Live mass, carcass and wool growth responses to supplementation of a roughage diet with sources of protein and energy in South African Mutton Merino lambs

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The effect of supplementing a diet of wheat straw plus urea with either 0, 100 or 200 g/d cottonseed oilcake meal (CSM) in combination with either 0, 100 or 200 g/d whole maize on wool and carcass growth of SA Mutton Merino lambs was studied. Voluntary intake of wheat straw was increased by CSM and decreased by maize ($P < 0{,}01$). Feed conversion ratio was improved by both supplements ($P < 0{,}01$). Although growth rate was increased by both supplements ($P < 0{,}01$), the response to CSM supplementation was almost double that for maize. The proportion of fat in the carcass was doubled by maize ($P < 0{,}01$), but was not affected by CSM. The proportion of fat in viscera was increased by both supplements ($P < 0{,}01$). Wool growth rate was increased by 89% and 226% when 100 or 200 g/d CSM were fed respectively, and by 46% and 96% when corresponding amounts of maize were fed. Wool fibre diameter was increased by 26% with 200 g/d CSM and by 6% with 200 g/d maize. Acetate clearance rate was not significantly increased by maize or CSM ($P > 0{,}05$). An interaction between treatment effects for feed conversion ratio suggests that responses to protein supplementation will depend on the level of energy supplied.

Die invloed van katoensaadoliekoekmeel (KOK) teen peile van 0, 100 of 200 g/d in kombinasie met heel mielies teen 0, 100 of 200 g/d as byvoeding tot 'n dieet van koringstrooi plus ureum vir SA Vleismerino-lammers is ondersoek. Vrywillige inname van koringstrooi is verhoog deur KOK, maar verlaag deur mielies ($P < 0{,}01$). Voeromsetverhouding is deur albei bronne verbeter ($P < 0{,}01$). Alhoewel groeitempo deur albei bronne verhoog is ($P < 0{,}01$), was die respons tot KOK bykans dubbel dié van mielies. Persentasie vet in die karkas is verdubbel deur mielies ($P < 0{,}01$), maar is nie deur KOK beïnvloed nie. Persentasie vet in die ingewande is egter deur albei bronne verhoog ($P < 0{,}01$). Wolgroeitempo is met 89% en 226% verhoog met 100 en 200 g/d KOK onderskeidelik en met 46% en 96% deur ooreenstemmende hoeveelhede mielies. Wolveseldikte is met 26% verhoog met 200 g/d KOK en met 6% met 200 g/d mielies. Asetaatverdwyningstempo is nie deur mielies of KOK verhoog nie ($P > 0{,}05$). 'n Interaksie tussen behandelingseffekte vir voeromsetverhouding dui daarop dat die invloed van proteïenbyvoeding deur die vlak van energiebyvoeding beïnvloed mag word.

Keywords: Cottonseed, maize, ruminant, supplement.

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Many attempts have been made in South Africa to define the optimum combination of protein and energy for wool growth, feed intake or live mass-gain (Coetzee, 1964; Coetzee, 1969; Jacobsz, Cronjé, Baard & Van Schalkwyk, 1971; Jacobsz, Cronjé, Baard & Skea, 1971). Interpretation of many of the studies conducted before the advent of the concept of rumen degradable and bypass protein and energy is difficult, as the experimental design often precludes separation of these effects. Other studies have attempted to relate wool growth rate to rate of mass-gain or -loss. This approach has not been entirely successful, as Coetzee, Nel & Joubert (1968a) found that the relationship for sheep grazing natural pasture differed from that obtained under controlled feeding conditions (Coetzee, Nel & Joubert, 1968b), and obtained different relationships during two subsequent years on the same pasture. Other authors have attempted to define the optimum level of nutrition for live mass-gain and wool growth in terms of protein to energy ratios by supplying nutrients via the abomasum, either by infusion (Williams, Robards & Saville, 1972; Black, Robards & Thomas, 1973), or by maintenance of the oesophageal groove reflex (Kempton, Hill & Leng, 1978). Results obtained from an infusion study using mature wethers indicated that the optimum protein:energy ratio for wool growth was not constant but varied according to energy intake (Black *et al.*, 1973; Kempton, 1979). Although the abomasal infusion technique undoubtedly provides the most accurate measure of nutrient-response relationships, results so obtained are difficult to apply in practice, as the effects of supplements on rumen fermentation and voluntary intake are not taken into account. Furthermore, it has been shown that nutrient-response relationships may differ appreciably between breeds, depending on their genetic propensities to divert available nutrients to either wool or body-tissue growth (Du Plessis & De Wet, 1981; McC. Graham & Searle, 1982). This study was undertaken to evaluate live mass, carcass and wool growth responses of a local dual-purpose sheep breed, the South African Mutton Merino, to supplements likely to provide bypass nutrients predominantly in the form of energy (maize) or protein (cottonseed oilcake meal) under *ad libitum* feeding conditions.

Materials and Methods

Animals

Fifty-four South African Mutton Merino wether lambs of mean (± SEM) live mass 21 ± 0,4 kg were allocated to nine treatment groups of equal mean live mass. The treatment groups were supplemented with either 0, 100 or 200 g/d cottonseed oilcake meal (CSM) in combination with either 0, 100 or 200 g/d whole maize in a 3 × 3 factorial design. All sheep received a basal diet of wheat straw plus urea (5 g/kg), which was sprayed onto the straw as an aqueous solution and then sun-dried. The basal diet was fed on an *ad libitum* basis, and feed refusals were weighed daily. All sheep received a mineral supplement which supplied (g/d) Ca (2,2); P (1,7); Na (1); S (0,7), as well as trace minerals and vitamins. Vitamin A and anti-helmintics were administered at regular intervals throughout the experiment. The sheep were kept in individual pens with slatted floors under continuous illumination and had free access to water.

Experimental design

Wool growth rate was measured as mg greasy wool/100 cm^2 midrib sample over a 5-month growth period. Wool fibre diameter was determined with a calibrated air-flow meter. The experiment was terminated after 7 months, when the animals were slaughtered. The mass of the carcass, viscera (empty gut plus internal organs), and the remainder (fleece, skin, shanks, head) was determined immediately after slaughter. Mass of gut contents was determined by difference. The carcasses and viscera were frozen immediately and stored at –15°C until analysis.

Analysis of samples

The frozen carcasses and viscera were first ground through a meat mincer. Samples were then freeze-dried and ground through a 2-mm screen in a laboratory mill with the addition of solid CO_2 to prevent fat from adhering to the blades. These samples were then analysed for nitrogen, fat and ash content according to standard AOAC (1984) procedures. Dry-matter content was determined by drying triplicate 100 g samples of the original minced carcasses at 70°C for 48 h. Carcass energy content was calculated on the assumption that the energy content of protein and fat is 23,8 and 39,3 MJ/kg respectively (Hofmeyr, 1972).

Acetate clearance

Acetate clearance rate was determined approximately 1 h after feeding. Sodium acetate (4 mmol/kg live mass) was made up to 50 ml with sterile water and injected via a jugular catheter (1,19 mm ID) which had been inserted on the previous day. Blood samples were taken before the acetate injection and at 10-min intervals thereafter for 50 min. Heparinized blood samples were centrifuged to extract the plasma, which was then deproteinized with sulfosalicylic acid (0,5 ml of a 50% w/v sulfosalicylic acid solution per 5 ml plasma). Acetate concentrations were determined by gas chromatography, and acetate clearance rates were calculated as described by Cronjé (1987).

Statistics

Results were analysed as a factorial design by multi-factor analysis of variance. Significance of differences between means was determined using least significant differences protected by a significant f-value.

Table 1 Effects of supplementation with cottonseed oilcake or maize on feed intake, mass gain, feed conversion ratio and carcass energy content in lambs fed a basal diet of wheat straw plus urea. Relative values are expressed as a proportion of that of the unsupplemented diet (SEM: standard error of the mean)

	Straw intake (g/week)		Mass gain (g/d)		Feed conversion (g feed/g mass gain)		Carcass energy content (MJ)	
	mean	index	mean	index	mean	index	mean	index
Cottonseed oilcake meal								
0 g/d	3454^a	1,00	20^a	1,00	43,8^a	1,00	80,6^a	1,00
	(138)		(3)		(12,0)		(8,2)	
100 g/d	4124^b	1,19	48^b	2,40	16,7^b	0,38	109,4^b	1,36
	(164)		(4)		(2,1)		(9,4)	
200 g/d	4198^b	1,22	62^c	3,10	11,4^b	0,26	125,2^b	1,55
	(146)		(3)		(0,6)		(10,3)	
Significance	**		**		**		**	
Maize								
0 g/d	4296^a	1,00	30^a	1,00	38,6^a	1,00	70,9^a	1,00
	(141)		(5)		(12,6)		(6,9)	
100 g/d	4026^a	0,94	44^b	1,47	18,6^b	0,48	101,6^b	1,43
	(154)		(5)		(2,5)		(6,6)	
200 g/d	3454^b	0,80	56^c	1,87	13,7^b	0,35	141,6^c	2,00
	(147)		(5)		(1,3)		(9,1)	
Significance	**		**		**		**	
Interaction between treatments	NS		NS		**		NS	

$^{a-c}$ Column means with different superscripts differ significantly (** $P < 0{,}01$).

NS: not significant ($P > 0{,}05$).

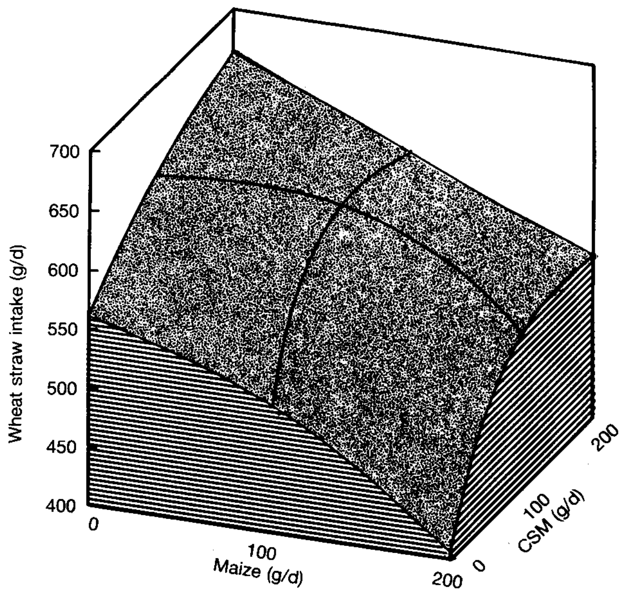

Figure 1 The effect of cottonseed oilcake meal (CSM) and maize, fed alone or in combination, on voluntary intake of wheat straw by lambs.

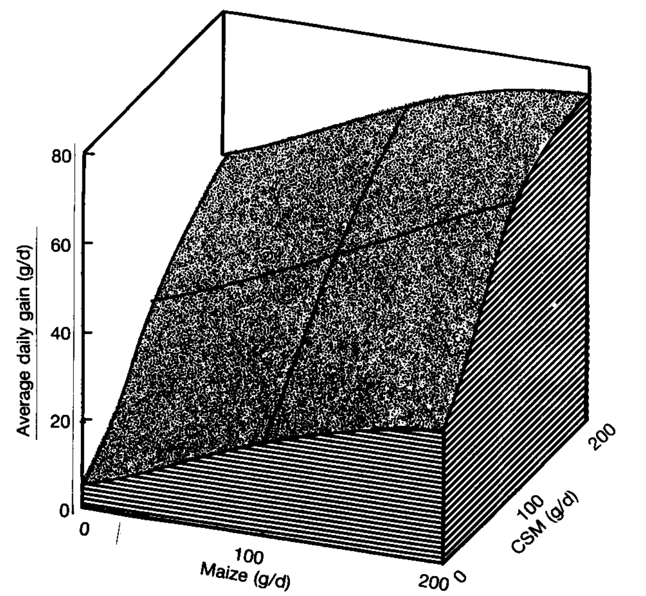

Figure 2 The effect of cottonseed oilcake meal (CSM) and maize, fed alone or in combination, on average daily live mass-gain of lambs fed a basal diet of wheat straw plus urea.

Results and Discussion

Voluntary intake

The main effects of supplementation with CSM and maize are shown in Table 1. Voluntary intake of wheat straw was increased by 19% by supplementation with 100 g/d CSM ($P < 0,01$), although any further increase resulting from additional supplementation (i.e. 200 g/d) was marginal ($P > 0,05$). On the other hand, maize supplementation had a significant inhibitory effect on voluntary intake of wheat

Table 2 Influence of cottonseed oilcake and maize supplements on the proportions of carcass constituents in lambs fed a basal diet of wheat straw plus urea (standard errors in parentheses). Index values are calculated relative to treatments receiving no supplement

	Dry matter		Crude protein		Fat		Ash	
	mean	index	mean	index	mean	index	mean	index
Cottonseed oilcake meal								
0 g/d	0,361^{a}	1,00	0,172^{a}	1,00	0,141^{a}	1,00	0,048^{a}	1,00
	(0,014)		(0,004)		(0,017)		(0,003)	
100 g/d	0,389^{b}	1,08	0,178^{a}	1,03	0,157^{a}	1,11	0,048^{a}	1,00
	(0,011)		(0,005)		(0,012)		(0,003)	
200 g/d	0,387^{b}	1,07	0,182^{a}	1,06	0,156^{a}	1,11	0,045^{a}	0,94
	(0,010)		(0,002)		(0,012)		(0,002)	
Significance	*		NS		NS		NS	
Maize								
0 g/d	0,339^{a}	1,00	0,185^{a}	1,00	0,099^{a}	1,00	0,053^{a}	1,00
	(0,011)		(0,002)		(0,012)		(0,003)	
100 g/d	0,374^{b}	1,10	0,178^{ab}	0,96	0,15^{b}	1,52	0,045^{b}	0,85
	(0,008)		(0,003)		(0,007)		(0,002)	
200 g/d	0,422^{c}	1,24	0,171^{c}	0,92	0,201^{c}	2,03	0,044^{b}	0,83
	(0,008)		(0,005)		(0,009)		(0,002)	
Significance	**		*		**		*	
Interaction between treatments	NS		NS		NS		NS	

$^{a-c}$ Means with different superscripts differ significantly (* $P < 0,05$; ** $P < 0,01$).
NS: non significant ($P > 0,05$).

straw, which was decreased by 20% when 200 g/d was fed ($P < 0{,}01$). There was no significant interaction between treatment effects ($P > 0{,}05$). Figure 1 shows the additive nature of the effects for all nine treatments.

Depression of intake by maize supplementation has been previously reported (Pieterse, Lesch, Oosthuizen & Le Roux, 1966; Nel & Van Niekerk, 1970; Swart, Nieman, Engels & Biel, 1971; Van Niekerk & Jacobs, 1985). This effect may be related to changes in rumen microbial populations (Gilchrist & Schwartz, 1972) or to metabolic factors (Gherardi & Black, 1989). Voluntary intake has been previously reported to be stimulated by supplementation with sources of bypass protein (Kemm, 1965; Swart *et al.*, 1971; Preston & Leng, 1987). This effect may be due to improvement of roughage fermentation by slow release of amino acids, sulphur, and energy in the rumen, or to the provision of amino acids and glucose at tissue level (Kellaway & Leibholz, 1983; Preston & Leng, 1987).

Growth rate

Live mass was increased over the experimental period by all treatments contrasted with the live mass of unsupplemented animals which remained virtually constant (Figure 2). Average daily gain (ADG) was increased by both CSM and maize supplementation ($P < 0{,}01$), and there was no significant interaction between the treatments (Table 1). The relative effect of CSM supplementation was almost double that of maize.

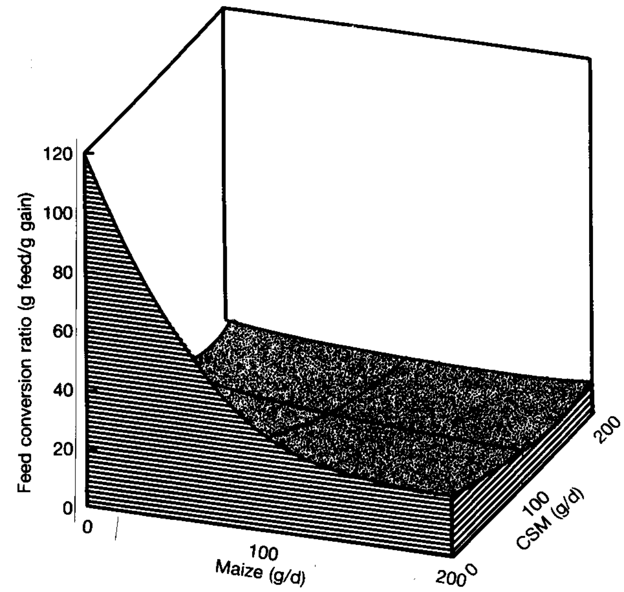

Figure 3 The effect of cottonseed oilcake meal (CSM) and maize, fed alone or in combination, on feed conversion ratio of lambs fed a basal diet of wheat straw plus urea.

Table 3 Influence of cottonseed oilcake and maize supplements on the proportional dry matter composition of internal organs (empty gut plus organs) in lambs fed a basal diet of wheat straw plus urea (standard errors in parentheses). Index values are calculated relative to treatments receiving no supplement

	Crude protein		Fat		Ash	
	mean	index	mean	index	mean	index
Cottonseed oilcake meal						
0 g/d	0,475[a] (0,044)	1,00	0,411[a] (0,045)	1,00	0,034[a] (0,004)	1,00
100 g/d	0,394[b] (0,030)	0,83	0,549[b] (0,035)	1,34	0,025[b] (0,003)	0,74
200 g/d	0,396[b] (0,025)	0,83	0,528[b] (0,027)	1,28	0,025[b] (0,002)	0,74
Significance	**		**		**	
Maize						
0 g/d	0,534[a] (0,027)	1,00	0,372[a] (0,032)	1,00	0,036[a] (0,003)	1,00
100 g/d	0,406[b] (0,024)	0,76	0,528[b] (0,028)	1,42	0,026[b] (0,002)	0,72
200 g/d	0,304[c] (0,018)	0,57	0,618[b] (0,025)	1,66	0,019[b] (0,002)	0,53
Significance	**		**		**	
Interaction between treatments	NS		NS		NS	

[a–c] Column means with different superscripts differ significantly (*$P < 0{,}05$; **$P < 0{,}01$).

NS: not significant ($P > 0{,}05$).

Feed conversion ratio

Feed conversion ratio was improved by supplementation with 100 g/d CSM or maize ($P < 0,01$), although no further improvement was evident when the level of either supplement was increased to 200 g/d. There was a significant interaction ($P < 0,01$) between treatment effects (Table 1). The interaction was evident as a significant improvement in feed conversion ratio by either supplement when fed in the absence of the other, but not when fed in the presence of each other (Figure 3). Both supplements improved feed conversion ratio, despite differences in feed intake effects, and ratios at equivalent supplementation levels (e.g. 100 g/d CSM vs 100 g/d maize) did not differ significantly ($P > 0,05$). This reflects the fact that the greater increment in growth rate due to CSM supplementation was accompanied by increased straw intake, while the smaller increase in growth rate due to maize supplementation was accompanied by a decreased straw intake.

Body composition

The mass of dry matter, protein, fat and ash in the carcass was significantly increased by both forms of supplementation ($P < 0,05$), and there was no interaction ($P > 0,05$) between treatment effects.

Carcass composition, expressed as a proportion of carcass mass, was significantly altered by maize supplementation, the most notable effect being a doubling of the proportion of fat ($P < 0,01$) (Table 2). The proportions of protein, fat and ash in the carcass were not influenced by CSM supplementation ($P > 0,05$), but the proportion of fat in viscera was increased by 28% (Table 3) at the expense of protein content, which was decreased ($P < 0,01$). Maize supplementation increased fat content of both fractions. These effects may reflect differences in the relative lipogenic capacity of different fat depots. Ingle, Bauman & Garrigus (1972a; 1972b) found that internal fat depots were more active in younger lambs, whereas subcutaneous depots were the most active in mature sheep.

The proportional contribution of the carcass to live mass was increased by both supplements while that of gut contents was reduced ($P < 0,01$). The effect of maize on the proportion of carcass mass was twice that of CSM (Table 4).

Wool production

Wool growth rate was increased by both CSM and maize supplementation ($P < 0,01$), and there was no significant interaction ($P > 0,05$) between treatments (Table 5).

Wool growth, when expressed relative to the mean of treatments containing no CSM, was increased by 89% and 226% when 100 or 200 g/d CSM, respectively, were fed. The corresponding increases due to supplementation with 100 or 200 g/d maize were 46% and 96% respectively. The effects of combinations of the two supplements are shown in Figure 4.

Table 4 Influence of cottonseed oilcake and maize supplements on the proportional contribution of different body components to live mass in lambs fed a basal diet of wheat straw plus urea (standard errors in parentheses). Index values are calculated relative to treatments receiving no supplement

	Carcass		Fleece, skin, shanks, head		Viscera		Gut content	
	mean	index	mean	index	mean	index	mean	index
Cottonseed oilcake meal								
0 g/d	0,303^{a} (0,008)	1,00	0,224^{a} (0,006)	1,00	0,110^{a} (0,002)	1,00	0,362^{a} (0,012)	1,00
100 g/d	0,317^{ab} (0,008)	1,05	0,224^{a} (0,005)	1,00	0,109^{a} (0,002)	0,99	0,350^{a} (0,011)	0,97
200 g/d	0,330^{b} (0,007)	1,09	0,251^{b} (0,006)	1,12	0,108^{a} (0,002)	0,98	0,312^{b} (0,010)	0,86
Significance	**		**		NS		**	
Maize								
0 g/d	0,289^{a} (0,005)	1,00	0,225^{a} (0,008)	1,00	0,105^{a} (0,002)	1,00	0,380^{a} (0,010)	1,00
100 g/d	0,315^{b} (0,007)	1,09	0,232^{ab} (0,004)	1,03	0,107^{a} (0,001)	1,02	0,347^{b} (0,008)	0,91
200 g/d	0,344^{c} (0,006)	1,19	0,242^{b} (0,007)	1,08	0,115^{b} (0,002)	1,10	0,299^{c} (0,008)	0,79
Significance	**		NS		**		**	
Interaction between treatments	NS		NS		NS		NS	

$^{a-c}$ Means with different superscripts differ significantly (* $P < 0,05$; ** $P < 0,01$).
NS: not significant ($P > 0,05$).

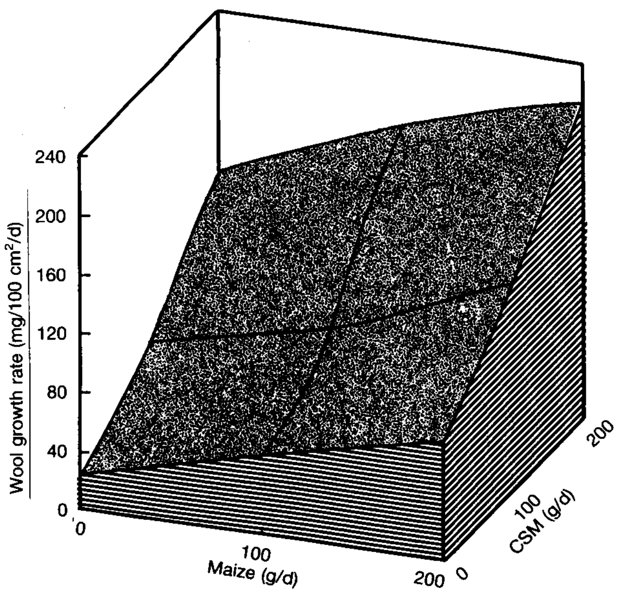

Figure 4 The effect of cottonseed oilcake meal (CSM) and maize, fed alone or in combination, on wool growth rate of lambs fed a basal diet of wheat straw plus urea.

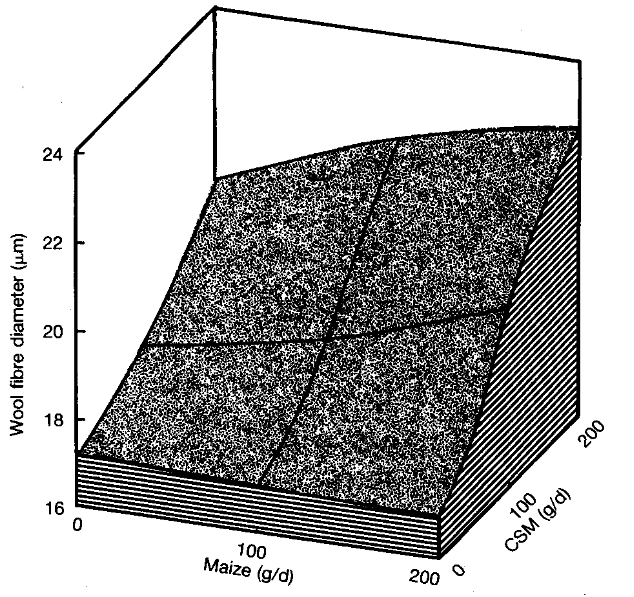

Figure 5 The effect of cottonseed oilcake meal (CSM) and maize, fed alone or in combination, on wool fibre diameter of lambs fed a basal diet of wheat straw plus urea.

Fibre diameter was increased ($P < 0,01$) by both CSM and maize supplementation (Table 5). The effect of 200 g/d maize was far less (6%) than that of 200 g/d CSM (26%). There was no significant interaction between the effects of CSM and maize ($P > 0,05$). Individual treatment effects are shown in Figure 5.

Staple length was increased ($P < 0,01$) by supplementation with CSM and maize (Table 5). The effect of CSM was

Table 5 Influence of cottonseed oilcake and maize supplements on wool growth of lambs fed a basal diet of wheat straw plus urea (standard errors of the mean in parentheses). Index values are calculated relative to treatments receiving no supplement

	Wool growth rate (mg/100 cm²/d)		Fibre diameter (µm)		Staple length (mm)	
	mean	index	mean	index	mean	index
Cottonseed oilcake meal						
0 g/d	53^{a} (6)	1,00	$17,0^{a}$ (0,17)	1,00	$23,6^{a}$ (1,2)	1,00
100 g/d	100^{b} (9)	1,89	$18,9^{b}$ (0,36)	1,11	$28,4^{b}$ (0,77)	1,20
200 g/d	173^{c} (9)	3,26	$21,4^{c}$ (0,36)	1,26	$35,2^{c}$ (1,0)	1,49
Significance	**		**		**	
Maize						
0 g/d	74^{a} (11)	1,00	$18,6^{a}$ (0,46)	1,00	$26,3^{a}$ (1,5)	1,00
100 g/d	108^{b} (13)	1,46	$19,1^{ab}$ (0,53)	1,03	$29,9^{b}$ (1,5)	1,14
200 g/d	145^{c} (14)	1,96	$19,7^{b}$ (0,58)	1,06	$31,1^{b}$ (1,3)	1,18
Significance	**		**		**	
Interaction between treatments	NS		NS		NS	

$^{a-c}$ Column means with different superscripts differ significantly (** $P < 0,01$).
NS: not significant ($P > 0,05$).

more pronounced, as in the case of fibre diameter. There was no significant interaction between treatment effects.

Acetate clearance rate

Acetate clearance rate (/d) was found to be 0,035, 0,036 and 0,043 for 0, 100 and 200 g/d CSM ($P > 0{,}05$) and 0,037, 0,038 and 0,039 for 0, 100 and 200 g/d maize ($P > 0{,}05$) respectively. Cronjé (1987) showed that acetate clearance rate of lambs fed a roughage diet increased as glucose entry rate was increased by supplementation with propionate or protein. He proposed that this measurement could possibly be used to evaluate the adequacy of supplementary feeding strategies under field conditions. In this experiment, acetate clearance rate was not significantly affected by maize or CSM. The failure to demonstrate significant treatment differences may be due to the high coefficient of variation (mean for all treatment groups = 35%) associated with the once daily feeding regime used, contrasted with that reported by Cronjé (1987) when supplements were fed using continuous feeders (mean for treatment groups = 28%). Fluctuations in blood metabolite and hormone concentrations after feeding may also have played a role, as measurements were conducted approximately 1 h after the supplements had been consumed. Further research is required in this regard.

Conclusions

Abomasal infusions of purified nutrients have provided much information on nutrient partitioning. However, this approach does not accommodate the effects of supplements on rumen fermentation and feed intake, which are likely to occur in practical situations. The results reported here suggest that the optimum type and level of supplementation is determined by a complex and variable interaction between metabolic priorities for various body functions and also between intake effects. In this experiment, supplementation with CSM increased average daily gain and wool growth rate to a far greater extent than maize. The relatively greater increase in wool growth rate with CSM was, however, accompanied by a correspondingly greater increase in wool fibre diameter. On the other hand, maize decreased roughage intake considerably, while CSM stimulated intake. In practical terms, the optimum supplement for the SA Mutton Merino would probably be represented by a combination of the two sources. In such a case the greater mass gain and wool growth rate achieved with CSM is balanced against the smaller increase in wool fibre diameter afforded with maize supplementation, while ensuring that intake is not depressed. Although the effects of CSM and maize on intake, live mass-gain, and carcass composition may be predicted using additive procedures, the existence of a treatment interaction for feed conversion ratio indicates that responses to protein supplementation will depend on the level of energy absorbed. The ratio of protein:energy may have induced changes in the partitioning of nutrients between different productive functions in accordance with metabolic priorities. These priorities will differ according to the genetic abilities of the animal (McC. Graham & Searle, 1982). Responses to these supplements could therefore be expected to differ between breeds. Further experimentation of this nature would greatly facilitate selection of animals which are more adapted to the nutritive limitations of their environment, and so enable the costs of supplementary feeding to be reduced to a minimum.

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References

AOAC, 1984. Official methods of analysis (14th edn.). Association of Official Analytical Chemists, Inc. Arlington, Virginia.

BLACK, J.L., ROBARDS, G.E. & THOMAS, R., 1973. Effects of protein and energy intakes on the wool growth of Merino wethers. *Aust. J. Agric. Res.* 24, 399.

COETZEE, C.G., 1964. Invloed van oorwinteringspeil op produksie van Döhnemerinoskape. 1. Wolproduksie van droë ooie. *S. Afr. J. Anim. Sci.* 7, 193.

COETZEE, C.G., 1969. Proteïenaanvullings op hoë en lae voedingspeile. *Proc. S. Afr. Soc. Anim. Prod.* 8, 43.

COETZEE, C.G., NEL, J.W. & JOUBERT, D.M., 1968a. Akspekte van oorwintering van nie-dragtige wolskape op grasveld. 2. Verhouding tussen wolgroeitempo en liggaamsgewig op grasveld aangevul met voerkorrels. *S. Afr. J. Agric. Sci.* 11, 697.

COETZEE, C.G., NEL, J.W. & JOUBERT, D.M., 1968b. Aspekte van oorwintering van nie-dragtige wolskape op grasveld. 1. Verhouding tussen wolgroeitempo, liggaamsgewig en voerinname op 'n rantsoen van konstante samestelling. *S. Afr. J. Agric. Sci.* 11, 503.

CRONJÉ, P.B., 1987. Acetate clearance rate and the metabolism of glucose, acetate and amino acids in lambs fed roughage diets. Ph.D. thesis, University of New England, Armidale, Australia.

DU PLESSIS, J.J. & DE WET, P.J., 1981. Nitrogen utilization by sheep. 1 Nitrogen utilization by weaned lambs of a wool, a wool/mutton and a mutton/wool breed for wool and body protein formation. *Agroanimalia* 13, 21.

GILCHRIST, F.M.C. & SCHWARTZ, H.M., 1972. Microbiology of the rumen in relation to the nutrition and physiology of the animal. *S. Afr. J. Anim. Sci.* 2, 161.

GHERARDI, S.G. & BLACK, J.L., 1989. Influence of post-rumen supply of nutrients on rumen digesta load and voluntary intake of a roughage by sheep. *Br. J. Nutr.* 62, 589.

HOFMEYR, H.S., 1972. Kwantifisering van faktore wat die brutodoeltreffendheid van energie-omsetting van voer by skape beïnvloed. D.Sc. thesis, University of Pretoria.

INGLE, D.L., BAUMAN, D.E. & GARRIGUS, U.S., 1972a. Lipogenesis in the ruminant: *in vitro* study of tissue sites, carbon source and reducing equivalent generation for fatty acid synthesis. *J. Nutr.* 102, 609.

INGLE, D.L., BAUMAN, D.E. & GARRIGUS, U.S., 1972b. Lipogenesis in the ruminant: *in vivo* site of fatty acid synthesis in sheep. *J. Nutr.* 102, 617.

JACOBSZ, J.Z.H., CRONJÉ, P.J., BAARD, M.A. & VAN SCHALKWYK, A., 1971. Byvoeding van twee tipes Merinoskape op *Cymbopogon–Themeda* veld gedurende die winter. 1. Invloed op wolproduksie. *S. Afr. J. Anim. Sci.* 1, 27.

JACOBSZ, J.Z.H., CRONJÉ, P.J., BAARD, M.A. & SKEA, E.C., 1971. Byvoeding van twee tipes Merinoskape op *Cymbopogon–Themeda* veld gedurende die winter. 2. Invloed op liggaamsgewig en karkaseienskappe. *S. Afr. J. Anim. Sci.* 1, 33.

KELLAWAY, R.C. & LEIBHOLZ, J., 1983. Effects of nitrogen supplements on intake and utilization of low-quality forages. *Wld. Anim. Rev.* 48, 33.

KEMM, E.H., 1965. Fishmeal as protein supplement to low-quality *Eragrostis curvula* hay for maintenance of Dorper wethers. *Proc. S. Afr. Soc. Anim. Prod.* 4, 104.

KEMPTON, T.J., HILL, M.K. & LENG, R.A., 1978. The effects of varying bypass amino acid and glucose availablity on lamb growth and wool growth. *Proc. Aust. Soc. Anim. Prod.* 12, 142.

KEMPTON, T.J., 1979. Protein to energy ratio of absorbed nutrients in relation to wool growth. In: Physiological and environmental limitations to wool growth. Eds. Black, J.L. & Reis, P.J. University of New England Publishing unit, Armidale, Australia. p. 209.

McC. GRAHAM, N. & SEARLE, T.W., 1982. Energy and nitrogen utilization for body growth in young sheep from two breeds with differing capacities for wool growth. *Aust. J. Agric. Res.* 33, 607.

NEL, J. & VAN NIEKERK, B.D.H., 1970. The value of protein and energy-rich supplements in the maintenance of Merino sheep grazing sour grassveld. *Proc. S. Afr. Soc. Anim. Prod.* 9, 155.

PIETERSE, P.J.S., LESCH, S.F., OOSTHUIZEN, F.J. & LE ROUX, D.P., 1966. The effect of various supplementary levels of urea and maize on nitrogen utilization by sheep fed poor quality roughage. *S. Afr. J. Agric. Sci.* 9, 87.

PRESTON, T.R. & LENG, R.A., 1987. Matching ruminant production systems with available feed resources in the tropics and subtropics. Penambul Books, Armidale, Australia.

SWART, J.A., NIEMAN, P.J., ENGELS, E.A.N. & BIEL, L.C., 1971. The influence of fishmeal and yellow maize on the nutritive value of *Themeda triandra* for Merino sheep. *S. Afr. J. Anim. Sci.* 1, 25.

VAN NIEKERK, B.D.H. & JACOBS, G.A., 1985. Protein, energy and phosphorus supplementation of cattle fed low-quality forage. *S. Afr. J. Anim. Sci.* 15, 133.

WILLIAMS, A.J., ROBARDS, G.E. & SAVILLE, D.G., 1972. Metabolism of cystine by Merino sheep genetically different in wool production. *Aust. J. Biol. Sci.* 25, 1269.