CHAPTER 4

4.0 BROILER LITTER AS A SOURCE OF SELENIUM FOR SHEEP

4.1 INTRODUCTION

In a survey of the mineral composition of poultry manure from South African sources, Van Ryssen *et al.* (1993) recorded relatively high concentrations of selenium viz. 0.62 ± 0.24, 0.47 ± 0.25 and 0.42 ± 0.22 mg/kg DM in broiler litter, pure laying hen manure and pullet litter, respectively. Similarly, high selenium concentrations were recorded elsewhere, e.g., 1.09 mg (Westing *et al.*, 1985) and 0.95 mg selenium (Ben-Ghedalia *et al.*, 1996) /kg dry poultry litter. Poultry litter is frequently used as feedstuff for ruminants (Fontenot, 1991) and could, therefore, be a good source of selenium to the ruminant provided it is available to the animal.

Ullrey (1992) stated that unabsorbed inorganic selenium in animal faeces consists largely of insoluble elemental selenium and metal selenides, and in urine it is in the form of trimethylselenonium which has a poor availability to the animal. In monogastric animals such as rats, pigs and humans a large proportion of the dietary selenium is excreted via the urine, also as trimethylselenonium, a volatile compound which is converted to forms poorly available to plants (Stowe & Herdt, 1992). The chemical form of selenium containing metabolites in urine of other domestic species is apparently not well established (Stowe & Herdt, 1992; Sankari, 1993). Whether the selenium in poultry urine would be available to a ruminant consuming poultry manure, is not clear. However,

Ganther *et al.* (1990) pointed out that demethylation can result in selenium becoming available from compounds such as trimethylselenonium which, they pointed out, have been reported as metabolically inert. It can be assumed that the selenium in faeces of poultry would be a combination of unavailable dietary selenium and endogenous selenium which is possibly available. However, even if the selenium in poultry manure is present in a chemical form which is available to the ruminant, poultry manure is often rich in minerals which can interact with selenium metabolism such as sulphur (Pope *et al.*, 1979), mercury, cadmium, arsenic (McConnell & Carpenter, 1971; Hill, 1974), copper (Hill, 1974; Hartmann & Van Ryssen, 1997; Van Ryssen *et al.*, 1998) and calcium (Harrison & Conrad, 1984).

The objective of this investigation was to establish to what extent selenium in broiler litter is available to sheep consuming the litter. The opportunity was afforded to investigate selenium metabolism in sheep in the studies where broiler litter was evaluated as a sole feed or mixed with a small quantity of molasses for sheep in drought feeding situations (Chapters 2 and 3).

4.2 MATERIALS AND METHODS

Two trials were conducted with South African Mutton Merino wethers. Experimental treatments and wether pre-experimental preparations were as described in Chapters 2 and 3.

Experiment 4.1

A partial digestion study was conducted with six mature wethers, surgically fitted with ruminal cannulas and T-type abomasal and ileal cannulas. The sheep were allocated to three treatments (100, 92.5 and 85 percent litter) as described in Chapter 3. Feed sampling, feeding, sample collection and feeding times of the animals was presented in Chapter 3.

The double marker technique of Faichney (1975) (chromium-EDTA as the liquid-phase and *y*ttebium-acetate as the particulate phase marker) was used and preparation of the markers was as described in 3. The procedure for the infusion of the markers and collection of ruminal, abomasal and ileal samples is detailed in 3. Immediately after collection the pH of the rumen content was measured and abomasal, ileal and faecal samples were stored as described in Chapter 3. After thawing abomasal, ileal and faecal samples were prepared and analysed for markers, dry and organic matter contents and selenium concentration of the digesta as described in Chapter 3. Total digesta and selenium flow were calculated as presented in Chapters 2 and 3.

Experiment 4.2

A feeding trial was conducted with 18 wethers (*ca.* 2 years old and *ca.* 42 kg body weight), allocated randomly to the three treatments. Details of the trial were reported in Chapter 2. The sheep were fed individually in elevated slatted-floor feeding pens and had free access to water. After an adaptation period of 2 weeks the sheep received their

respective experimental diets *ad libitum*. Feed intakes were recorded and feed samples were taken. Blood was collected at regular intervals throughout the trial by venipuncture in heparinised vacutainers. After an average of 83 days the wethers were slaughtered over a period of 10 days and their livers, hearts and kidneys were collected. Representative samples of the liver, fat-free cardiac muscle and kidney cortex were taken, dried at 80^0 C and stored pending analyses.

4.2.1 Analytical techniques

Selenium concentration in the experimental diet, tissues, digesta and faeces was determined as described in Chapter 2. The standard AAS technique was used to measure the calcium, magnesium and copper concentrations in the diets. An acetylene-nitrous oxide flame on the AAS was used in assaying for chromium in the litter and chromium and ytterbium in the digesta and faeces. The cadmium, arsenic and mercury concentrations in the diets were determined by ICP-MS after a nitric acid digestion where the temperature was kept at 120^0 C to minimize Hg losses. Dietary sulphur was determined by the method described by the Ministry of Agriculture, Fisheries and Food (1986).

4.2.2 Statistical analyses

A Latin-Square analysis using the ANOVA proceeding in the Statistical Analysis System (1994) programme was performed on the results of Trial 1. Tukey's test was used to test for statistical significant differences. In Trial 2 a simple ANOVA in the SAS programme was used to compare differences.

4.3 RESULTS

The mineral composition of the broiler litters used in the two trials is presented in Table 4.1. The inclusion of molasses did not change the mineral composition of these treatments substantially, and is not presented.

Experiment 4.1

The addition of molasses to the litter increased the DM intake of the sheep with the consequent increased intake in selenium. However, differences were not significant (Table 4.2). A higher abomasal and ileal selenium flow was measured at the higher molasses inclusion levels. However, variations in these measurements were high and differences among treatments were not significant. The apparent dietary selenium disappearance from the rumen was negligibly small. Selenium disappearances between abomasum and ileum were 28 percent, 41percent and 51percent and between the ileum and faeces 28, 2 and 2 percent of selenium intake intake for the 100, 92.6 and 85 percent litter treatments. Differences were not significant (Table 4.2). The average rumen pH was 6.84, 6.86 and 6.67 for the 100, 92.5 and 85 percent treatments, respectively.

Experiment 4.2

Total DM intake of the sheep increased ($p< 0.05$) with the addition of molasses from 1300 g at the 100 percent broiler litter to 1500 g in the 92.5 percent and 2100 g in the 85 percent broiler litter treatments. This was also evident in selenium intake (Table 4.3).

Selenium concentrations in the tissues did not differ significantly among treatments (Table 4.3). Selenium concentrations in blood and plasma throughout the trial are depicted in Figure 4.1. Mean plasma selenium concentration at the onset of the trial was 0.04 mg/l, increased to a concentration of 0.13 mg/l and tendered to plateau beyond that. The whole blood sample from day 1 was lost. However, concentrations increased with time from first collection, though, followed a curvilinear trend towards the end of the trial.

Table 4.1: Mineral composition of the broiler litters used in the two trials (Dry matter basis)

Elements	**Trial 1**	**Trial 2**
	mg/kg	
Selenium	1.00	0.68
Copper	58.4	22.00
Cadmium	0.36	0.26
Mercury	0.10	0.10
Arsenic	1.89	1.01
	g/kg	
Calcium	12.70	15.0
Phosphorus	12.50	8.10
Magnesium	2.22	4.71
Sulphur	6.50	4.30

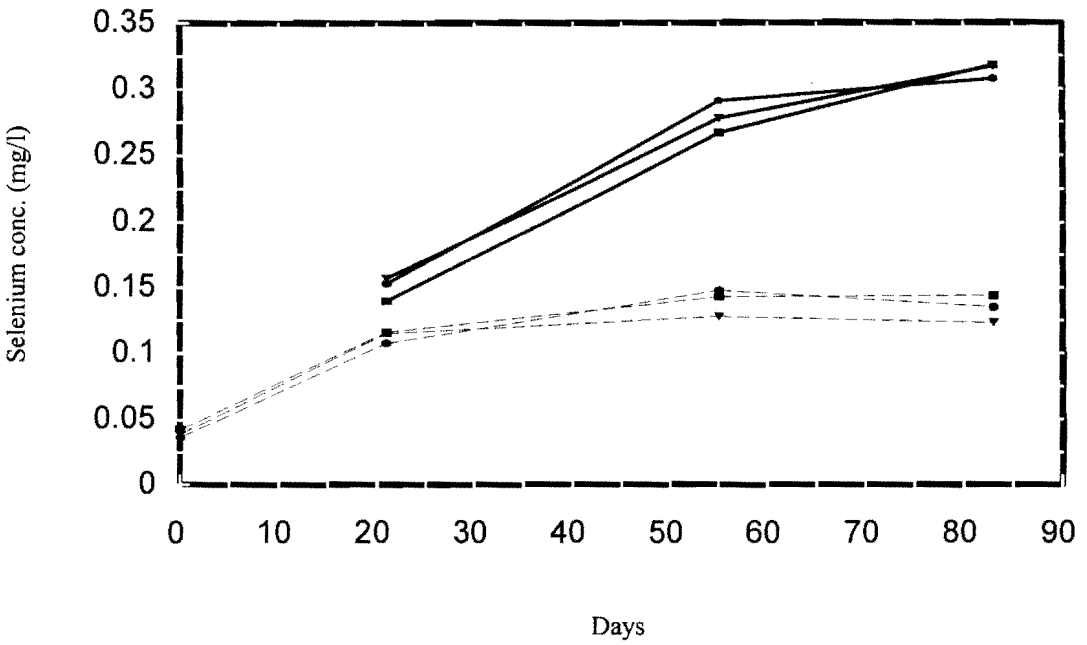

Figure 4.1: Selenium concentration in whole blood (——) and plasma in sheep (— —) receiving 100% broiler litter (▼) 92.5% litter and 7.5% molasses (■) and 85% litter and 15% molasses (●) for 83 days.

Table 4.2: Intake, flow rate and disappearance of selenium (Se) from the digestive tract of sheep consuming high levels of broiler litter during Trial 1

Broiler litter(%)	**100**	**92.5**	**85**	**MSE**
Molasses(%)	**0**	**7.5**	**15**	**N = 9**
DM intake (g/d)	858	1128	1358	491
Se intake (ng/d)	806	1173	1737	171
Se flow (ng/d)				
Abomasal	805	1133	1692	169
Ileal	581	654	866	56
Faecal	386	625	840	112
Apparent Se disappearance(ng/d) from[a]				
Rumen	1 (0.001)	40 (3.4)	45 (2.6)	11 (1.3)
Small intestine	224 (28)	479 (41)	826 (51)	252 (14)
Large intestine	225 (28)	29 (2)	26 (2)	53 (13)
Apparent Se digestion(%)	52	47	52	15

[a]Values in parenthesis denote % of intake.

[b]Calculated from selenium intake and total selenium excretion

Table 4.3: Mean selenium intake and selenium concentrations in the tissues of sheep after an 83 day feeding period in Trial 2

Broiler Litter	**Molasses**	**Selenium intake**	**Concentration of selenium (mg/kg DM)**		
(%)	**(%)**	**(mg/d)**	**Liver**	**Heart**	**Kidney cortex**
100	0	0.750	3.07	1.35	7.21
92.5	7.5	0.887	2.23	1.42	8.98
85	15	1.136	2.30	1.60	8.33
SEM	15	0.002	0.575	0.354	1.416

[a]Within columns means with different superscripts are significantly different at $p < 0.05$

4.4 DISCUSSION

Evidence in the literature of the bio-availability of selenium in poultry manure is limited. In a digestibility study with dairy cows consuming a diet containing 10% poultry litter which contained 0.9 mg selenium/kg DM, Ben–Ghedalia *et al.* (1996) concluded that selenium in the litter was highly digestible. Angus *et al.* (1978) reported substantially higher selenium concentration in the livers of lambs receiving 60 percent broiler litter in their diets compared to lower levels of litter inclusion. Westing *et al.* (1985) included broiler litter containing 1.09 mg selenium /kg in a number of diets for beef heifers. A substantial proportion of the total dietary selenium originated from the broiler litter. From the selenium concentrations in the livers, kidneys and muscle of the heifers it could be deducted that the selenium in the litter was absorbed. In the present study an apparent absorption (digestibility) of selenium in broiler litter varied between 47 and 52 percent.

In a review of the literature, Oldfield *et al.* (1994) concluded that about 60 percent of selenium taken in by ruminants is excreted in the faeces, i.e. an apparent digestibility of 40 percent. Present results indicated a lower faecal excretion for broiler litter implying that the selenium in litter was even more available to sheep than that in other feedstuffs. Harrison & Conrad (1984), employing a balance technique in nonlactating dairy cows, observed apparent selenium absorptions of between 17 and 50 percent of intake. Absorption was minimal at low and high calcium intakes and maximal at a concentration of about 8.0 g calcium /kg feed. Koenig *et al.* (1997) reported an absorption of 41.8 percent of dietary selenium when their sheep consumed forage and 52.8 percent when on concentrate.

The present results on broiler litter agreed with those of Wright & Bell (1966) who used radio-active selenium and concluded that no net absorption or secretion of selenium took place in the rumen of sheep. The negative flow of selenium in the rumen could be due to inaccuracies inherent in the dual-phase marker technique. However, Langlands *et al.* (1986) observed an entering of selenium into the rumen through saliva. Using the dual-phase marker technique, Koenig *et al.* (1997) measured a selenium disappearance in the pre-intestinal region of 11.8 percent for sheep on roughage and 27.3 percent when on concentrate diets. In the present study between 28 and 49 percent of the selenium in the broiler litter entering the abomasum disappeared between the abomasum and the ileum. Endogenous selenium entering the digestive tract would affect such a value. Langlands *et al.* (1986) suggested that endogenous selenium enters the anterior portion of small intestine and is absorbed in the lower sections of the small intestine. In the study by Koenig *et al.* (1997) 36.6 percent of the selenium in forage and 36.4 percent in the concentrate disappeared in the small intestine. They concluded that absorption of diet-derived selenium occurred primarily in the small intestine. Wright & Bell (1966) measured limited absorption of selenium in the abomasum but resecretion of selenium in the first section of the small intestine. Selenium was absorbed from the remainder of the small intestine without a net change in the caecum or colon, but a net absorption of 36 percent in the second section of the colon. In the present study between 2 and 28 percent of dietary selenium apparently disappeared in the large intestine.

Langlands *et al.* (1986) concluded that the exogenous selenium excreted in faeces is predominantly selenium which has been reduced to unavailable forms during passage

through the rumen. They suggested that the extent of selenium reduction varies with the quantity of organic matter fermented in the rumen. Our results on the availability of selenium in broiler litter in terms of disappearance of selenium from the digestive tract compared well with the disappearance of selenium from other sources; as reported in the literature (Oldfield *et al.*, 1994). Hakkarainen (1993) pointed out that where methods other than prevention of diseases are used to determine bioavailability, there are many factors which may interfere with metabolism of selenium in the body, e.g., interactions with heavy metals. The concentrations of cadmium, mercury and arsenic, which interact with selenium in the body were relatively low in the broiler litter used, though the sulphur and copper concentrations were higher than those in typical sheep diets. However, these minerals apparently did not have a major affect on the availability of selenium in broiler litter if compared with the reported disappearances of selenium in other selenium sources. Ehlig *et al.* (1967) found that selenium in sheep is excreted predominantly in faeces when dietary levels were low, <0.1 mg/kg, but selenium concentration in the urine approached and even exceeded that of faeces when dietary levels were < 5 mg/kg. In the present study selenium excretion through urine was not measured. However, the accumulation of selenium in the tissues during Trial 2 in the present study suggested that the selenium was absorbed and bioavailable. The plasma selenium concentration of 0.04 mg/l at the onset of the trial indicated that the sheep were marginally deficient in selenium (Puls, 1994). The gradual increase in the selenium concentration in plasma followed the typical initial increase in concentration and then a levelling off at ± 0.13 mg selenium/l, while selenium concentrations in whole blood continued to increase with time (Hartmann & Van Ryssen, 1997). Henry *et al.* (1988) demonstrated that at high levels of dietary selenium the

accumulation of selenium in tissues can be used to estimate the bioavailability of dietary selenium. At selenium intakes ranging from 0 to 1.0 mg selenium/kg feed, Moksnes & Norheim (1983) reported an increase in selenium accumulation according to dietary selenium concentration, in the liver and whole blood in sheep. Similarly, Van Ryssen *et al.* (1998) reported increases in the selenium concentrations of the liver, heart, skeletal muscle, whole blood and plasma of sheep with an increase in dietary selenium concentrations between 0.35 and 1.34 mg selenium/kg feed. In the present study dietary selenium concentration (0.68 mg/kg) and duration of trial (83 days) were very similar to those of Van Ryssen *et al.* (1998). The selenium concentrations at the end of the trial in the liver, kidneys and heart were at levels similar to sheep receiving diets containing between 0.5 and 1.0 mg selenium (as sodium selenite)/kg DM for between 60 and 80 days (Hartmann & Van Ryssen, 1997; Van Ryssen *et al.*, 1998). At high or prolonged selenium intakes differences in tissue selenium concentrations due to different selenium intakes tended to decrease (Moksnes & Norheim, 1983). This may explain why differences between concentrations were not observed in the present trial despite the differences in selenium intake.

Although relative bio-availability of selenium in broiler litter could not be calculated in the present investigation, the results suggest that selenium in broiler litter is readily available to sheep consuming the litter. In a drought feeding situation, therefore, where up to 100 percent litter may be fed, exists a potential for selenium toxicity.

CHAPTER 5

5.0 SITES OF DIGESTION OF NUTRIENTS IN DIETS CONTAINING DIFFERENT LEVELS OF BROILER LITTER

5.1 INTRODUCTION

In the previous partial digestion study (Chapter 3) the main effect of adding 15 percent molasses to the pure litter was a significant increase in feed intake. A consequence was apparently a change in the site of digestion of the nutrients away from the rumen to the lower digestive tract. The magnitude of this change was so large that it seemed biologically unlikely to be true. To test these previous results, a second trial was conducted in which the site of disappearance of nutrients in broiler litter plus 15 percent was compared with the disappearance of nutrient from diets containing lower levels of broiler litter.

5.2 MATERIALS AND METHODS

5.2.1 Animals and treatments

Four mature SA Mutton Merino wethers fitted with ruminal and T-type abomasal and terminal ileal cannuli were used in the trial. The treatments were: diets containing 33, 66 and 85 percent broiler litter, formulated to be isonitrogenous and containing approximately the same concentrations of fibre (Table 5.1). The broiler litter, with sunflower husks as bedding material, and the sheep were prepared as reported before

(Chapter 3). To reduce the time required for the rumen micro-organisms to adapt to a completely different diet with each change in treatment and to simplify the execution of the trial, all four wethers were adapted to the same diet, starting with the 33 percent broiler litter treatment. After sampling (for four days) the wethers were adapted for seven days to the diet containing 66 percent broiler litter and after the collection period, to the diet containing 85 percent litter. This procedure was then repeated in reverse order, starting with the 85 percent litter diet, followed by the 66 percent and then by the 33 percent litter diets. This procedure gave a total of eight animals per treatment and two periods of collection. For three days of the adaptation period the sheep were group-fed in a pen. For the rest of the time they were kept in metabolism crates where they received the diet *ad libitum*, supplied four times a day, and had free access to water. Feed intake was recorded and representative feed samples were taken. The experiment was conducted under the supervision and approval of the Ethics Committee for Animal Experimentation of the University of Pretoria.

Chromium oxide (500g/500 kg) was used as the only marker, added to the experimental diets during mixing. The actual concentration of chromium in the diets was determined by atomic absorption spectrophotometry. After a seven day adaptation period, feed, abomasal and ileal samples were collected over a period of four days (as described in Chapter 3) and preserved pending chemical analyses.

Table 5.1: Composition of diets fed to sheep in partial digestion Trial

Ingredients (g/kg)			
Broiler litter	330	660	850
Molasses	150	150	150
Oats hay	390	76	0
Starch	80	37	0
Sunflower meal	62	13	0
Urea	34	12	0
Salt	3	3	0

5.2.2 Analytical procedures

Abomasal and ileal digesta were prepared for chromium, ammonia nitrogen and digesta DM and ash content assays, as presented in Chapter 3. The remainder of the digesta (composite and supernatants) and faecal samples were dried, ground and analysed for chromium (faecal samples) and ammonia nitrogen (digesta samples) concentrations, as described in Chapter 3. The DM, organic matter and nitrogen concentrations in feed, and composite abomasal, ileal and faecal samples were obtained. The following analyses were done as described in Chapter 3: neutral and acid detergent, calcium, phosphorus, magnesium, copper, sodium, manganese, potassium, and zinc concentrations in the diets. The dry sieve technique with a maximum sieve diameter of 2 mm was used to measure the distribution of particle sizes of the litter.

5.2.3 Calculations

Abomasal and ileal digesta flows were calculated based on chromium concentrations in the digesta (Titgemeyer, 1997). Nutrient disappearance in the different section of the digestive tract was calculated by difference, based on dietary, abomasal ileal and faecal flow rates and concentrations. Microbial nitrogen flow at the abomasum was estimated, using the value 30 g microbial nitrogen per kg organic matter that apparently disappeared in the rumen (ARC, 1980). Non-ammonia nitrogen was assumed to represent the true protein concentration and is the difference between total nitrogen and ammonia nitrogen flows at a specific site.

5.2.4 Statistics

Data were analysed using the multifactor analysis of variance and significance of differences tested with the Least Square Difference method using the General Linear Models (GLM) procedure of SAS (SAS Institute, 1992).

5.3 RESULTS

Increasing levels of broiler litter in the diets increased their ash and mineral concentrations, while the crude protein and neutral and acid detergent fibre concentrations of the diets were very similar (Table 5.2). The particle size of 26% of the pure broiler litter was > than 2 mm; 11.4% >1 mm; 40.2 percent > 0.5 mm; 8.2% > 0.3 mm; 8.7% > 0.1 mm and 4.8% < 0.1 mm.

The organic matter intake per sheep decreased ($p<0.05$) with increasing litter in the treatment diets (Table 5.3). Less ($p<0.05$) organic matter was digested in the rumen, both in quantity and percentage of intake in the 85 percent litter diet than in the other two diets. In the case of the 85 percent litter diet, more dietary organic matter (31%) was digested in the small intestine than in the rumen (21%) (Table 5.3). This was not the case for the diets containing lower levels of litter, though the difference between organic matter digestibility in the rumen versus the small intestine was less in the 66 than in the 33 percent litter diet. The total apparent digestibility of organic matter was lower ($p<0.05$) for the high than the lower broiler litter diets. The flow of dry matter followed a similar though less pronounced difference between treatments than organic matter (Table 5.4).

Flow rates and the disappearance of nitrogen in the different section of the digestive tract did not differ among treatments, except for the lower ($p<0.05$) quantity of nitrogen that was apparently digested in the rumen of the sheep on the 85 percent diet compared to the other treatments (Table 5.5). Total apparent nitrogen digestion also decreased ($p<0.05$) with an increase in litter in the diets. Non-ammonia nitrogen flow beyond the rumen did not differ among treatments, though the apparent non-ammonia nitrogen digestibility in the small intestine was higher ($p<0.05$) in the low than the high litter diets. Likewise, the calculated microbial nitrogen flow in the abomasum was higher ($p<0.05$) in the low versus the high litter diets (Table 5.6).

Table 5.2: Chemical composition of the diets (Dry matter basis)

	----------Broiler litter----------		
Parameter	**33**	**66**	**85**
Dry matter(g/kg)	880	880	900
Organic matter(g/kg)	870	810	720
Crude protein(g/kg)	190	200	180
Ash (g/kg)	120	180	280
NDF (g/kg)*	410	390	380
ADF (g/kg)*	220	230	220
Calcium (g/kg)	9.7	16.5	19.4
Phosphorus(g/kg)	5.1	9.8	11.1
Potassium (g/kg)	13.2	17.7	19.7
Sodium (g/kg)	3.6	4.5	4.3
Magnesium (g/kg)	3	4.8	5.1
Manganese(mg/kg)	190	300	390
Copper (mg/kg)	40	70	80
Chromium oxide (g/kg)	1.05	1.0	1.07

*NDF – Neutral detergent fibre

*ADF – Acid detergent fibre

Table 5.3: Organic matter intake, flow and its apparent digestion in sheep fed various levels of broiler litter

	----------Broiler litter----------			
Parameter	**33**	**66**	**85**	**MSE**
Organic matter intake (g/d)	1231[a]	1029[b]	921[c]	109
Total flow (g/d)				
Abomasum	751	699	727	71
Ileum	496	457	444	145
Faecal	471	406	421	106
Quantity apparently digested (g/d)				
In rumen	480[a]	330[a]	194[b]	126
In small intestine	255	242	283	131
In large intestine	25	51	23	20
In total tract	760	623	500	140
Apparent digestion coefficients (% of organic matter intake)				
Rumen	39[a]	32[a]	21[b]	11
Small intestine	21	24	31	13
Large intestine	2	5	3	3
Total tract	62[a]	60[ab]	54[b]	21

*Means on the same row with the same superscripts are not significantly different ($p<0.05$).

Table 5.4: Feed dry matter intake and digesta flow in sheep fed diets containing broiler litter

	----------Broiler litter----------			
Parameter	**33**	**66**	**85**	**MSE**
DM intake (kg/d)	1.4	1.3	1.3	0.26
Digesta flow (l/d)				
Abomasum	18.31	20.87	18.50	12.34
Ileum	5.07	5.69	3.80	3.60
Faecal (g/d DM)	674[a]	621[ab]	662[b]	142

*Means on the same row with different superscripts are different at $p < 0.05$

Table 5.5: Nitrogen intake, flow and its apparent digestion by sheep fed various levels of broiler litter

	----------Broiler litter----------			
Parameters	**33**	**66**	**85**	**MSE**
Nitrogen intake (g/d)	43	41	37	28
Total nitrogen flow (g/d)				
Abomasum	27	27	26	8
Ileum	13	17	18	14
Faecal	11	14	15	5
Quantity apparently digested (g/d)				
Rumen	16^{a}	14^{ab}	11^{b}	5
Small intestine	14	10	8	6
In large intestine	2	3	3	4
In total tract	32	27	22	7
Apparent digestion coefficients (% nitrogen)				
Rumen	37	34	30	16
Small intestine	33	24	22	14
Large intestine	5	7	8	3
Total tract	74^{a}	66^{ab}	59^{b}	8

* Means on the same row with different superscript are significantly different ($p<0.05$).

Table 5.6: Nitrogen, non ammonia nitrogen, ammonia nitrogen flows and apparent digestion of nitrogen fractions in the gastrointestinal tract

	----------Broiler litter----------			
Parameters	**33**	**66**	**85**	**MSE**
Nitrogen flow (g/d)				
At abomasums	27	27	26	6
At ileum	13	17	18	14
Ammonia nitrogen flow (g/d)				
At abomasums	0.12	0.10	0.14	0.04
At ileum	0.09	0.05	0.07	0.02
Non ammonia nitrogen flow (g/d)				
At abomasums	27	27	26	9.5
At ileum	13	17	18	4.3
Microbial nitrogen flow (g/d)				
At abomasums	16^{a}	11^{ab}	7^{b}	5
Apparent disappearance (g/d)				
Rumen	16	14	11	5
Small intestine	14	10	8	6
Apparent digestion coefficients as % of nitrogen flow at abomasum				
Small intestine	52^{a}	37^{b}	31^{b}	7
NAN digestion (%intake N)	33	24	22	6

Means on the same row with different superscripts are different at $p < 0.05$

5.4 DISCUSSION

The dry matter intake of the 85 percent litter diet in the present study was very similar (1279 g / sheep / day) to 85 percent litter diet in the previous study (Chapter 3), viz. 1365 g / sheep / day. In the present study, despite the high inclusion rates of urea, especially in the 33 percent litter diet, feed and specifically organic matter intakes were higher than that in the 85 percent litter diet. In general, a recommendation in the USA seems to be that long hay should be added to litter containing diets to improve conditions in the rumen and improve feed intake (Fontenot, 1991; Patil *et al.*, 1995). This was evident in the present study.

In the present study 21 percent of the organic matter in the 85 percent litter diet disappeared in the rumen compared to 31 percent in the small intestine. This confirmed the result in the previous trial (Chapter 3) where 28 percent organic matter disappeared in the rumen and 48 percent in the small intestine. In Chapter 3 it was suggested that the change in site of digestion of organic matter was the result of a higher flow rate of digesta through the rumen at the higher level of feed intake, i.e. in the 85 percent litter diet. In the present trial the flow rate of organic matter through the rumen was higher (727 g/d) than those of the 100 and 92.5 percent diets in the trial in Chapter 3 (viz, 458 and 531 g/d) where no change in site of digestion was observed, but lower than the 1038 g/d for the 85 percent litter diet, the treatment in which the change was observed. In the present study the relative proportions of organic matter that disappeared in the rumen versus the small intestine were higher for the diet containing 66 percent litter, than for the 33 percent litter diet, suggesting a shift in site of digestion, even at lower level of litter

inclusion. These results, therefore, confirms the observation in the previous study, suggesting that some characteristic(s) of broiler litter in a high litter diet creates a situation that results in a biologically uncommon phenomenon where more organic matter disappears from the lower digestive tract than from the rumen. As has been mentioned in Chapter 3, this phenomenon would not necessarily really be beneficial to the ruminant depending on what components are actually escaping rumen microbial degradation, especially under drought feeding conditions.

The shift in site of digestion towards the lower digestive track was attributed to the small particle size of the litter, which may have contributed to an increased rate of passage (Chapter 3). Patil *et al.* (1995) demonstrated that ruminal digesta passage rates with diets high in broiler litter (i.e, 50%) may be slow when dietary roughage levels are minimal, with an accompanying low feed intake. In the present study feed intakes and organic matter digestibility increased with the inclusion of other the ingredients in diet, though the flow rate of the organic matter did not differ among treatments. This result is comparable to that reported by Rossi et al. (1998) when steers were fed litter diets composed of litter from different sources. Inclusion of grass hay, starch and molasses may be responsible for the difference observed.

In the previous trial (Chapter 3) a large proportion of the nitrogen in broiler litter disappeared from the rumen. However, at the 85 percent litter diet this proportion was substantially less than for the 92.5 and 100 percent litter diets. Since all the nitrogen in a ruminants diet should be digested in the lower digestive tract if microbial conversion of

nitrogen is efficient, it only shows that a large proportion of the nitrogen in the litter was highly rumen degradable and was lost from the rumen. The high inclusion rates of urea in the 33 and 66 percent diets to give isonitrogenous experimental treatments would explain the high apparent nitrogen digestion coefficients of these diets in the rumen.

Total apparent nitrogen digestion was recorded as 74, 66 and 59% for this trial. These results are comparable to those of Bhattacharya & Fontenot (1966) (72 to 74%), Patil *et al.* (1995) (67 to 73%) and Chaundry *et al.* (1996) (61 to 71%). It should be noted that these researchers used lower litter levels in their diets than in the present experiment.

Microbial synthesis in the rumen is controlled by the quantity of fermentable metabolisable energy in the organic matter digested in the rumen (AFRC, 1992). In the present experiment proportionally less microbial nitrogen was formed in the rumen of sheep fed the high litter (66 and 85 percent) diets ($p<0.05$) compared to the more normal diet (33 percent litter). The addition of molasses to the 85 percent litter diet in this experiment was not advantageous in terms of microbial nitrogen flowing at the abomasum as estimated by calculating it from the organic matter disappearance in the rumen. The apparent non-ammonia nitrogen digestion coefficients in the small intestine, when expressed as percent of abomasal non-ammonia nitrogen flow showed differences between treatment diets. The 33 percent litter diet indicated a higher true protein concentration flowing into the small intestine thus resulting in the 74% total track nitrogen digestion compared to the high litter containing (66 and 85 percent litter) diets. However, when non-ammonia nitrogen disappearance was expressed as a percent of intake nitrogen no differences between treatments were observed.