mastitis.

Chlorine
In associations with sodium and potassium, chlorine is essential in acid-base balance and osmotic regulation. Chlorine is fundamental in gastric secretion, where it is in the form of hydrochloric acid and as chloride salts (ARC, 1980; INRA, 1978, 1988; NRC, 1975, 1985; Suttle, 1983b). The content of the element in ewe milk (NRC, 1985) is on average 0.075% (Table 2). The supplementation of chlorine is associated with that of sodium.

Sulphur
In the animal organism most of it is in the sulphur-containing amino acids (cysteine and methionine), but it is also present in the vitamins thiamin and biotin, in insulin and coenzyme A (ARC, 1980; INRA, 1978, 1988; NRC, 1975, 1985; Suttle, 1983b). The inorganic form of sulphur is present in the animal body only in a small amount, although sulphates are found in limited quantities in the blood. Wool is rich in sulphur-containing amino

acids (particularly in cysteine) and the sulphur content reaches about 4%. The content of sulphur in ewe milk is on average 0.05% (Table 2). When the diet for ruminant animals contains high levels of non protein nitrogen, the addition of sulphur to the rations may be beneficial (Bray *et al.*, 1969). Aiming to avoid, in these cases, the limiting factor for the ruminal synthesis of cystine, cysteine and methionine, the addition of sulphate to the ration is opportune (1.5-2 g/kg D.M. elemental sulphur or sodium sulphate).

Magnesium

About 60-70% of the total magnesium of the organism is localised in the skeleton, where it is closely associated with calcium and phosphorus; the remainder is found in the soft tissues and body fluids. It is fundamental for many enzyme systems and is the most common enzyme activator. It plays an important role in activating phosphate transferases, decarboxylases and acyl transferases. Moreover, it is essential for many functions: transmission of nerve impulse, contraction of muscles, synthesis of protein, fat and nucleic acids, utilization of glucose, trans-methylation. Magnesium is a co-factor in many reactions and participates as a moderator in the neuro-muscular excitation. In adult animals only a very small part (2%) of magnesium can be mobilised from bone; therefore a dietary deficiency of magnesium cannot be counteracted by mobilisation from bone reserves (Chicco et al, 1973b). The suggested minimum magnesium requirements are 0.12, 0.15 and 0.18% DM for growing lambs, for ewes in late pregnancy, and for ewes in early lactation, respectively (NRC, 1975, 1985; INRA, 1988). The administration of magnesium oxide (about 7 g head/d in the concentrate) can prevent the risk of hypomagnesaemic tetany in lactating ewes. (Chicco *et al.*, 1973a; Amos *et al.*, 1975; NRC, 1985). The content of magnesium in ewe milk is on average 0.016% (Table 2).

Trace elements

Iron

Most iron is combined with proteins; it participates in the composition of haemoglobin, myoglobin, cytochromes, catalases, peroxidases. In the haematic plasma it is carried as a complex with transferrin. A form of storage of iron is represented by ferritin, a protein that carries up to 20% of the element and is localised mainly in the spleen, lever, kidney, bone marrow and intestine walls. Haemosiderin is a similar storage compound containing up to 30-35% of the element. About 65-70% of iron in the animal body is combined with haemoglobin and myoglobin (Underwood, 1977). Most of feeds for ruminants are good sources of iron and its deficiency is not common in ruminants under normal conditions (INRA, 1978, 1988; NRC, 1985). Milk has a rather poor content of this element (Table 2), but newborn animals have reserves which cover their requirements until they are able to utilise solid feeds (Lawlor *et al.* 1965).

Copper

Copper is essential for the synthesis of haemoglobin; it is present in some other plasma proteins that are involved in the mobilisation and transfer of iron (ceruloplasmin). A deficiency of copper, therefore, reduces the adsorption of iron. Copper is a component of some other proteins in blood such as erythrocuprein, which plays a role in oxygen metabolism in erythrocytes. The element is involved in several enzyme systems, in the synthesis of the elastin, collagen and myelin sheath of the nerve fibres. It is also a component of cytochrome oxidase. Copper is important for the maintenance of the integrity and for the normal development of the central nervous system (Underwood, 1977). It is involved in the synthesis of cutaneous pigments and it is important for crimp, tensile strength, elasticity and affinity for dyes of wool (NRC, 1985). The adsorption of copper is limited when the diet contains high levels of molybdenum and in the presence of sulphur (Suttle, 1983a). In this case a chain reaction leads to the formation of insoluble copper thiomolybdate ($CuMoS_4$) limiting the availability of dietary copper for absorption (Wiener, 1979). The content of copper in ewe milk (Table 2) is on average 0.05-0.15 mg/l (NRC, 1985). A prolonged ingestion of copper exceeding nutritional requirements (5-7 ppm DM) leads to an accumulation of the element in the tissues, especially in the liver. Chronic copper poisoning is, therefore, rather frequent in ovines (Buck *et al.*, 1969; NRC, 1980) and occurs when the diet contains 15-20 ppm DM of the element and low levels of molybdenum even under natural conditions because the maximum tolerable level is very low (Table 3).

Cobalt

Cobalt is utilised by rumen microorganisms for the synthesis of vitamin B12 of which cobalt is an essential component (Underwood, 1977). Owing to body reserves of vitamin B12 in the liver and kidneys, symptoms of cobalt deficiency may appear after some months from the beginning of the deficiency. Vitamin B12 is involved in the metabolism of propionic acid into succinic acid even at the ruminal level; therefore, the rumen microorganisms need cobalt. In particular, vitamin B12 is necessary for the conversion of methylmalonil coenzyme A into succinyl coenzyme A. Moreover, cobalt seems to have other functions in the animal body as an activating ion in some enzyme reactions. The normal requirements (Table 1) in ruminants are covered when the diet contains 0.1-0.2 ppm DM of the element (INRA, 1978, 1988; NRC, 1985).

Iodine

A very small amount of iodine is present in the animal body and most of it (70-80%) is localised in the thyroid gland (Underwood, 1977). The major role of iodine is supposed to be the contribution to the synthesis of thyroid hormones (triiodothyronine and tetraiodothyronine). The normal requirements of iodine in ruminants are covered when the diet contains 0.25ppm DM of the element; in lactating ewes the requirement reaches 0.50-0.80 ppm DM (INRA, 1978, 1988; NRC, 1985).

Manganese

The content of manganese in the animal body is extremely limited; it is more concentrated in the bones, liver, kidneys, pancreas and pituitary gland. It is an important enzyme activator (phosphate transferases, arginases and decarboxylases). Manganese participates in the production of mucopolysaccharides and therefore in the formation of several connective tissues, particularly the bone. It is required for coordination of movements and to keep balance, preventing ataxia in lambs. It is necessary for the normal functionality of the reproductive apparatus in both the male and female (Underwood, 1977). The manganese (Table 3) requirement of ruminants is 40-50 ppm DM of the ration with a good tolerance limit (INRA, 1978, 1988; NRC, 1980, 1985). The requirements can increase when the levels of calcium and phosphorus in the diet are high (NRC, 1985). The content of manganese in ewe milk (NRC, 1985) is on average 0.06 mg/l (table 2).

Zinc

Zinc has the tendency to accumulate in bone tissue rather than in the liver (as many other trace elements), but it is found in every tissue and reaches rather high levels in skin, hair and wool. Zinc plays a role in the formation of several enzymes: carbonic anhydrase, thymidine kinase, alkaline phosphatase, lactate dehydrogenase and pancreatic carboxypeptidase (Underwood, 1977). The element is an activator of several enzyme systems and enters in the composition of insulin. Zinc requirements (Table 3) are 20-33 ppm DM of the ration (Apgar et al, 1979; Pond, 1983; Suttle, 1983b).

Molybdenum

Molybdenum is a component of several fundamental enzymes in animals: xanthine oxidase, aldehyde oxidase and sulphite oxidase (Underwood, 1977). Molybdenum deficiency is not observed in animals under normal feeding conditions (Ellis *et al.* 1958; Suttle, 1983c).

Selenium

In the 1950s it was demonstrated that most ovine myopathies can be prevented by adding selenium or vitamin E to the diet (Allaway *et al.*, 1966; Muth, 1970). The element is a component of glutathione peroxidase, which catalyses the removal of hydrogen peroxide (Underwood, 1977). Moreover, selenium treatment of animals in areas where it is deficient can be helpful in the prevention of mastitis and infertility (Muth, 1970; Piper *et al.*, 1980; Suttle, 1983c; Ullrey *et al.*, 1977). Selenium requirements (Table 3) are 0.1-0.2 ppm DM of diet (INRA, 1978, 1988; NRC, 1983, 1985).

Aluminium

It is an element that is present in ewe milk (NRC, 1985) on average 1.70 mg/l (Table 2). The role of aluminium in the animal organism, like that of some other trace elements, is not completely clear and its deficiency is not observed in animals under normal feeding conditions.

Conclusions

Nearly 40 minerals, classified as either major or trace elements, are essential to the normal vital functions of animals, performing numerous and heterogeneous functions. However, the deficiency of many mineral trace elements can be

Table 7. Daily requirements of Ca and P in milking sheep in relation to the daily gain of lambs, to the production of milk and to the distance from lambing.

Daily gain of lambs (g)		150	250	350	450	550
Up to 3 weeks after lambing:						
Milk production	kg/d	0.90	1.40	1.90	2.60	3.00
Ca	g	5.4	8.4	11.4	15.6	18.0
P	"	2.3	3.5	4.8	6.5	7.5
4 to 6 weeks after lambing:						
Milk production	kg/d	0.75	1.15	1.60	2.25	2.60
Ca	g	4.5	6.9	9.6	13.5	15.6
P	"	1.9	2.9	4.0	5.6	6.5
7 to 10 weeks after lambing:						
Milk production	kg/d	0.50	0,8	1,05	1,45	1,65
Ca	g	3.0	4.8	6.3	8.7	9.9
P	"	1.3	2.0	2.6	3.6	4.1
11 to 14 weeks after lambing:						
Milk production	kg/d	0.30	0.40	0.60	0.80	0.90
Ca	g	1.8	2.4	3.6	4.8	4.8
P	"	0.8	1.0	1.5	2.0	2.3

Table 8. Requirements of Ca and P for milk production of ewes in relation to the stage of lactation and to the content of fat and of protein in milk.

Stage of lactation (months)	Fat content (g/l)	Protein content (g/l)	Ca (g/kg of milk)	P (g/kg of milk)
1-4	58-75	49-60	6.4	2.5
5-6	80-90	62	7.0	2.8

Table 9. Daily requirements of Ca and P in ewe lambs in relation to the live weight, daily weight variation, period of gestation, and first 6-8 weeks of lactation with single lamb and twins suckling and weaning at 8 weeks.

	Live weight (kg)	Daily weight variation (g)	Ca (g)	P (g)
Maintenance beginning gestation period	30		3.5	2.2
	40		4.4	2.5
First 15 weeks of gestation – non lactating	40	160	5.5	3.0
	50	135	5.2	3.1
	60	135	5.5	3.4
Last 4 weeks of gestation (100-120% lambing rate prevision)				
	40	180	6.4	3.1
	50	160	6.3	3.4
	60	160	6.6	3.8
Last 4 weeks of gestation (130-175% lambing rate prevision)				
	40	225	7.4	3.5
	50	225	7.8	3.8
	60	225	8.1	4.3
First 6-8 weeks of lactation suckling single lamb	40	-50	6.0	4.3
	50	-50	6.5	4.7
	60	-50	6.8	5.1
First 6-8 weeks of lactation suckling twins	40	-100	8.4	5.6
	50	-100	8.7	6.0
	60	-100	9.0	6.4

Table 10. Daily requirements of Ca e P in growing male and female replacement lambs in relation to the live weight and daily gain.

Live weight (kg)	Daily gain (g)	Ca (g)	P (g)
10	200	4.0	1.9
10	250	4.9	2.2
15	150	4.2	1.7
15	200	5.3	2.1
15	250	6.4	2.5
15	300	7.5	2.9
20	150	4.6	1.9
20	200	5.7	2.3
20	250	6.8	2.7
20	300	8.0	3.0
25	150	5.2	2.2
25	200	6.4	2.6
25	250	7.6	3.0
25	300	8.9	3.3
25	350	10.3	3.7
30	150	5.8	2.4
30	200	7.1	2.8
30	250	8.5	3.2
30	300	9.7	3.6
30	350	11.1	4.0
30	400	12.6	4.4
35	150	6.5	2.8
35	200	8.0	3.2
35	250	9.5	3.6
35	300	10.9	4.0
35	350	12.4	4.4
35	400	13.9	4.8
35	450	15.4	5.2
40	200	9.0	3.5
40	250	10.5	3.9
40	300	12.0	4.4
40	350	13.6	4.8
40	400	15.3	5.2
40	450	16.8	5.6

Table 11. Daily requirements of Ca and P in growing male and female replacement lambs in relation to the live weight, daily gain and sex.

Live weight (kg)	Daily gain (g)	Ca (g)	P (g)
Female replacement lambs:			
30	227	6.4	2.6
40	182	5.9	2.6
50	120	4.8	2.4
Male replacement lambs:			
40	330	7.8	3.7
60	320	8.4	4.2
80	290	8.5	4.6

obtained only under experimental conditions, because these minerals are required in minute quantities and are widely distributed in foods. Moreover, some elements, although essential, can become toxic when ingested in excessive quantities. The mineral requirements of ovines in different physiological situations are not always completely clear. In fact, studies regarding mineral requirements of sheep very often refer to breeds specialised in meat production. In dairy sheep, however, these requirements can be different, especially during the milking period, which is much longer in dairy sheep. Moreover, the content of minerals in milk can change as the lactation advances.

REFERENCES

AGRICULTURAL RESEARCH COUNCIL, 1980. The Nutrient Requirements of Ruminant Livestock. Tech. Rev. Agric. Res. Council Working Party. Commonwealth Agricultural Bureaux, Farnham Royal, UK.

ALLAWAY, W.H., MOORE, D.P., OLDFIELD, J.E., MUTH, O.H., 1966. Movement of physiological levels of selenium from soils through plants to animals. J. Nutr. 88:411-421.

AMMERMAN, C.B., CHICCO, C.F., MOORE, J.E., VAN WALLEGHEM, P.A., ARRINGTON, L.R., 1971. Effect of dietary magnesium on voluntary feed intake and rumen fermentations. J. Dairy Sci. 54:1288-1299.

AMOS, R.L., CRISSMAN, G.J., KEEFER, R.F., HORVATH, D.J., 1975. Serum magnesium levels of ewes grazing orchardgrass topdressed with dolomite or calcite. J. Anim. Sci. 41:198-207.

APGAR, J., TRAVIS, H.F., 1979. Effect of a low zinc diet on the ewe during pregnancy and lactation. J. Anim. Sci. 48:1234-1245.

BRAITHWAITE, G.D., 1982. Endogenous faecal loss of calcium by ruminants. J. Agric. Sci. 99:355-369.

BRAITHWAITE, G.D., 1983a. Calcium and phosphorus requirements of the ewe during pregnancy and lactation. l. Calcium. Br. J. Nutr. 50:711-722.

BRAITHWAITE, G.D., 1983b. Calcium and phosphorus requirements of the ewe during pregnancy and lactation. 2. Phosphorus. Br. J. Nutr. 50:723-734.

BRAITHWAITE, G.D., 1984a. Changes in phosphorus metabolism of sheep in response to the increased demands for P associated with an intravenous infusion of calcium. J. Agric. Sci. 102:135-147.

BRAITHWAITE, G.D., 1984b. Some observations on phosphorus homoeostasis and requirements of sheep. J. Agric. Sci. 102:295-303.

BRAY, A.C., Hemsley, J.A., 1969. Sulphur metabolism of sheep. IV. The effect of a varied dietary sulphur content on some body fluid sulphate levels and on the utilization of urea-supplemented roughage by sheep. Aust. J. Agric. Res. 20:759-772.

BUCK, W.B., SHARMA, R.M., 1969. Copper toxicity in sheep. Iowa State Univ. Vet. 31:4-19.

CALHOUN, M.C., SHELTON, M., 1983. Source and level of potassium in high concentrate lamb diets. J. Anim. Sci. 57(Suppl. 1):423-432.

CAMPBELL, L.D., ROBERTS, W.K., 1965. The requirements and role of potassium in ovine nutrition. Can. J. Anim. Sci. 45:147-161.

CHICCO, C.F., AMMERMAN, C.B., LOGGINS, P.E., 1973a. Effect of age and dietary magnesium on voluntary feed intake and plasma magnesium in ruminants. J. Dairy Sci. 56:822-831.

CHICCO, C.F., AMMERMAN, C.B., FEASTER, J.P., DUNAVANT, B.G., 1973b. Nutritional interrelationships of dietary calcium, phosphorus and magnesium in sheep. J. Anim. Sci. 36:986-998.

ELLIS, W.C., PFANDER, W.H., MUHRER, M.E., PICKETT, E.E., 1958. Molybdenum as a dietary essential for lambs. J. Anim. Sci. 17:180-192.

Farningham, D.A.H., 1988. Hypocalcaemia in the ewes. Vet. Ann. 28: 74-77.
Field, A.C., 1983a. Maintenance requirements of phosphorus and absorbability of dietary phosphorus in sheep. J. Agric. Sci. 100:231-242.
Field, A.C., Coop, R.L., Dingwall, R.A., Munro, C.S., 1982. The phosphorus requirements for growth and maintenance of sheep. J. Agric. Sci. 99:311-325.
Grace, N.D., 1983. Amounts and distribution of mineral elements associated with fleece-free empty body weight gains in grazing sheep. Nz. J. Agric. Res. 26:59-76.
INRA, 1978. Alimentation des Ruminants. INRA Publ., Versailles, France.
INRA, 1988. Alimentation des Bovins, Ovins & Caprins. INRA Publ., Paris, France.
Lawlor, M.J., Smith, W.H., Beeson, W.M., 1965. Iron requirement of the growing lambs. J. Anim. Sci. 24:742-751.
Lee, H.J., Marston, H.R., 1969. The requirement for cobalt of sheep grazed on cobalt-deficient pastures. Aust. J. Agric. Res. 20:905-912.
Muth, O.H., 1970. Selenium-responsive disease of sheep. J. Am. Vet. Med. Assoc. 157:1507-1521.
National Research Council, 1975. Nutrient Requirements of Sheep. Ed. National Academy of Sciences, Washington, DC, USA.
National Research Council, 1980. Mineral Tolerance of Domestic Animals. Ed. National Academy of Sciences, Washington, DC, USA.
National Research Council, 1982. United States-Canadian Tables of Feed Composition. 3rd ed. National Academy Press, Washington, DC, USA.
National Research Council, 1983. Selenium in Nutrition. National Academy Press, Washington, DC, USA.
National Research Council, 1985. Nutrient Requirements of Sheep. 6th rev. ed. National Academy Press, Washington, DC, USA.
Piper, L.R., Bindon, B.M., Wilkins, J.F., Cox, R.J., Curtis, Y.M., Cheers, M.A., 1980. The effect of selenium treatment on the fertility of Merino sheep. Proc. Aust. Soc. Anim. Prod. 13:241-250.
Pond, W.C., 1983. Effect of dietary calcium and zinc levels on weight gain and blood and tissue. Mineral concentrations of growing Columbia-and Suffolk-sired lambs. J. Anim. Sci. 56:952-961.
Suttle, N.F., 1983a. Effects of molybdenum concentration in fresh herbage, hay and semi-purified diets on copper metabolism of sheep. J. Agric. Sci. 100:651-664.
Suttle, N.F., 1983b. Meeting the mineral requirements of sheep. In: W. Haresign (ed.) Sheep Production. Proc. Nottingham Easter School, Butterworth, London, UK, pp 167-183.
Suttle, N.F., 1983c. The nutritional basis for trace element deficiencies in ruminant livestock. In: N.F. Suttle, R.G. Gunn, M.w. Allen, K.A. Linklater, G. Wiener (eds.) Trace Elements in Animal Production and Veterinary Practice. Br. Soc. Anim. Prod. Occas. Publ. n.7, London, UK, pp 19-25.
Takayoshi, A., Taketoshi, U., Yoshitaka, K., 1992. The least number of phosphate groups for crosslinking of casein by colloidal calcium phosphate. J. Dairy Sci. 75: 971-975.
Ullrey, D.E., Brady, P.S., Whetter, P.A., Ku, P.K., Magee, W.T., 1977. Selenium supplementation of diets for sheep and beef cattle. J. Anim. Sci. 45:559-567.
Underwood, E.J., 1977. Trace Elements in Human and Animal Nutrition. Ed. Academic Press, New York, USA.