genotype to 215 days for the 1/2D × 1/2R, after which it increased to 228 days for the Romanov. This pattern indicates that heterosis might be important for this trait and implies that non-additive genes could be involved. This would support the conclusion of Dyrmundsson (1973).

Toteda *et al.* (1987) reported a mean age of 206 ± 4.5 days and a mean mass of 31.1 ± 1.05 kg at puberty in Romanov ewes. Boshoff *et al.* (1975) found that Romanov crosses exhibited oestrus significantly earlier than Karakul ewes. Age and mass of the crosses were significantly lower than those of Karakul ewes. Their results agree with the results of this study in that the crosses were significantly lighter at oestrus than the indigenous breed. In this study, the Dorper ewes were, however, younger at first oestrus than the crosses. It would appear that an increase of more than 50% in the proportion of Romanov genes resulted in a lengthening of the prepubertal period. This is in agreement with results of Dyrmundsson & Lee (1972), Keane (1974), and Quirke (1978) who indicated that a close association exists between body mass and the onset of puberty. The concept of a threshold mass for puberty within a specific management and feeding system is generally accepted by scientists, but is questioned by Baker & Morris (1986). The correlation between age and mass over the three different cycles was negative and very low, viz. –0.17. This may be an indication that the threshold mass was already crossed, after which age and mass at oestrus would appear to be independent.

Ovulation rate, adjusted for ewe mass and age at oestrus, showed a significant ($P < 0.01$) increase with an increase of Romanov genes from 1.1 in the 3/4D × 1/4R up to 1.9 in the Romanov. Ricordeau *et al.* (1978) also found that the number of ovulations increased with an increase in Romanov genes. The ovulation rate found in this study agrees well with that found by Land *et al.* (1973), viz. 1.13 to 2.57, but is lower than the rates reported by Toteda *et al.* (1987) and Ricordeau *et al.* (1978), viz. 2.4 to 3.7, and 2.3 to 2.9, respectively. These trends signify a strong additive inheritance pattern which partly explains why no heterosis is found for ovulation rate in the literature.

The infusion of Romanov genes into a population via crossbreeding advances the onset of puberty, increases ovulation rate and decreases ewe mass.

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Suitability of a lime source high in manganese as a feed ingredient for sheep

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An investigation was conducted to ascertain whether a source of feed lime (Ouplaas lime) high in manganese (5000 mg Mn/kg) is a safe feed ingredient for sheep. Two levels of Ouplaas lime, 1% and 4%, were included in a sheep finishing diet and compared with another lime source (Kulu lime; 45 mg Mn/kg) which was included at the same levels in the diets. Lambs were fed individually for 69 days. In the final feed mixtures none of the diets contained toxic levels of any minerals. No significant differences between treatments with the same level of lime inclusion occurred in: growth rate, feed intake and utilization, plasma enzyme levels, mineral concentrations in plasma, faeces and kidneys, mineral content of livers, haematology, histopathology of livers and kidneys and bone measurements. It is concluded that the Ouplaas lime, when included at realistic concentrations in diets, poses no risk to the health of sheep.

Ondersoek is ingestel na die veiligheid om 'n voerkalk (Ouplaaskalk) met 'n hoë mangaaninhoud (5 000 mg Mn/kg) aan skape te voer. Die Ouplaaskalk is teen 1% en 4% in 'n vetmestingsrantsoen vir lammers geplaas en vergelyk met 'n ander bron van kalk (Kulukalk; 45 mg Mn/kg), ingesluit teen dieselfde vlakke. Lammers in die vier behandelings is vir 69 dae individueel gevoer en daarna geslag. Die finale rantsoene het geen minerale teen toksiese vlakke bevat nie. Geen statisties-betekenisvolle verskille tussen behandelings wat dieselfde peil kalk bevat het, is waargeneem in: groeitempo, voerinname, voeromsetting, ensiempeile in plasma, konsentrasie van minerale in die plasma, mis en niere, mineraalinhoud van die lewer, haematologie, histopatologie van die lewers en niere en metings op ribmonsters nie. Dit blyk dat Ouplaaskalk, mits dit teen realistiese vlakke in rantsoene gevoeg word, geen gesondheidsrisiko vir skape inhou nie.

Keywords: Feed lime, health, manganese, sheep.

The feed lime excavated at the Ouplaas mine of Anglo-Alpha (Ltd) in north-western Cape has a greyish, cement-like colour. This colour is probably due to a very high level of manganese (Mn) in the lime, up to 5 000 mg/kg. Since this is not a well-recognized colour for feed lime, concern was expressed about the safety of the product to livestock. In fact, cases of poor health and deaths among livestock which consumed rations containing the Ouplaas lime, were attributed to the lime. To ascertain whether the Ouplaas source of lime is indeed a safe feed ingredient, sheep were fed a finishing diet containing either the Ouplaas lime or a widely used feed lime from Umzinkulu, known as Kulu lime.

Thirty-two weaned SA Mutton Merino lambs, with an average mass of 27.4 kg, were grouped into blocks of four according to body mass and sex. One sheep per block was allocated at random to one of the following four treatments: 1% Kulu lime; 4% Kulu lime; 1% Ouplaas lime; 4% Ouplaas lime, included in a commercial sheep finishing ration with no calcium (Ca) added to the basic diet. The sheep were housed individually and fed *ad libitum*. Feed intake and mass gains were recorded over a period of 69 days. Blood was collected on four occasions (before fresh feed was supplied in the morning) during the trial to determine mineral concentrations in plasma, the packed cell volume, haemoglobin levels in whole blood and the concentrations of plasma enzyme, aspartate transaminase (AST: EC 2.6.1.1), alkaline phosphatase (ALP: EC 3.1.3.1), aldolase (ALS: EC 4.1.2.13) and creatine kinase (CK: EC 2.7.3.2). Any sign of abnormal health was recorded. On day 69, when the lambs were slaughtered, the average mass was 43 kg. Carcass, liver and kidney masses were recorded. The concentrations of Mn, copper (Cu) and zinc (Zn) in the livers and kidney cortices were determined. These tissues, preserved in formosaline, were histologically evaluated (Dr W.S. Botha, Consultant Veterinary Pathologist, Pretoria). The plasma enzyme levels were determined with the use of Boehringer Mannheim standard kits (Boehringer Mannheim GmbH Diagnostics, West Germany). The third rib was collected for measurement of bone mineralization (Sykes *et al.*, 1973). Minerals in the feed (Tables 1 and 2), in faeces grab samples collected over a 10-day period [Ca and phosphorus (P)], in plasma [Ca, inorganic phosphate, magnesium (Mg), sodium (Na), Cu and Zn], and in livers and kidney cortices (Mn, Cu and Zn) were determined using atomic absorption spectrophotometry, except for P and inorganic phosphate, where methods published by AOAC (1985) were used. The accuracy of mineral analyses was controlled with National Bureau of Standard's reference samples (NBS, Washington, DC). Data were subjected to analyses of variance, using the Minitab Statistical Software (Minitab Inc. State College, PA 16801, USA).

The Ouplaas lime contained about 5 000 mg/kg Mn, as reported by the manufacturer, i.e. almost 100 times the concentration of Mn in the Kulu lime. The Kulu lime contained much higher levels of Al (10 times) and Fe (twice) than the Ouplaas lime. The other minerals were present at more or less the same concentrations in the two lime sources (Table 1).

The mineral concentrations of the final mixtures were approximately the same, except for Ca, Mn, Fe and Al, as presented in Table 2. The 4% Ouplaas diet contained 331 mg Mn/kg as compared to less than 200 mg Mn/kg in the other diets. The 331 mg Mn/kg is well below 1 000 mg/kg, which is the suggested maximum safe level of Mn for farm animals (NRC, 1980). The concentrations of Ca in the 4% lime diets were over 1.5%, which is well above the requirements of sheep of 0.4 to 0.5% (NRC, 1985), but not at a toxic level (NRC, 1980). High Ca intakes are reported to be antagonistic to the metabolism of Mn in the body (Miller, 1979). At a very high Mn intake, Mn may interfere with Fe absorption, especially if Fe is at a deficient level (Underwood, 1979), a situation which did not exist in the present trial. The high concentrations of Al and Fe in the Kulu lime were diluted in the diets to levels that should pose no risk of toxicity to the animal (NRC, 1980; Black *et al.*, 1985).

No differences in body mass gains (average of 245 ± 38 g/d) were observed between treatments. The total feed intakes of the two 4% groups were higher ($P < 0.05$) than those of the 1% lime groups (Table 3), though efficiency of feed utilization (average 5.7 ± 0.6) did not differ between treatments. No health problem related to the treatments was observed during the trial. The sheep in the two Kulu treatments had heavier livers ($P < 0.05$) than those which received the Ouplaas lime. This was also reflected in the ratios of liver

Table 1 Mineral composition of the pure lime sources (dry basis)

Lime sources	Mg (%)	Na (%)	K (%)	Fe (mg/kg)	Mn (mg/kg)	Al (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
Kulu	0.84	0.07	0.04	2620	45	3331	40	6.5
Ouplaas	0.54	0.07	0.02	1604	4959	356	47	7.3

Table 2 Calcium, manganese, iron and aluminium concentrations of experimental diets (dry basis)

Experimental diet	Calcium (%)	Manganese (mg/kg)	Iron (mg/kg)	Aluminium (mg/kg)
1% Kulu	0.65	121	377	122
4% Kulu	1.73	121	481	310
1% Ouplaas	0.70	174	323	83
4% Ouplaas	1.84	331	387	133

Table 3 Parameters showing significant differences or trends when different sources and levels of lime were fed to sheep

Experimental diet	Total feed intake [1] (kg)	Liver		Faecal concentrations (dry basis)	
		Mass wet (g)	As % body mass	Calcium (%)	Phosphorus (%)
1% Kulu	89.8^{a} ± 3.0	736^{a} ± 36	1.69^{a} ± 0.05	1.7^{a} ± 0.13	0.72^{a} ± 0.02
4% Kulu	97.9^{b} ± 3.2	725^{a} ± 39	1.63^{a} ± 0.06	4.7^{c} ± 0.14	0.60^{c} ± 0.02
1% Ouplaas	88.4^{a} ± 3.0	634^{b} ± 36	1.46^{b} ± 0.05	1.7^{a} ± 0.13	0.78^{a} ± 0.02
4% Ouplaas	93.2^{b} ± 3.2	648^{b} ± 39	1.53^{b} ± 0.06	5.3^{c} ± 0.14	0.57^{c} ± 0.02

$^{a-b}$ Values within columns with different superscripts differ significantly at $P < 0.05$.

$^{a-c}$ Values within columns with different superscripts differ significantly at $P < 0.01$.

[1] On 'as fed' basis; recorded over a period of 69 days.

mass to body and carcass masses (Table 3), although these values were within the normal range for sheep (Van Ryssen, 1981). No obvious explanation can be given for this difference.

The concentrations of Mn in the livers of the two Ouplaas groups were higher ($P < 0.05$) than those found in the livers of the Kulu groups. When expressed as liver Mn content, no differences were observed between the groups (Table 4).

Table 4 Manganese in the livers and kidneys of the sheep which received the different sources of lime

Experimental diet	Liver		Kidney cortex
	Mn concentration (mg/kg DM)	Mn content (g)	Mn concentration (mg/kg DM)
1% Kulu	13.8 ± 0.89^{a}	3.10 ± 0.26	6.7 ± 0.28
4% Kulu	14.4 ± 0.95^{a}	3.21 ± 0.28	7.1 ± 0.30
1% Ouplaas	16.9 ± 0.87^{b}	3.38 ± 0.26	7.9 ± 0.28
4% Ouplaas	17.6 ± 0.95^{b}	3.52 ± 0.28	6.7 ± 0.30

$^{a-b}$ Values with different superscripts differ significantly at $P < 0.05$.

These Mn concentrations corresponded well with those in the literature, e.g. at a dietary level of 500 mg Mn/kg, Black *et al.* (1985) measured 19.5 mg Mn/kg in the livers and 6.4 mg Mn/kg in the kidneys of sheep, while Ivan & Hidiroglou (1980) reported a level of 13 mg Mn/kg in the livers and 7 mg Mn/kg in the kidneys of sheep which consumed a diet containing 300 mg Mn/kg.

None of the following measurements showed significant differences between treatments: liver Cu (334 ± 79 mg/kg DM) and Zn (113.5 ± 23.7 mg/kg DM), kidney cortex Cu (21.5 ± 2.8 mg/kg DM) and Zn (126.7 ± 24.5 mg/kg DM), mineral concentration in plasma (Ca: 9.2 ± 0.7 mg/100 ml; P: 6.8 ± 1.2 mg/100 ml; Mg: 27.7 ± 1.7 mg/l; Na: 3.63 g/l; Cu: 0.77 ± 0.13 mg/l and Zn: 1.26 ± 0.17 mg/l), haemoglobin levels (10.8 ± 0.8 g/100 ml) and packed cell volume in blood (32.9 ± 2.3%). The histopathological evaluation of the livers and kidneys did not reveal any abnormalities. Plasma enzyme concentrations did not differ between treatments (ALP: 515 ± 142 U/l; AST: 72 ± 18.8 U/l; ALS: 8.3 ± 2.1 U/l and CK: 92 ± 50 U/l), indicating that a catabolism of body tissue did not take place in any of the sheep. The bones of the 4% lime groups contained more ($P < 0.01$) ash than those of the 1% lime treatments (Table 5). This was evident also from the bone ash to bone volume ratio and the ash to organic matter ratio. This may suggest that the two sources of lime supplied Ca with an equal efficiency for bone formation.

It can be concluded that, at realistic inclusion rates of lime in sheep diets, the lime will constitute such a small proportion of the total diet that only lime containing very toxic substances would affect the animal. It seems unlikely that Mn, which is a very 'safe' mineral (Miles *et al.*, 1986), could present a risk at the inclusion rates demonstrated in the present investigation.

Table 5 Effect of different levels of lime on measurements of the third rib

Experimental diet	Ash (%)	Ratios		
		Ash : Volume	Organic matter : Volume	Ash : Organic matter
1% Kulu	60.2 ± 0.5^{a}	0.64 ± 0.02^{a}	0.43 ± 0.02	1.52 ± 0.03^{a}
4% Kulu	62.9 ± 0.5^{b}	0.76 ± 0.03^{b}	0.46 ± 0.02	1.70 ± 0.03^{b}
1% Ouplaas	61.1 ± 0.5^{a}	0.64 ± 0.02^{a}	0.41 ± 0.02	1.58 ± 0.03^{a}
4% Ouplaas	63.9 ± 0.5^{b}	0.71 ± 0.03^{b}	0.40 ± 0.02	1.77 ± 0.03^{b}

$^{a-b}$ Values within columns with different superscripts differ significantly at $P < 0.01$.

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