Chapter 8

8. Growth Rate and Wool Production in Xinjiang Merino Sheep Supplemented with Different Levels of Cottonseed Meal

8.1 Introduction

The results from the previous study showed that CSM and SFM supplementation both increased clean wool production to a similar extent (1.7 vs 2.1 and 2.2 g/100 cm^2), although only the effect of SFM supplementation was statistically significant (Table 7.4). However, supplementation of sheep for wool production is unlikely to be profitable in Xinjiang Province due to low prices of wool (CASRP 1996).

The results of live-weight gain in sheep from the previous study showed that only CSM supplementation significantly increased N retention (0.8 vs 5.1 g/d, Table 7.5) and promoted live-weight gain by 349% (13 vs 59 g/d, Table 7.4). Furthermore, as shown in Table 7.8, the feed conversion efficiency (live-weight gain/total DM intake) in sheep supplemented with CSM was significantly higher than that in the control animals. Therefore, CSM supplementation appeared to be a better option than SFM for profitable production in Xinjiang Merino sheep under feeding conditions similar to those in the previous study.

Supplementation of ruminants fed low quality forages with CSM may increase forage intake (McCollum and Galyean 1985; Bird *et al.* 1993; Hennessy *et al.* 1995). This is largely related to an increased rumen volume and dilution rate of rumen digesta (Krysl *et al.* 1987; Bird *et al.* 1993), improved dietary fibre digestion (Sudana and Leng 1986; Caton *et al.* 1988; Gaskins *et al.* 1990; Bird *et al.* 1993) and an improved balance of nutrients absorbed (Preston and Leng 1987). As a result, supplementation of ruminants with CSM usually increases the N retention and intake of minerals and other nutrients, consequently improves growth rate, milk yield, wool production and reproductive performance (Preston and Leng 1987).

Furthermore, the response in growth rate of cattle fed forages is curvilinearly rather than linearly related to supplemental CSM intake (Leng 1995; McLennan *et al.* 1995). This relationship indicates that live-weight gain approaches a plateau when CSM intake exceeds a certain level.

In order to examine production variations in Xinjiang Merino sheep with CSM supplementation, this experiment was therefore designed to measure the response in growth rate and wool production to different levels of CSM supplementation. In addition, the effectiveness of CSM supplementation on sheep production was assessed by comparing with a concentrate-based diet.

8.2 Materials and methods

8.2.1 Animals, treatments and management

Twenty-four ewe weaners used in the previous experiment were also used in this experiment. They were around 14 months old with an average liveweight of 27.8 (s.d. 2.2) kg.

Owing to the limited availability of metabolism pens, the experiment was carried out in two periods. According to liveweight of the animals, the heaviest 12 animals were used in the first period, and the lightest 12 were retained for the second period.

At the beginning of the first period, the heaviest 12 sheep with an initial liveweight of 28.9 (s.d. 1.8) kg were drenched as described in the previous experiment, and moved into individual metabolism pens maintained in the same naturally lit animal house with temperature ranging from 15 to 25°C. They were then stratified into two groups by liveweight and animals within each group were allocated randomly to the following six treatments:

Treatment 1 (C): No supplement
Treatment 2 (80): 80 g CSM/h.d
Treatment 3 (160): 160 g CSM/h.d
Treatment 4 (240): 240 g CSM/h.d
Treatment 5 (320): 320 g CSM/h.d
Treatment 6 (CONC): 1,000 g concentrate/h.d

The concentrate was formulated by using the GrazFeed program (version 2.06b, 1989, CSIRO, Australia) and was offered to increase the total energy and protein intakes to the recommended requirements of house-fed 30 kg sheep with a growth rate of 200 g/d. The concentrate was composed of 72% maize grain, 16% CSM and 12% SFM. It contained 89.8% of DM and 15.5% of CP.

The experimental period included a one-week introductory part and a five-week trial part. At 10:00 h every day, the daily allocation of CSM, and half of the daily allocation of concentrate were given to the sheep. Then 300 g of chopped pasture hay mixed with 10 g mineral mix and 20 ml water containing 10 g urea was offered to each sheep. The other half of the daily allocation of concentrate was given at 18:00 h, and chopped pasture hay was offered *ad libitum* to each sheep.

The amount of hay offered each day was adjusted to 110% of the previous day's consumption to ensure *ad libitum* intake. Water was available all the time.

During the first period, the lightest 12 sheep were kept in a group pen and fed chopped pasture hay with a daily supply of 10 g mineral mix to each animal. During the second period, the experimental procedure above was repeated in these 12 sheep which then had an initial liveweight of 28.5 (s.d. 1.5) kg. There was thus a total of four animals in each treatment which started the experiment with approximately the same liveweight.

8.2.2 Measurements

The feed composition, feed intake, live-weight gain, apparent digestibility of DM and N, plasma urea-N concentration, N balance and microbial N supply were monitored as described in the previous experiment. Wool grown in mid-side patches during the experimental period was harvested for clean wool and fibre diameter measurements as described in the previous experiment.

8.2.3 Statistical analysis

All measurements were subjected to analysis of variance for a completely random experimental design using the Minitab program (version 9.1, 1992, Minitab Inc., USA). An analysis of covariance was made for live-weight gain, clean wool weight and fibre diameter by using the same covariates measured under the pre-experimental regime of the previous experiment. Multiple comparisons were conducted by the least significant difference (LSD) test according to Steel and Torrie (1980). Orthogonal contrasts, (1) control vs CSM; (2) CSM vs the concentrate, were further carried out.

8.3 Results

The results for live-weight gain, clean wool weight and fibre diameter are present as the least square means obtained from the analysis of covariance. The results of comparisons among the treatments of the control, and CSM and concentrate feeding from the orthogonal contrasts are also reported.

8.3.1 Feed analysis

The composition of feeds is shown in Table 8.1. *In vitro* dry matter digestibility (IVDMD) and protein degradability (dg) of feeds are shown in Table 8.2.

Table 8.1. *The content of gross energy (GE), dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and crude ash (Ash) of feeds.*

	GE	DM	g/kg DM			
	(MJ/kg)	(g/kg)	CP	CF	EE	Ash
Pasture hay	16.3	926	106	367	16	100
Maize grain	16.6	902	90	20	39	12
Cottonseed meal	17.0	903	450	109	6	70
Sunflower meal	19.4	900	269	256	93	75
Concentrate	17.6	898	175	63	40	26

Table 8.2. *In vitro DM digestibility (IVDMD, %) and protein degradability (dg, %) of feeds.*

	IVDMD	dg*
Pasture hay	45.6	66.8
Maize grain	ND	43.2
Cottonseed meal	ND	55.6
Sunflower meal	ND	68.4
Concentrate	ND	50.2

ND: Not determined.

*: Net disappearance of protein from sample when placed in the rumen of sheep for 24 h.

8.3.2 Feed intake

Hay DM intake was depressed ($P<0.05$), but total DM intake was increased ($P<0.05$) by CSM supplementation. Compared with sheep given CSM, sheep receiving the concentrate had a lower ($P<0.05$) hay DM intake but a higher ($P<0.05$) total DM intake (Table 8.3).

8.3.3 Live-weight gain

Live-weight gain in sheep was increased by CSM feeding ($P<0.05$). Sheep receiving the concentrate grew considerably faster than those given CSM ($P<0.05$) (Table 8.3).

8.3.4 Wool production

Clean wool production was increased (P<0.05) but fibre diameter was not affected (P>0.05) by CSM feeding. Clean wool growth was higher in sheep offered the concentrate than in those supplemented with CSM (P<0.05) (Table 8.3), but fibre diameter was similar between the two groups of sheep (P>0.05) (Table 8.3).

Table 8.3. *Hay and total dry matter intake (DMI, g kg $W^{0.75}$.d) by sheep and average daily gain (ADG, g d), clean wool weight (CWW, g/100 cm^2) and fibre diameter (FD, μm) of wool grown by sheep given no supplement (C), or 80, 160, 240, 320 g CSM/d, or 1,000 g concentrate/d (CONC) (mean ± se).*

	Treatment						Contrast‡	
	C	80	160	240	320	CONC	1	2
DMI								
Hay	67.0^{a}±2.5	65.0^{ab}±1.2	64.3^{ab}±1.3	61.2^{bc}±0.9	58.5^{c}±1.3	35.2^{d}±2.3	*	**
Total	67.0^{a}±2.5	70.5^{ab}±1.2	75.2^{b}±1.1	77.2^{b}±0.8	79.7^{b}±1.3	95.8^{c}±2.3	**	**
ADG	-4.2^{a}±15.0	25.5^{ab}±15.8	69.8^{bc}±7.7	90.9^{c}±20.2	106.1^{c}±32.3	201.7^{d}±21.4	**	**
CWW	3.2^{a}±0.3	4.4^{ab}±0.7	4.8^{b}±0.3	5.5^{b}±0.5	5.3^{b}±0.2	6.7^{c}±0.6	**	**
FD	19.7^{a}±1.0	20.1^{a}±1.0	20.9^{ab}±0.6	22.6^{b}±0.6	21.2^{ab}±1.1	22.5^{b}±0.6	NS	NS

‡: Orthogonal contrasts: 1 = C vs (80+160+240+320); 2 = (80+160+240+320) vs CONC.

$^{a, b, c, d}$: Means bearing different superscripts in the same row within treatment differ (P<0.05).

NS: Non-significant.

8.3.5 Apparent digestibility of DM and N

The apparent digestibility of DM (DMD) and N (ND) was increased by CSM feeding (P<0.05). The sheep given the concentrate had a higher DMD than those given CSM (P<0.05), but the difference in ND between sheep fed the concentrate and CSM was not significant (P>0.05) (Table 8.4).

8.3.6 Plasma urea-N concentration

CSM-supplemented sheep had a higher PUN concentration than the control animals (P<0.05). PUN was lower in sheep offered the concentrate than in those offered CSM (P<0.05) (Table 8.4).

8.3.7 Nitrogen balance

As shown in Table 8.4, CSM supplementation increased (P<0.05) total N intake, faecal N excretion and N retention by sheep. Sheep given the concentrate had higher N intake and N retention but lower urinary N excretion than those given CSM (P<0.05).

Table 8.4. *Apparent digestibility of dry matter (DMD, %) and nitrogen (ND, %), plasma urea-nitrogen (PUN, mg/100 ml) concentrations, nitrogen intake (NI, g/d), output of faecal nitrogen (FN, g/d) and urinary nitrogen (UN, g/d)), and nitrogen retention (NR, g/d) by sheep given no supplement (C), or 80, 160, 240, 320 g CSM/d, or 1,000 g concentrate/d (CONC) (mean ± se).*

	Treatment						Contrast‡	
	C	80	160	240	320	CONC	1	2
DMD	47.0^{a}±2.0	52.2^{bc}±1.6	49.9^{ab}±0.8	53.3^{bc}±0.4	54.2^{c}±1.7	65.7^{d}±0.7	**	**
ND	56.5^{a}±2.8	66.1^{b}±3.3	66.3^{b}±4.7	73.8^{bc}±1.0	79.2^{c}±3.3	75.6^{c}±3.2	**	NS
PUN	19.0^{ab}±1.7	18.3^{ab}±1.5	20.4^{ab}±1.4	22.2^{b}±1.7	29.6^{c}±1.3	17.4^{a}±1.4	*	**
NI	14.7^{a}±0.6	24.3^{b}±0.4	29.7^{c}±0.7	34.6^{d}±0.4	39.3^{e}±0.4	38.4^{e}±0.6	**	**
FN	6.4^{a}±0.7	8.2^{ab}±0.6	9.9^{b}±1.2	9.1^{ab}±1.2	8.1^{ab}±1.2	9.4^{b}±1.3	*	NS
UN	9.4^{abc}±0.2	8.3^{ab}±0.5	9.8^{abc}±1.5	12.3^{bc}±1.8	13.0^{c}±2.9	6.8^{a}±0.4	NS	*
NR	-1.2^{a}±0.2	7.8^{b}±1.5	10.0^{bc}±2.2	13.2^{c}±1.6	18.2^{d}±2.0	22.2^{d}±1.5	**	**

‡: Orthogonal contrasts: 1 = C vs (80+160+240+320); 2 = (80+160+240+320) vs CONC.

$^{a, b, c, d}$: Means bearing different superscripts in the same row within treatment differ (P<0.05).

NS: Non-significant.

8.3.8 Microbial protein yield

Feeding CSM to sheep increased (P<0.05) the total urinary excretion of allantoin and microbial protein production. Furthermore, the total urinary allantoin excretion and estimated microbial N production were higher (P<0.05) in sheep offered the concentrate than in those offered CSM (Table 8.5).

Table 8.5. *Excretion of urinary allantoin (UA, mmol/d) and net microbial nitrogen flow out of the rumen (MN, g N/d) predicted from excretion of UA by sheep given no supplement (C), or 80, 160, 240, 320 g CSM/d, or 1,000 g concentrate/d (CONC) (mean ± se).*

	Treatment						Contrast‡	
	C	80	160	240	320	CONC	1	2
UA	2.7^{a}±0.2	4.5^{b}±0.4	4.9^{b}±0.3	5.0^{b}±0.8	5.1^{b}±0.5	13.4^{c}±0.7	*	**
MN	1.3^{a}±0.8	3.3^{b}±0.4	3.7^{b}±0.3	3.8^{b}±0.9	3.9^{b}±0.4	11.5^{c}±0.7	**	**

‡: Orthogonal contrasts: 1 = C vs (80+160+240+320); 2 = (80+160+240+320) vs CONC.

$^{a, b, c}$: Means bearing different superscripts in the same row within treatment differ ($P<0.05$).

8.4 Discussion

8.4.1 Hay intake and digestibility

Hay DM intake was depressed ($P<0.05$) by both CSM and concentrate supplementation in this study. The substitution rates were 204, 23, 110 and 187 g hay per kg of CSM when CSM was supplemented at 6.5, 13.0, 19.5 and 26.0 g/kg $W^{0.75}$.d, respectively. The concentrate feeding had the highest substitution rate of 369 g hay per kg of concentrate when fed at 80.6 g/kg $W^{0.75}$.d.

The stimulative effect of CSM supplementation on forage intake is detailed by Preston and Leng (1987). Provision of protein supplements low in rumen degradability to sheep fed low N, high fibre forages usually increases forage intake by sheep (Sudana and Leng 1986; Krysl *et al.* 1987; Bird *et al.* 1993; Osuji *et al.* 1993). For example, Bird *et al.* (1993) reported that intake of 4.8% CP grass hay by wethers was increased by 34% when CSM was given as a supplement supplying 2.5 g CP/kg $W^{0.75}$.d. Likewise, the studies of McCollum and Galyean (1985) and Hennessy *et al.* (1995) showed that CSM supplementation stimulated intake of low protein forages by cattle.

However, CSM supplementation is not always effective in stimulating forage intake. Caton *et al.* (1988) reported that a supplemental CP supply of 5.4 g/kg $W^{0.75}$.d from CSM had no effect on intake of 5.8% CP forage by lambs, which was possibly related to a relatively high level of CSM feeding. Gaskins *et al.* (1990) noted that intake of grass-alfalfa hay with a 6% CP content by sheep and goats was unaffected by CSM or alfalfa supplementation. Nunez-Hernandez *et al.* (1991) observed that OM intake of blue grama hay with a CP content of 3.4% DM by sheep remained unchanged when sheep received 2.9 g CP/kg $W^{0.75}$.d from CSM. Similar results were also obtained in some studies with cattle given CSM (Judkins *et al.* 1987; Judkins *et al.* 1991) or CSM-based supplements (Freeman *et al.* 1992). The lack of a stimulative effect on intake of low

quality forages in response to CSM supplementation is possibly related to intake and gossypol content of CSM, or some limiting nutrients other than protein.

CSM supplementation may increase apparent digestibility of DM, ADF and NDF in sheep fed roughages. Caton *et al.* (1988) reported that the apparent digestibility of NDF and DM in lambs fed a mixture of hay and oat straw was increased by a supply of 5.4 g CP/kg $W^{0.75}$.d from CSM. The results of Bird *et al.* (1993) showed that a supply of 2.5 g CP/kg $W^{0.75}$.d from CSM increased the apparent digestibility of ADF and DM in wethers fed 4.8% CP grass hay. In the current study, the apparent digestibility of DM was improved in sheep given CSM supplementing an average amount of 7.7 g CP/kg $W^{0.75}$.d. The increased DM digestibility in those sheep therefore probably resulted from both ingestion of more digestible supplement and improved fibre digestion.

8.4.2 Animal performance

8.4.2.1 Live-weight gain

In this study, although average daily gain in sheep was increased by CSM supplementation, it did not seem to be linearly related to the level of CSM supplementation. Additional average daily gains in sheep compared with the control animals were 30, 74, 95 and 110 g/d when CSM was supplemented at 80, 160, 240 and 320 g/d, respectively. These results showed that there was a curvilinear relationship between average daily gain and CSM intake (Figure 8.1). It was also noted that, although growth rate of sheep was increased with an increase in the duodenal protein supply, it did not seem to be linearly related to CSM intake (Figure 8.1). On the other hand, Osuji *et al.* (1995) reported that live-weight gain in dairy cows fed 2.8% CP straw was linearly related to CSM intake. McLennan *et al.* (1995) suggested that an exponential relationship existed between live-weight gain and intake of CSM by cattle fed on low quality forages and silages, i.e., that the incremental increase in the rate of live-weight gain diminished with increasing CSM intake, and live-weight gain remained constant when intake of CSM exceeded a certain level. Furthermore, an exponential relationship between live-weight gain and CSM intake was developed by Leng (1995) from several sets of published data from studies on cattle, i.e., live-weight gain (kg/d) = 0.069 + 0.679 (1 - $e^{-1.12q}$), where q was CSM intake (kg/d).

The increased growth rate of CSM-supplemented sheep in this study probably resulted from the increase in duodenal protein supply and ME intake, as shown in Table 8.6 and figure 8.1, and possibly an increase in mineral intake. von Keyserlingk and Mathison (1993) concluded that improved live-weight gain in animals with unchanged forage intake after protein supplementation mainly resulted from either the increased proportion of energy retained as protein or the increased digestibility of the diet. Bird *et al.* (1993) supplemented wethers fed grass hay with

CSM supplying 2.5 g CP/kg $W^{0.75}$.d, and noted an increase in live-weight gain due to the increased VFA production and post-ruminal supply of dietary nutrients. Ruminal VFA production may be altered by CSM supplementation. The studies of McCollum and Galyean (1985) and Judkins *et al.* (1987) showed that CSM supplementation shifted VFA production slightly towards propionate without affecting total VFA concentration. The relative increase in glucogenic VFA and increase in potential for gluconeogenesis may have contributed to a more efficient use of energy for tissue growth. In contrast, Freeman *et al.* (1992) summarised the results from their own study and several others, and concluded that when CSM-based supplements were offered to steers, they increased total VFA production with little effect on the molar proportion of VFA.

The effect of protein supplementation on growth rate of sheep may involve the role of altered secretion of hormones, such as growth hormone, insulin and glucagon. For example, Krysl *et al.* (1987) reported that CSM supplementation increased serum concentrations of insulin but decreased serum growth hormone in sheep. Hennessy *et al.* (1995) noted that urea plus protein supplementation increased plasma concentrations of insulin and growth hormone in some specific genotypes of steers. An increase in insulin release may enhance the uptake of amino acids and glucose by peripheral tissues (Amos and Evans 1980).

Table 8.6. *Calculated values for rumen-degraded protein (RDP, g/d), metabolisable energy intake (MEI, MJ/d), the ratio of RDP to MEI (RDP/MEI, g/MJ), efficiency of utilisation of RDP for microbial protein synthesis (MCP/RDP) and total duodenal protein flow (DPF, g/d) from sheep given no supplement (C), or 80, 160, 240, 320 g CSM/d, or 1,000 g concentrate/d (CONC).*

	Treatment					
	C	80	160	240	320	CONC
RDP	92.9	110.1	129.5	146.3	162.4	149.7
MEI*	5.2	6.3	6.5	7.5	7.9	13.0
RDP/MEI	18.0	17.4	19.9	19.6	20.4	11.5
MCP/RDP	0.16	0.19	0.18	0.16	0.15	0.48
DPF‡	14.0	62.5	79.9	93.1	107.6	162.2

*: Predicted from apparent DM digestibility of diets (SCA 1990).

‡: = total CP intake - RDP + microbial protein production (predicted from urinary excretion of allantoin).

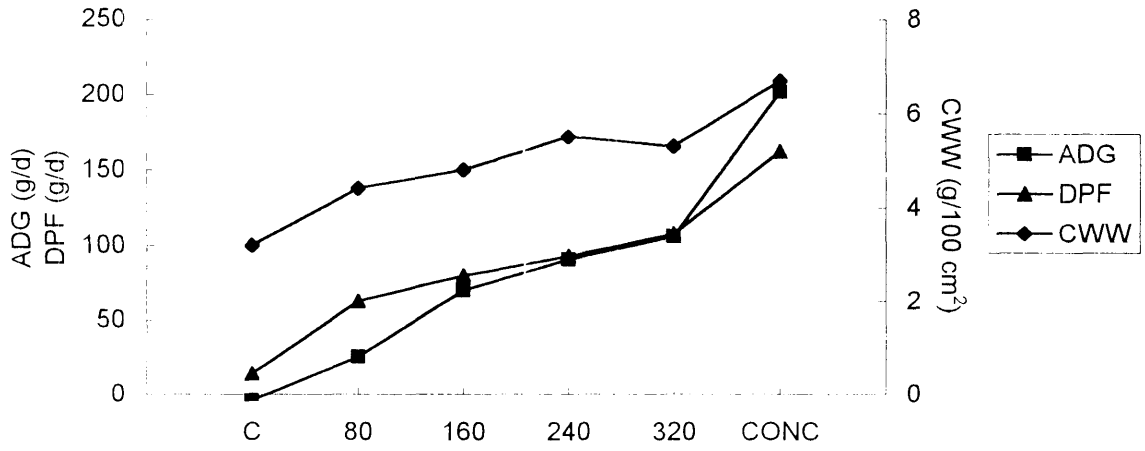

Figure 8.1. *Average daily gain (ADG, g/d), clean wool weight (CWW, g/100 cm^2) and duodenal protein flow (DPF, g/d) from sheep given no supplement (C), or 80, 160, 240, 320 g CSM/d, or 1,000 g concentrate d (CONC).*

8.4.2.2 Clean wool production

Clean wool production was increased by either CSM or concentrate feeding. The increased wool production was associated with the increased availability of duodenal protein as shown in Table 8.6 and figure 8.1. Wool growth is positively correlated with the amount of amino acids absorbed from the small intestine (Reis 1979; Reis and Sahlu 1994). Kempton (1979) reported that wool growth rate increased with the increasing supply of digestible protein to the duodenum of sheep by either post-ruminal infusions of protein or feeding bypass protein. However, in the present study, although clean wool production in sheep receiving CSM was increased with the increasing availability of duodenal protein, it was not linearly related to CSM intake (Table 8.6 and Figure 8.1). In addition, the highest level of wool production in sheep given the concentrate was associated with the highest intestinal supply of protein.

As shown in Table 8.3, CSM or concentrate supplementation increased clean wool production, and tended to increase fibre diameter but the effect was not statistically significant. Reis and Sahlu (1994) concluded that 70-80% of the increased wool production in Merino sheep was attributed to an increase in fibre diameter, whereas only 20-30% was attributed to an increase in length growth rate of wool fibres. These authors also pointed out that the length growth rate (L) and diameter (D) of wool fibres produced by Merino sheep were increased simultaneously when wool growth rate was increased by nutritional manipulations, and the ratio of L/D remained nearly constant over a wide range of wool output. As a result, an increase in wool production in response to any nutritional manipulations was always accompanied by an increase in fibre diameter. The latter reduced the quality and value of a given weight of wool.

8.4.3 Plasma urea-N concentration

In this study, sheep receiving the maize-based concentrate had a lower PUN level than those given CSM. Since the solubility of maize protein is lower than that of CSM protein (NRC 1985), the inclusion of maize in ruminant diets usually reduces rumen degradability of dietary protein. For example, Oke *et al.* (1991) demonstrated that when energy and N intakes of sheep fed concentrates were similar, increasing maize grain content of the concentrates from 50 to 75% reduced degradability of dietary N in the rumen from 18 to 12%, and consequently decreased PUN concentrations. Freeman *et al.* (1992) noted that when isonitrogenous amounts of supplements were offered to beef steers, the degradation rate of dietary N in the rumen was higher for a CSM-based supplement than for a maize-CSM-based supplement. It might be inferred that, in the present study, the ruminal degradation of protein-N in the concentrate-based diet was lower than that of the other diets containing CSM. Furthermore, utilisation of ruminal NH_3 by rumen microbes might have been enhanced by the high availability of maize starch from the concentrate, and this suggestion is supported by a higher estimate of microbial yield from the rumen of sheep given the concentrate than those given CSM (Table 8.5). The lower PUN concentration in sheep given the concentrate might be as a result of the decreased degradation of dietary N and increased utilisation of ruminal NH_3.

8.4.4 Energy and protein supplies to the rumen

In this study, the availability of rumen-degradable protein was adequate for microbial protein synthesis since, as shown in Table 8.6, for all diets the ratio of RDP to ME intake (RDP/MEI) was much higher than 8.4 g/MJ which is regarded as sufficient for microbial growth (ARC 1984).

However, although the RDP supply was approximately proportional to CSM intake, the efficiency of utilisation of RDP for microbial protein synthesis expressed as the ratio of MCP to RDP (MCP/RDP), was only around 0.17 in sheep given CSM (Table 8.6). Apart from a possible deficiency in mineral intake or other nutrients, an imbalance between the supply of energy and protein to the rumen of those sheep was probably also responsible for the low ratio. This assessment was also confirmed by the ratio of RDP to ME intake, which was much higher than 8.4 g/MJ, in those sheep (Table 8.6). Moreover, the calculated average supply of RDP was similar between sheep receiving CSM and the concentrate (137 vs 150 g/d), but microbial N yield was 213% higher in sheep given the concentrate (3.7 vs 11.5 g N/d). These results, on the other hand, probably indicated that the supplies of energy and nitrogen to the rumen of sheep fed the concentrate were much better synchronised for microbial growth. As a result, compared with sheep given CSM, the sheep receiving the concentrate had a lower PUN concentration (22.6 vs 17.4 mg/100 ml) and a much higher efficiency of utilisation of RDP for microbial protein synthesis (0.17 vs 0.48).

8.5 Conclusion

Both live-weight gain and wool production in sheep increased with increasing CSM intake, but the incremental increase in the rate of gain became less when CSM intake was higher than 160 g/d. As shown in Figure 8.2, average daily gains in sheep supplemented with CSM at 80, 160, 240 and 320 g/d were equivalent to respectively 13, 35, 45 and 53% of the gain in sheep receiving a better balanced concentrate diet, and correspondingly wool production accounted for 66, 72, 82 and 79% of the production in sheep given the concentrate.

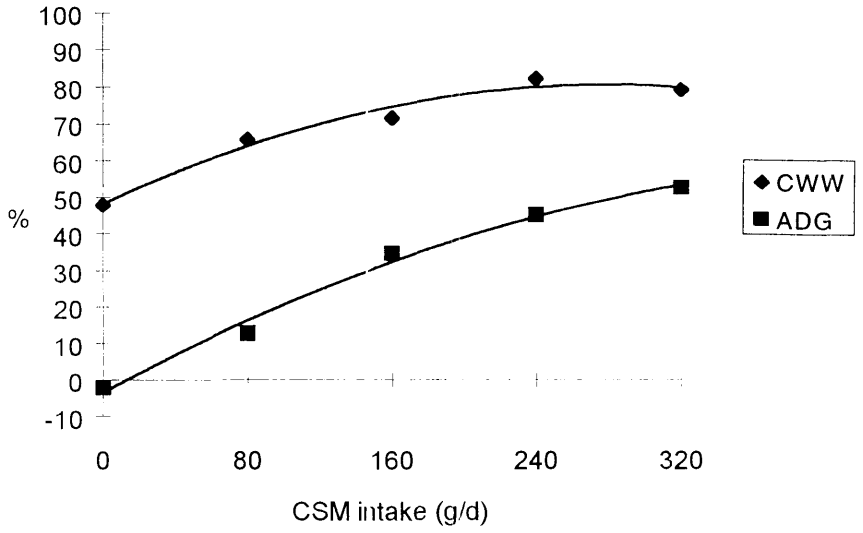

Figure 8.2. *Percentage (%) of average daily gain (ADG) and clean wool weight (CWW) in sheep given 0, 80, 160, 240 and 320 g CSM/d relative to ADG and CWW in sheep given the concentrate.*

The results from this study showed that supplementing CSM to sheep at 160 g/d might be the best option under feeding conditions similar to those in the current study, giving increased live-weight gain and wool production but unchanged hay intake and fibre diameter.

Chapter 9

9. General Discussion

9.1 Experimental protocols

Owing to the limited experimental facilities, each of the current two studies was carried out successively in two groups of 12 sheep with similar average starting liveweights, and the data from the two groups were combined for statistical analysis. It could be argued that the results obtained with the second group of animals would have been different if all 24 animals had been studied simultaneously. However, in this situation the range of liveweight of the group would have been much greater, leading to a different source of variation. It therefore seemed most appropriate to study the lighter group of sheep when they had reached the same starting liveweight as the first group.

9.2 Forage intake

Substitution effects on forage intake induced by protein or energy supplementation were observed in the present two studies. In the first study, when maize grain was given to sheep at 19.0 g/kg $W^{0.75}$.d, hay intake was depressed from 735 to 646 g/d with a substitution rate of 446 g hay per kg maize. In the second study, CSM supplemented at an average level of 16.3 g/kg $W^{0.75}$.d substituted hay intake at an average rate of 131 g/kg CSM.

Forage intake is usually increased markedly by a moderate level of protein supplementation when basal diets are initially deficient in N (McCollum and Galyean 1985; Preston and Leng 1987; Orskov 1988; Bird *et al.* 1993; Osuji *et al.* 1993). In general, intake of low quality forages by ruminants is more likely to be stimulated by a low level of energy or protein supplementation than that of high quality forages (Rafiq *et al.* 1995). In addition, protein supplements with a high true protein content are more capable of stimulating forage intake than cereal supplements, and this is likely due to that true protein supplements are more effective in improving rumen fermentation and increasing the intestinal amino acid supply (Doyle 1987; McLennan *et al.* 1995). However, for a specific supplement, the incremental increase in intake of forages diminishes with increasing supplement intake.

The increased forage intake due to protein supplementation is usually associated with an increased rumen volume and an increased ruminal digestion rate of forages resulting from the increased ruminal N supply. Krysl *et al.* (1987) reported that an increased prairie hay intake by ewes supplemented with CSM was accompanied by a tendency towards an increase in ruminal fluid dilution rate. Bird *et al.* (1993) observed that supplementing wethers fed low CP grass hay with CSM increased forage intake by 34%, while salivary secretion, dilution rate and outflow rate of rumen fluid were increased by 30%, 16% and 52%, respectively. On the other hand, McCollum and Galyean (1985) reported that supplementing beef steers fed prairie hay with a relatively large amount of CSM supplying 5.4 g CP/kg $W^{0.75}$.d had no effect on rumen volume and did not stimulate hay intake. More recently, Freeman *et al.* (1992) noted that a supply of 3.2 g supplemental CP/kg $W^{0.75}$.d to beef steers fed prairie hay had no effect on ruminal fluid volume or dilution rates of ruminal fluid and particulate digesta, and did not stimulate hay intake.

In addition, any increased forage intake in response to protein meal supplementation is also related to an increased rumen bacteria population and improved ruminal digestion of dietary fibre and N (Sudana and Leng 1986; Caton *et al.* 1988; Gaskins *et al.* 1990; Bird *et al.* 1993). Furthermore, the additional supply of amino acids to the small intestine of animals from protein supplements may also enhance forage intake through metabolic mechanisms (Preston and Leng 1987) mediated via the brain and nervous system (Nolan, J.V., pers. comm., 1997).

The substitution effect of supplements on intake of forages is a critical factor affecting the utilisation of both forages and supplements, and the economic return from supplementation. Both forage intake and total feed intake decline when total energy intake of animals receiving energy or protein supplements is higher than their energy requirement. On the other hand, the substitution effect is minimised when protein feeds adequately supplement forages to increase the digestion rate of fibre, microbial protein yield and N retention (Jarrige *et al.* 1986).

In general, the substitution effect is related to the quality of forages, intake of supplements and physiological status of animals (Doyle 1987; McLennan *et al.* 1995). Other factors can also affect the substitution effect of energy supplements (Jarrige *et al.* 1986; Doyle 1987; McLennan *et al.* 1995). Firstly, the chemical composition of supplements, such as their lipid and NPN content, affects the magnitude of substitution effects. Secondly, energy supplements with different ruminal DM degradability supply different amounts of carbohydrates to the small intestine, thereby affecting the supply of glucose to ruminant tissues and ultimately the extent of substitution effect with different energy supplements. Thirdly, the efficiency of utilisation of energy by ruminants also affects the degree of substitution. Fourthly, time of supplementation appears to be important. Howard *et al.* (1992) and Abou El-Nasr *et al.* (1994) demonstrated that feeding energy supplements to grazing animals in the morning rather than in the afternoon increased the intake of pasture herbages, total DM and N by animals.

Likewise, the substitution effect of protein supplements is also affected by the nature of protein and NPN intake by animals. Poppi and McLennan (1995) found that the substitution effect of fish meal was less than that of CSM. McLennan *et al.* (1995) reported that intake of ammoniated-straw by steers was decreased, but intake of untreated straw was unaffected by CSM supplementation.

9.3 Nitrogen metabolism

Protein intake usually affects digestibility and retention of N in animals. As shown in the present studies, N digestibility *in vivo* was increased by SFM and CSM supplementation, and N retention was improved significantly by CSM feeding. Increases in N digestibility (Caton *et al.* 1988; Gaskins *et al.* 1990; Nunez-Hernandez *et al.* 1991; Sultan and Loerch 1992) and N retention (Nunez-Hernandez *et al.* 1991) arising from increasing protein supplement intake have been reported in sheep. Sultan and Loerch (1992) reported that, as a result of the improved balance of duodenal amino acids and N digestibility, lambs given high protein diets retained 41% more N than those given low protein diets. Similarly, von Keyserlingk and Mathison (1993) reported that an increase in dietary CP content from 7.4 to 12.0% increased energy retained as protein by 31%.

Energy intake also affects N metabolism in ruminants. As shown in the current studies, digestibility and retention of N were improved when maize grain or a maize-based concentrate was offered to sheep. These results were in agreement with the conclusion that energy supplementation may significantly improve N utilisation and N retention by animals (Sultan and Loerch 1992, Osuji *et al.* 1993). Oke *et al.* (1991) reported that when the total N intake by sheep was constant, N digestibility increased from 58 to 71% as maize grain content of concentrates increased from 50 to 75%, and the increased N digestibility was attributed by the authors to a reduction in ruminal N degradation and an increase in intestinal N digestibility. Results of Sultan and Loerch (1992) also showed that lambs fed high energy diets retained 23% more N than those fed low energy diets probably due to the increased utilisation of ruminal NH_3 by rumen microbes.

Furthermore, the improved N retention in response to energy supplementation may be associated with a positive effect of increased intestinal supply of starch on amino acid metabolism. Oke *et al.* (1991) observed that increasing the amount of maize grain in concentrates from 50 to 75% decreased ruminal starch degradation and thus increased the intestinal starch flow by 24%. Over a wide range of diets and intake levels, little dietary glucose is absorbed from the small intestine of ruminants due to extensive fermentation of dietary carbohydrates in the rumen (Dijkstra 1994), and glucose required by tissue metabolism is synthesised mainly via gluconeogenesis. Glucogenic amino acids may supply around 10-30% of the total glucose synthesised via gluconeogenesis in ruminants (Cridland 1983; Bergman 1983), and an increase in intestinal absorption of exogenous starch 'protects' these glucogenic amino acids from gluconeogenesis.

For example, Oke *et al.* (1991) observed that an increase in the intestinal starch supply spared the absorbed amino acids from gluconeogenesis thus increasing the availability of amino acids at the tissue level (as suggested by the decreased plasma concentration of essential amino acids and urea-N) and N retention by sheep.

In the current two studies, PUN concentration was positively correlated with dietary N intake by sheep. However, PUN concentration is usually more closely related to the ruminal NH_3 concentration than dietary N intake (Kennedy and Milligan 1980). A linear relationship between the PUN concentration (Y, mg N/l) and the ruminal NH_3 concentration (X, mg N/100 ml) was developed by SNUR (1985), i.e., Y=79.0 + 14.5X. Therefore, PUN can be treated as an index of the ruminal NH_3 concentration.

In addition, PUN can be used to assess the N status of sheep. Preston *et al.* (1965) suggested that a PUN level higher than 10 mg/100 ml indicated an adequate protein intake by lambs. According to this criterion, the N supply to all sheep in the current two studies was sufficient. Pfander *et al.* (1975) further proposed that PUN maintained at around 15 mg/100 ml was required for the highest growth rate of lambs. This conclusion is not supported by the results from sheep supplemented with CSM in the second study which showed that average daily gain in these sheep increased from 26 to 106 g/d as PUN increased from 18 to 30 mg/100 ml (Table 8.3 and 8.4). However, the highest growth rates of sheep in the first and second study, i.e., 73 and 202 g/d, were observed when PUN concentrations were 18 and 17 mg/100 ml, respectively (Appendix and Table 8.4).

9.4 Temperature and animal performance

Sheep receiving the same amount of CSM (80 g/d) in the current two studies differed in their growth rates and wool production. Average daily gain was higher (44.3 vs 25.5 g/d) but clean wool production was lower (1.7 vs 4.4 g/100 cm^2) in sheep kept at a low temperature (-5 to 5°C) in the first study than those kept at a high temperature (15 to 25°C) in the second study. Apart from differences in ages, diets and liveweight, the different temperatures were possibly also responsible for those performance differences. Sun *et al.* (1994) reported that clean wool production from mid-side patches of Romney sheep fed high quality lucerne chaff was higher at 6°C than at 25°C (1.7 vs 1.2 g/100 cm^2). In another study, von Keyserlingk and Mathison (1993) noted that live-weight gains in sheep maintained at 4.7 and 21.0°C were similar (93 vs 91 g/d), although the sheep kept at 4.7°C had a higher heat production (148 vs 131 kcal/kg $W^{0.75}$) measured by a calorimetry method.

In the present two studies, the estimated duodenal protein supplies were similar in sheep receiving 80 g CSM/d at a low or a high temperature (68 vs 63 g/d). In the cold, basal metabolic

rate of animals is increased so that absorbed nutrients are partitioned away from protein and fat synthesis, towards heat production. As a result, a larger amount of absorbed amino acids was likely to be utilised as glucose precursors for heat production in those sheep at the low temperature. However, those sheep, which probably had a lower availability of nutrients for production, were higher in live-weight gain (44.3 vs 25.5 g/d) but lower in wool production (1.7 vs 4.4 g/100 cm^2) than those at a high temperature. The depression effect of the cold on the length growth rate of wool fibres as reviewed by Bottomley (1979), was probably also responsible for the lower clean wool production at the low temperature. However, the reason for the higher growth rate of sheep exposed to the cold was unknown. Maybe partition of absorbed nutrients into tissue deposition was enhanced at the low temperature.

On the other hand, the lower growth rate of those sheep given 80 g CSM/d at the high temperature was associated with a lower total DM intake compared with those at the low temperature (71 vs 82 g DM/kg $W^{0.75}$.d, Table 8.3 and Appendix). In addition, extra heat produced from increasing protein synthesis in response to protein supplementation might have limited growth rate of sheep at the high temperature. Poppi and McLennan (1995) stated that protein supplementation would fail to promote live-weight gain regardless of nutritive status of animals when the upper level of heat dissipation was reached, which more likely occurred in young animals.

9.5 Manipulation of protein supplementation

In the second study, as shown in Figure 8.4, average daily gain (ADG) and clean wool weight (CWW) in sheep receiving 80 to 320 g CSM/d accounted for respectively 13-53% of ADG and 66-79% of CWW in sheep receiving a well-balanced concentrate. In addition, wool production in sheep from the control group, which lost liveweight, was equivalent to 48% of that in sheep given the concentrate. These results seemed to indicate that wool follicles had a priority over other body tissues in utilising the absorbed nutrients for wool fibre synthesis in Xinjiang Merino sheep. However, since feeding sheep for wool production is unprofitable, manipulations to improve the efficiency of utilisation of nutrients for body tissue deposition rather than for wool production, and thereby to improve the economic return from protein supplementation may therefore deserve further study.

In the second study, the incremental increase in growth rate of sheep given CSM began to drop when CSM was supplemented at rates higher than 160 g/d. This was possibly due to an imbalance between protein and energy supplies to the animals. In general, the amount of amino acids and total energy-yielding substrates available at the tissue level mainly determines growth rate of animals (Poppi and McLennan 1995). In addition, the efficiency of utilisation of absorbed amino acids for growth is further related to the supply of non-protein energy-yielding substrates

and limiting essential amino acids (Pond *et al.* 1995). In the second study, although the duodenal protein flow increased with increasing CSM intake, the incremental increase in growth rate decreased when CSM intake was higher than 160 g/d (Figure 8.1). It seemed that the ratio of protein to energy in the absorbed nutrients in sheep receiving high levels of CSM was excessively high. This may have depressed the efficiency of utilisation of the duodenal protein and consequently restricted live-weight gain in those sheep. McLennan *et al.* (1995) indicated that growth rate of animals given energy supplements usually continued to increase with increasing supplement intake even though supplement intake was much high. Therefore, in the second study, the energy supply to those sheep given high levels of CSM was probably inadequate relative to their protein intake. A further increase in live-weight gain in those animals was possibly dependent on an increase in the supply of energy.

In developing countries where low quality roughages are abundant and concentrates are usually scarce and expensive, the first priority of supplementation is to maximise intake and ruminal degradation of roughages. Low to medium levels of protein supplementation are therefore preferred. In contrast, with highly productive ruminants, such as lot-fed animals, stimulating forage intake by supplementation may be a secondary consideration, and high levels of protein supplementation may be needed for those animals. In this case, as discussed above, energy supplements may also be needed for those animals.

Feed intake is usually decreased and ruminal degradation of dietary protein is increased in animals under heat stress. The increased ruminal protein degradation results from the extended retention time of dietary protein in the rumen of animals in the heat (Bunting *et al.* 1992). Therefore, protein supplements need to be properly treated before fed to animals under heat stress to reduce the adverse effect of heat stress on ruminal degradation of dietary protein. This manipulation may improve the ratio of protein to energy in absorbed nutrients and efficiency of utilisation of nutrients by ruminants in a hot environment (Leng 1990; Bunting *et al.* 1992).

In the current second study, apart from high intakes of energy, N and minerals, the complementary effect of dietary escape protein supplied from maize, SFM and CSM was possibly also responsible for the highest growth rate and wool production in sheep given the concentrate. Maize grain is low in lysine, methionine and cystine, whereas CSM is relatively high in lysine but low in methionine and cystine, and SFM is a good source of methionine and cystine (McDonald *et al.* 1988). The mixture of proteins would thus provide a more appropriate balance of amino acids available to sheep given the concentrate. Merchen and Titgemeyer (1992) suggested that, since most protein feeds were poor sources of at least one essential amino acid for production purposes and varied in the intestinal digestibility of individual amino acids, protein supplements which were resistant to ruminal degradation but readily available to the intestinal digestion and absorption should be selected and blended to optimise the composition of intestinal

amino acids available for a specific production. These authors also suggested that such manipulations were probably valuable when microbial protein yield from the rumen was low and supplemental protein accounted for a relatively large proportion of the total duodenal protein supply to animals.

When microbial protein flowing out of the rumen was the only amino acid source available for animals, Richardson and Hatfield (1978) reported that methionine, lysine and threonine were the first, second and third most limiting amino acids for growing calves, and Storm and Ørskov (1983) found that methionine and lysine were the first and second most limiting amino acids for growing lambs. However, the deficiency of essential amino acids for growth may vary with different feeding conditions. Poppi and McLennan (1995) reported that an abomasal infusion of a mixture of six amino acids (methionine, lysine, histidine, arginine, cysteine and threonine) was as effective as an abomasal infusion of whey protein in stimulating live-weight gain in lambs grazing white clover, but infusions of two (methionine and lysine) and four amino acids (methionine, lysine, histidine and arginine) had no effect on live-weight gain.

If the limiting essential amino acids for a specific production purpose under a feeding condition are identified, they can be properly protected and supplemented with protein sources in such a way that the essential amino acids complement the intestinal amino acid profile of the protein sources. Such an approach may have a potential of reducing dietary protein levels and feeding costs without affecting animal performance (Merchen and Titgemeyer 1992).

As shown in the current first study, CSM was a more effective supplement than SFM for growth of sheep, thus CSM can be used to improve meat production of sheep in Xinjiang Province. In addition, identification of limiting nutrients of SFM supplementation for growth, and manipulations (e.g., physical or chemical treatments and use of specific protected amino acids) to improve its feeding value for meat production need further study. In the second study, although growth rate of sheep increased with increasing CSM intake, the growth rate of sheep supplemented with the highest level of CSM (i.e., 320 g/d) which accounted for nearly one-third of total DM intake, approached only around 53% of the growth rate of sheep given a well-balanced concentrate diet. Further investigation of limiting nutrients for growth of animals with a high CSM intake is warranted. Moreover, evaluation of other locally available protein meals in Xinjiang Province, such as rapeseed meal, for sheep production, and the economic return from protein meal supplementation in Xinjiang Province also deserve further study.