THE NUTRITIONAL VALUE OF BROILER LITTER AS A FEED SOURCE FOR SHEEP DURING PERIODS OF FEED SHORTAGE

BY

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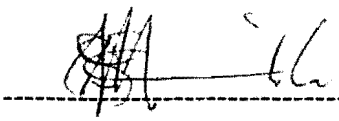
DECLARATION

I declare that this thesis is my own work. It is being submitted for the Doctor of Philosophy in the University of Pretoria. It has not been submitted before for any degree or examination at any other University.



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ABSTRACT

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ABSTRACT

The primary objective of the study was to evaluate the use of broiler litter as a survival feed for sheep. In growth and partial digestibility studies South African Mutton Merino wethers were used to investigate the utilization of broiler litter in sheep and the consequences it could have on the animals. Prior to each trial the sheep were vaccinated against botulism and it was ensured that the litter was well dried and free of lumps or dead chickens.

The crude protein concentration of the broiler litter obtained from different sources was approximately 200 g/kg, which is low comparing to published results elsewhere in the world. A surprisingly low uric acid concentration was measured in the one sample analysed. The litter did not contain abnormally high copper concentrations. One consignment of litter contained apparently a substantial proportion of soil that

accumulated in the rumens and abomasums of the sheep. The selenium in the litter proved to be highly bio-available in sheep.

In the first trials the sheep were kept in individual feeding pens and were fed experimental diets containing pure broiler litter or litter plus 7.5 or 15 percent molasses. The activity of different plasma enzymes and concentration of blood metabolites were measured. After an average of 83 days the wethers were slaughtered and carcass, liver and kidney weights were taken. Histopathological analyses were done on the tissues. The addition of 15 percent molasses to the litter resulted in a significant increase in feed intake. None of the enzymes showed activities above normal, neither did any of the blood metabolites indicate any abnormality in the sheep. Histopathological analyses and weights did not differ among treatments. The sheep in all three treatments increased in weight.

In a partial digestibility trial apparent digestion coefficients of nutrients in broiler litter and litter plus molasses were determined at different sites of the digestive tract. The addition of 15 percent molasses increased rate of passage of nutrients through the digestive tract and thus total dry matter intake. The result was that the site of digestion of organic matter shifted from the rumen to the small intestine, where a significantly higher proportion of the organic matter was digested compared to the treatment of pure broiler litter. The advantages or disadvantages of such a shift is not clear, though the phenomenon was confirmed in a second trial.

Up to 50 percent of the nitrogen in pure broiler litter and the litter plus 7.5 percent molasses diet disappeared from the rumen. Although a higher proportion of the nitrogen in the 15 percent molasses diet disappeared in the lower tract, because of the higher intake the total quantity of nitrogen absorbed from the rumen was similar to those in the other two diets. It was concluded that the bodies of sheep consuming diets with such high levels of broiler litter are heavily burdened with the catabolism of the excessive ammonia absorbed from the rumen.

In a growth study where 0, 33, 66 and 85 percent broiler litter was included in the diets, the growth rate of the wethers decreased significantly at 85 percent litter diet compared to the others. This was most obvious during the first 37 days of the trial, while the differences disappeared when the litter was fed for a longer period. It seemed as if sheep required a longer period than normal to adapt to diets high in broiler litter. This was also apparent during the first trial. The internal organs of sheep on high litter diets were heavier than organs from sheep on the diets containing no or 33 percent litter. It was suggested that such a phenomenon would mean that more energy would be required to maintain animals on high litter diets than at the lower diets. This would be undesirable in a survival feeding situation. No abnormal blood enzyme and metabolite levels were obtained also in this trial. All sheep were slaughtered at reaching a live weight of 55 kg and a taste panel evaluated the tensile properties of the mutton. At the addition of 15 percent molasses slight deviations in taste were observed.

It has been concluded that during periods of food shortage, sheep could be fed successfully on high levels of broiler litter, provided certain precautions are taken, e.g. the animals are vaccinated against botulism and that the product is dry enough to inhibit pathogenic growth. It seems as if the intake of litter may have to be restricted to approximately 1.5 percent of body weight and that the addition of molasses would only be necessary when the litter intake is unacceptably low.

KEYWORDS: broiler litter, sheep, droughts, emergency feeding, digestion, growth, carcass quality, ammonia, volatile fatty acids, dry matter

OPSOMMING

DIE VOEDINGSWAARDE VAN BRAAIKUIKENMIS AS VOERBRON VIR SKAPE TYDENS PERIODES VAN VOERSKAARSTE

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Die hoofdoel van die studie was om die gebruik van braaikuikenmis as oorlewingsrantsoen vir skape te evalueer. In groei- en parsiële verteringsproewe is Suid-Afrikaanse Vleismerino hamels gebruik en die benutting en gevolge van die voer van braaikuikenmis is ondersoek. Die diere is vooraf teen lamsiekte ingeënt en daar is verseker dat die mis goed droog was en klonte en kuikenreste uitgesif is.

Die braaikuikenmis uit verskillende bronne het ruproteïenvlakke van ongeveer 200 g/kg droë materiaal bevat, wat laag was in vergelyking met oorsese waardes. 'n Merkwaardige lae vlak van uriensuur is in die een monster wat ontleed is, gemeet. Die kuikenmis het geen abnormale hoë vlakke koper bevat nie. Een besending mis het skynbaar groot hoeveelhede grond bevat, want die grond het in die rumen en abomasums van die skape aangesamel. Die selenium in die kuikenmis het 'n hoë bio-beskikbaarheid in die diere gehad.

In die eerste proewe is die diere in individuele voerhokke gehou en het proefrantsoene ontvang wat bestaan het uit suiwer braaikuikenmis, of kuikenmis plus 7.5 of 15 persent melasse. 'n Verskeidenheid van plasma-ensieme en bloedmetaboliete is tydens die proef ontleed. Na 'n

gemiddeld van 83 dae is die hamels geslag en karkas, lewer en niergewigte is gemeet. Monsters van die weefsels is ook vir histologiese evaluering geneem. Die byvoeging van 15 persent melasse tot die mis het 'n dramatiese verhoging in voerinname tot gevolg gehad. Geen van die ensieme se aktiwiteite of die vlakke van bloedmetaboliete het egter enige abnormaliteite getoon nie. Die skape in aldrie die behandelings het toegeneem in gewig. Histopatologiese ondersoeke en orgaangewigte het ook geen verskille tussen behandelings getoon nie.

In 'n parsiële verteringsproef is die skynbare vertering van nutriënte in hoedermis en in mis plus melasse op verskillende punte in die spysverteringskanaal bepaal. Weereens het die byvoeging van melasse die inname van hoendermis drasties verhoog. Die byvoeging van 15 persent melasse het 'n betekenisvolle toename in spoed van deurvloei van spysverteringskanaalinhoud deur die spysverteringskanaal tot gevolg gehad. Dit het veroorsaak dat 'n betekenisvolle hoër persentasie van die organiese materiaal in die laer spysverteringskanaal verdwyn het as in die rumen, in teenstelling met die situasie by die lae of geen melassebyvoegingsgroepe. Die voor- of nadele van so 'n verskuiwing was nie duidelik nie. Die neiging is met 'n opvolgproef bevestig.

Tot 50 persent van die stikstof in hoendermis het met die suiwer hoendermis en 7.5 persent melasse diëte vanuit die rumen verdwyn. Hoewel 'n hoër persentasie stikstof van die 15 persent melasse dieet in die laer spysverteringskanaal verdwyn het, was die totale hoeveelheid stikstof wat uit die rumen absorbeer is, soortgelyk aan die van die ander twee diete. Dit is afgelei dat die liggame van al die skape op die hoë braaikuikenmis diëte, swaar belas was met die metabolisering van die oormaat absorbeerde stikstof.

In 'n groeistudie waar 0, 33, 66 en 85 persent braaikuikenmis in die rantsoene was, is gevind dat die groei van hamels betekenisvol laer was as die dieet uit 85 persent kuikenmis bestaan het. Hierdie verskynsel was veral merkbaar tydens die eerste 37 dae van die proef, en het daarna feitlik verdwyn. Dit wou voorkom, ook uit die eerste proef, asof die skape 'n langer as normale periode nodig gehad het om by die hoë hoendermisdiëte aan te pas. Die inwendige organe van die diere op die hoë misrantsoene was swaarder as dié in die ander behandelings. Dit is voorgestel dat so 'n enegievereisende verskynsel tydens oorlewingsvoeding ongewens is en dat dit wenslik is dat laer vlakke van hoendermis verskaf moet word. Ook in hierdie proef is geen abnormale ensiem en bloedmetabolietvlakke waargeneem nie. Die skape in hierdie proef is almal op 'n eindgewig van 55 kg geslag en 'n proe-paneel het die smaaklikheid van die vleis evalueer. Teen die 15 persent melassse-byvoegings kon geringe smaakafwykings van die normale waargeneem word.

Daar is tot die slotsom gekom dat skape tydens tye van voedselskaarste suksesvol vir oorlewing op diëte wat hoë vlakke braaikuikenmis bevat, kan gedy. Sekere voorsorgmaatreëls is egter noodsaaklik, soos inenting teen lamsiekte, dat die produk droog moet wees en dat die misinnames laag moet wees, nie meer as 1.5% van liggaamsmassa nie. Die byvoeging van melasse mag slegs nodig wees as kuikenmisinname onaanvaarbaar laag is.

CHAPTER 1

1.0 REVIEW OF LITERATURE

1.1 GENERAL INTRODUCTION

In the 1950's, poultry waste emerged in the USA as an alternate source of nitrogen in ruminant nutrition (Fontenot, 1991). The product has been classified into two main types because of their distinct differences in composition: broiler litter, consisting of the excreta (urine and faeces) from broilers kept on deep litter systems with "bedding" material, and pure poultry excreta from layers housed in battery cages (dried caged poultry waste)(Fontenot & Jurubescu, 1980). Broiler litter differs in composition from layer manure mainly because of the differences in diets fed and the bedding material that is mixed with the broiler excreta.

The dramatic growth of the poultry industry over the last 40 years created a serious waste disposal problem. The utilisation of the waste through ruminant animals became a convenient option of disposing of the waste. The product is readily accepted by the cattle and sheep farmer, not because of any superior feeding qualities, but simply because it is cheaply available.

The feeding of poultry waste prompted active research in the USA on the use of the product. Aspects such as its nutritive value, its effect on the health of the animal and the human and suitable methods of processing the waste have been investigated (Belasco, 1954; Brugman *et al.*, 1954; Ammerman *et al.*, 1966; Bhattacharya & Fontenot, 1966;

Bhattacharya & Taylor, 1975; Smith *et al.*, 1978). Guidelines have been compiled on the use of poultry waste as a ruminant feed (Fontenot, 1991; Carter & Poore, 1998; Crickenberger & Goode 1998). Presently, the main thrust in research in the USA seems to be on methods of processing and storing of the product and effects there-of on nutritive value (Carter & Poore, 1998; Kwak *et al.*, 1998).

World wide, research has been conducted on the use of poultry excreta as an animal feed, e.g. in the 1990's research continued in Africa (Manyuchi *et al.*, 1992; Ngongoni & Manyuchi, 1993) and in the Middle East (Deshck *et al.*, 1998; Brosh *et al.*, 1998).

In South Africa the first report of cattle fed poultry manure, appeared in a farmer's magazine in 1960 (Anonymous, 1960). In the 1970's results of a number of investigations on the feeding and use of the product have been reported (Bishop *et al.*, 1971; Van der Westhuizen & Hugo, 1972; Bosman, 1973; Van der Merwe *et al.*, 1975; Van Ryssen *et al.*, 1977; Kargaard & Van Niekerk, 1978). In 1980 legislation was introduced to control the feeding of the product in South Africa (Act 36 of 1947), stipulating that poultry waste products may only be sold as a livestock feed if the specific product is registered with the Registrar of Feeds as an animal feed, complying to specific nutritional and hygienic standards (Government Gazette, 1980). Despite that, unregistered poultry waste was and is still used extensively by farmers, both as a winter supplement and as an ingredient in feedlot rations (Kitching, 1986; Van Ryssen, 1988). This resulted in strong opposition to the feeding of the product because of major health concerns, and also from private feed companies whose turn-over in sales of protein supplements was affected detrimentally

(Kitching, 1986; Van Ryssen, 1988). Probably because of this, since 1980 research in South Africa focused mainly on possible harmful effects of poultry manure as a livestock feed (Ogonowski *et al.*, 1984; Nel, 1989; Fourie *et al.*, 1991; Van Ryssen, 1991; Van Ryssen *et al.*, 1993; Bastianello *et al.*, 1995).

1.2. COMPOSITION OF POULTRY WASTE

Poultry waste, in general, is classified as a bulky protein supplement (Kitching, 1986). The product is of an alkaline nature with a positive cation-anion balance (Pugh *et al.*, 1994), resulting in a high buffering capacity in the rumen of animals.

1.2.1 Crude protein

Relatively high crude protein (nitrogen X 6.25) concentrations of up to and over 300 g/kg dry matter (DM) have been reported (Bull & Reid, 1971; Flegal & Zindel, 1970; Hodgetts, 1971; Polin *et al.*, 1971; Fontenot & Jurubescu, 1980). The crude protein consists of both true protein nitrogen and non-protein nitrogen, with uric acid the main non-protein nitrogen constituent in poultry wastes (Noland, 1955; Ruffin & McCaskey, 1998). In manure containing 68 g/kg nitrogen, 26 to 34 g/kg units consisted of uric acid and 21 g/kg units of amino acid nitrogen (Smith *et al.*, 1978). Other non-protein nitrogen components in manure include ammonia, urea and creatinine (Fontenot & Webb, 1974). Caged layer manure analysed by Fontenot & Webb (1974) contained 41 g amino acids /kg DM and 59 g non-protein nitrogen /kg DM. The total nitrogen in poultry waste analysed by Jakhmola *et al.* (1988) contained 49 to 60 g/kg, and that of Ruffin & McCaskey (1998) over 40 g/kg non-protein nitrogen. Bhattacharya & Fontenot (1966) observed that the

true protein in peanut hull and wood-shaving broiler litter is high in glycine and somewhat low in arginine, lysine, methionine and cystine compared to lucerne hay.

1.2.2 Ash and minerals

Broiler litter is not only recognised as a crude protein supplement, but also as a mineral source for beef cattle (Doctorian & Evers, 1998).

Differences in ash content between layer and broiler wastes is to be expected because of the difference in composition of the feed fed to the two classes of birds (Benne, 1970). According to Deshck *et al.* (1998) the total ash concentration of layer manure is approximately twice as high as that in broiler litter. Dehydrated cage layer waste contained 280 g ash /kg DM (Benne, 1970). Brugman *et al.* (1964), Bhattacharya & Fontenot (1966) and Fontenot *et al.* (1971) reported ash concentrations in broiler litter of approximately 150 g/kg DM versus 280 g/kg in dry layer waste. In South African samples Van Ryssen *et al.* (1993) measured an average ash concentration in dried broiler litter of 137 g/kg versus 350 g/kg DM in layer manure. Silva *et al.* (1976) cited an ash content of 600 g/kg in dried poultry waste, but attributed this high concentration to the charring of the product during drying.

Ash in layer manure consists largely of calcium and phosphorus, constituting 88 and 25 g/kg DM respectively (Long *et al.*, 1969; Flegal & Zindel, 1970; Hodgetts, 1971; Polin *et al.*, 1971). Similarly, South African layer manure samples contained 88 g calcium and 23 g phosphorus /kg DM (Van Ryssen *et al.*, 1993). Fontenot & Jurubescu (1980) and Van

Ryssen *et al.* (1993) measured calcium and phosphorus concentrations in broiler litter of 24 and 18, and 25 and 15 g/kg DM, respectively. According to a report by Fontenot & Jurubescu (1980) dehydrated cage layer waste contained 6.7 g magnesium, 9.4 g sodium, 23.3 g potassium, 150 mg copper, 406 mg manganese and 463 mg zinc /kg DM. In the same report broiler litter contained 4.4 g magnesium, 5.4 g sodium, 17.8 g potassium, 451 mg iron, 98 mg copper, 225 mg manganese and 235 mg zinc /kg DM. Westing *et al.* (1985) measured mineral concentrations of broiler litter of 37 g calcium, 6.3 g magnesium, 37 g potassium, 6.6 g sodium, 1023 mg iron, 593 mg copper, 271 mg manganese and 496 mg zinc /kg DM.

1.2.3 Available energy

Bhattacharya & Fontenot (1966) reported a digestible energy value of broiler litter of 10.21 MJ /kg DM for sheep, that of dehydrated layer waste 8.00 MJ /kg DM and that of Lucerne hay 10.37 MJ / kg DM. Bhattacharya & Taylor (1975) cited dehydrated layer manure samples containing a digestible energy concentration of 8.37 MJ /kg DM for sheep and cattle. A digestible energy value of layer manure for cattle was found to be 7.85 MJ /kg DM (Bull & Reid, 1971) and for sheep 8.00 MJ /kg DM with a total digestible nutrient (TDN) value of 573 g/kg (Tinnimit *et al.*, 1972). Bhattacharya & Fontenot (1966) also measure a metabolisable energy value of 9.13 MJ /kg broiler litter, which did not change when bedding material was changed from wood shavings to peanut hulls. However, when citrus pulp was used as bedding material, the digestible and metabolisable energy values increased (Malik & Bhattacharya, 1971).

1.2.4 Fat and fibre

Studies by Long *et al.* (1969), Bull & Reid (1971), Flegal & Zindel (1971) and Hodgetts (1971) reported low fat (20 g/kg) and relatively high crude fibre (127 g/kg) concentrations in dried layer waste. Similarly, broiler litter contained 33 g fat and 168 g crude fibre /kg DM (Brugman *et al.*, 1964; Bhattacharya & Fontenot, 1966; Fontenot *et al.*, 1971).

1.2.5 Vitamins

The literature is silent on vitamin content of broiler litter.

1.3 ANIMAL PERFORMANCE

Poultry litter has been successfully used as a protein supplement for gestating-lactating ewes (Noland *et al.*, 1955; Fontenot *et al.*, 1971), wintering cattle (Fontenot *et al.*, 1964), growing lambs (Galmez *et al.*, 1970) and fattening cattle (Southwell *et al.*, 1958; Drake *et al.*, 1965; Harmon *et al.*, 1975; Cullison *et al.*, 1976). Cullison *et al.* (1976) reported no differences in the performance of steers receiving dried broiler excreta as 0, 50 and 100 percent of their supplemental protein. The daily weight gains were observed as 1.20, 1.18 and 1.11 kg, respectively, for 0, 50 and 100 percent dried broiler litter diets. Chester-Jones *et al.* (1972) observed that cattle fed diets of corn silage supplemented with soybean meal, deep-stacked or ensiled broiler litter, gained 1.09, 1.07 and 1.01 kg/day, respectively. In another study, cattle were fed a hay concentrate based diet with 0, 20, 40 and 60 percent ensiled or deep-stacked litter (dry bases). The incorporation of 60 percent litter decreased dry matter intake below that of the control. The average daily gains of the cattle on the 20 percent deep-stacked litter (1.03 kg) or 20 percent ensiled litter (0.92 kg)

were higher than for those on the control (0.94 kg). Cattle fed 40 percent ensiled litter in their diet had similar gains to the 0 percent litter control (0.92 kg). Gains were lowest for steers fed the 60 percent level of deep-stacked (0.58 kg) and ensiled (0.55 kg) litter compared to the control. Feed conversion efficiency was similar for the control, 20 and 40 percent litter diets, however, decreased markedly at the 60 percent level.

1.4. POTENTIAL PROBLEMS AND RISKS OF FEEDING POULTRY WASTES

Bishop *et al.* (1971) described the using of poultry manure as a supplement and as a complete feed for sheep in South Africa. Forced by drought and total lack of edible roughage, one farmer fed 2000 sheep molasses-moistened laying-hen manure as their total diet. After one month the ewes that were close to lambing developed a lameness of the limbs and could not move about. The farmer lost 50 sheep. Some ewes that developed abnormalities, recovered when the proportion of litter in the diet was reduced to 400 kg manure in a diet with 400 kg sawdust, 180 kg maize meal and 56 kg molasses.

Within 8 weeks of feeding diets containing from 45 to 60 percent dried battery waste to weaning lambs (Angus *et al.*, 1978) lower feed intakes were reported, with concomitant hypoalbuminaemia, ascites, centrilobular necrosis and fibrosis of the liver. They also found that the feeding of high levels of broiler litter caused damage of renal tubular epithelial cells in the lambs. This could not be explained but was suggested to be due to lowered resistance because of kidney infection.

These serve as examples that problems can be anticipated in the animal consuming the poultry waste. However, the user should be aware also of health risk to humans consuming the products from animals fed the poultry waste. In the present investigation the effect of including high levels of broiler litter in sheep diets, were studied. Any problems associated with the feeding of litter would be accentuated under such conditions. Therefore, a review of the literature regarding risks and health aspect in the feeding of poultry excreta has been conducted. Potential problems are related to nutrition, and the transfer of diseases, drug and drug residues between the product and the animal.

1.4.1 Nutritional

Variation in composition

Poultry waste is a variable product which does not have a constant composition and feed value (Oosthuizen, 1979). The variation in composition complicates the formulation of rations with the product. Therefore, the product must be analysed to ascertain its chemical composition, especially the crude protein and ash concentrations, before it can be used in formulating animal rations (Brosh *et al.*, 1998).

Differences in composition of broiler litter will be affected by the duration of storage, age and strain of birds and the diets fed to the birds (Shuller, 1976). Furthermore, the composition of broiler litter will vary with different sources of bedding which may include maize cobs, peanut hulls, rice hulls, wood shavings, soybean hulls and straw (Ammerman *et al.*, 1966). Other bedding materials include sunflower husks and mature veld hay (Ngongoni & Manyuchi, 1993). The proportion of bedding material in the

manure has an influence on the composition of the final product which depends on the amount used, the density of birds on the floor and the duration of their stay in the houses (Van Ryssen *et al.*, 1977; Goetsch *et al.*, 1998). In South Africa the standard practice is to remove the litter from the houses after each batch of broilers. The method of processing will influence the composition of the litter (Jakhmola *et al.*, 1988).

An analysis of samples from various parts of South Africa indicated crude protein concentrations ranging from 100 to 300 g/kg, ash from 150 to 580 g/kg, moisture from 80 to 240 g/kg, phosphorus from 9 to 20 g/kg and potassium from 6 to 20 g/kg DM (Oosthuizen, 1979).

Moisture content

Fresh droppings from caged layers can contain up to 700 g moisture/kg DM, while well dried and cured manure will contain less than 100 g moisture/kg DM (Oosthuizen, 1979). Kitching (1986) reported 60 to 240 g/kg moisture in broiler litter. Factors affecting the moisture content include climate, ventilation in houses, diet of birds, condition of storage, processing and drying practice. A high moisture content causes not only problems with storage and transport of the product, but creates an ideal medium for pathogens to grow in. This is discussed in a later section.

Bulkiness and transport

Poultry litter is a bulky product and its transportation may be expensive when considered per unit nutrients. Bulkiness depends on moisture content and proportion and kind of

bedding material present. At a 70 percent moisture the volume of manure is 1 M^3/ton while with 20 percent moisture it is 2 to 2.5 M^3/ton (Van Ryssen, unpublished).

Crude protein

Poultry litter is a good source of non-protein nitrogen for ruminants (Smith & Calvert, 1976; Caswell *et al.*, 1978; Smith *et al.*, 1979), but according to Fontenot (1971) does not contain enough available energy for the rumen micro-organisms to utilise the nitrogen. Oltjen *et al.* (1968) observed that uric acid is broken down in the rumen at a slower rate compared to urea and consequently most of the ammonia is intercepted by the rumen micro-organisms, thus reducing the risk of ammonia toxicity of the ruminant. At high intakes of litter, high concentrations of ammonia will occur in the rumen. A proportion of the ammonia, depending on the rumen pH, would be absorbed through the rumen wall and be processed in the liver to urea (Symonds *et al.*, 1981). Silanikove & Tiomkin (1992) observed liver damage in cows fed poultry manure as the sole overwintering diet and attributed this to the high ammonia concentrations in the rumen due to non-protein nitrogen catabolism. However, Rossi *et al.* (1998) suggested that the liver damage observed by Silanikove & Tiomkins (1992) could have been due to copper toxicity.

Jordan & Swanson (1979) observed an increase in days from calving to conception and in number of services per conception in dairy cows with increasing concentrations of crude protein in the diets. They insinuated that the high plasma urea and ammonia concentrations increased the pH in the reproductive tract and thus reduced the motility and survival of sperm. Polman *et al.* (1981) confirmed these observations on reproductive

performance and speculated that production of ammonia or other substances in the rumen may reduce fertility by lowering plasma progesterone. Erb *et al.* (1976) reported reduced reproductive performance when dairy cows consumed 450 g/day urea and their data implicated ammonia. The above experiments may imply that if the feeding of broiler litter to cows result in elevated rumen and blood ammonia concentrations, it may have negative effects on fertility in cows. Also, the elevated rumen and blood ammonia concentrations may represent a drain on energy required to catabolize the ammonia .

Minerals

An abundance of most minerals is present in poultry excreta (Westing *et al.*, 1985) and it is an excellent source of minerals to the animal (Ruffin & McCaskey, 1990). Van Ryssen *et al.* (1993) concluded that "relatively high even toxic levels of some minerals can be present in manure" when they analysed poultry manure from South African sources. Since many of the toxic symptoms of minerals are induced deficiencies of other minerals, Van Ryssen *et al.* (1993) suggested that such deficiencies may not necessarily occur when poultry excreta is fed because of the high concentration of most minerals in the product.

Calcium and phosphorus

The calcium concentration of the South African broiler litter was 25 g/kg and in layer manure 88 g/kg and that of phosphorus 15 and 23 g/kg DM, respectively (Van Ryssen *et al.*, 1993). These calcium and phosphorus concentrations are well above the requirements of beef cattle and sheep (NRC, 1980; Ruffin & McCaskey, 1990). Ruffin & McCaskey (1990) indicated that, if brood cows are fed an 80 percent litter and 20 percent grain diet,

they will consume five times more calcium, phosphorus and potassium than required. The problem typically associated with high dietary calcium concentrations is milk fever (parturient paresis) which has been observed in beef cows at parturition (Kitching, 1986; Silanikove & Tiomkin, 1992; Pugh *et al.*, 1994; Rude & Rankins, 1997). Combined with the hypocalcaemia in cows on high litter diets, hyperphosphataemia was observed as well (Silanikove & Tiomkins, 1992; Rankins *et al.*, 1993). Feeding of broiler litter to pregnant cows has been shown to suppress serum calcium concentration even though calcium retention in the body of cows was increased (Muirhead, 1996; Rude & Rankins, 1997). The suppression of serum calcium concentration is as a result of continued deposition of calcium in the bones even at a time when the demand for it in milk synthesis was high (Muirhead, 1996). Feeding of hay together with broiler litter diets was found to minimise this potential problem (Muirhead, 1996).

Copper

Copper sulphate is included in broiler diets at a level of approximately 150 mg copper/kg feed to act as a growth promotant and fungicide (Fisher *et al.*, 1972; Vest & Dyer, 1993). Consequently, the excreta of these birds contains high concentrations of copper (Rankins *et al.*, 1993; Vest & Dyer, 1993) which could induce copper toxicosis in ruminants consuming the excreta. Fontenot *et al.* (1971) and Webb *et al.* (1973) reported cases of copper toxicity in sheep consuming diets high in poultry manure. In response to a problem of copper toxicity among sheep consuming poultry manure, Van Ryssen *et al.* (1977) conducted a survey of the mineral concentration of poultry manure samples in South Africa. They measured copper concentrations of up to 570 mg /kg DM in broiler

litter samples, but averages of 36 and 47 mg/kg DM in pure battery manure and in litter from pullets and broiler breeders on deep litter systems respectively. In a more comprehensive survey conducted in the early 1990's, Van Ryssen *et al.* (1993) observed that none of the litter samples contained high concentrations of copper. They concluded that the feed manufacturers in South Africa apparently discontinued the inclusion of copper sulphate in their poultry diets.

Legislation in South Africa stipulates that both broiler litter and layer excreta shall not contain more than 50 mg copper/kg, if it is to be registered as an animal feedstuff (Government Gazette, 1980). Even within these legal limits, the copper concentration in broiler litter is vastly above the copper requirements of sheep (NRC, 1985), the species of farm animals most susceptible to copper toxicosis. However, Van Ryssen & Jagoe (1982) found no increase in copper accumulation in the livers of sheep receiving rations containing up to 36 percent litter with a copper concentration of 17.8 percent in the final ration. They concluded that many of the antagonists to copper metabolism in the ruminant, such as zinc, iron, sulphur and molybdenum plus sulphur are usually present at high concentrations in litter and would reduce the availability of copper in the product. Furthermore, most of the sheep breeds (the Merino types) in South Africa are quite resistant to copper toxicosis compared to breeds in the United Kingdom and Europe (Harrison *et al.*, 1987). In contrast to the situation in South Africa, it seems as if copper sulphate is included extensively in poultry diets in the USA. Broiler litter collected in the State of Alabama, USA had an average copper concentration of 473 mg/kg, ranging from 25 to 1003 mg/kg (Ruffin & McCaskey, 1998). Westing *et al.* (1985) recorded a copper

concentration in broiler litter of 593, Vest & Dyer (1993) a concentration of 558 and Olson *et al.* (1984) a concentration of 257 mg/kg DM. At concentrations of between 262 and 272 mg copper /kg broiler litter, Rankins *et al.* (1993) observed a linear increase in the liver copper concentration of steers with the increasing addition of dietary broiler litter, though observed no signs of toxicity among the cattle. In cattle the high copper intake through litter is usually not a problem (Fontenot, 1991). However, Banton, *et al.* (1987) reported cases of copper toxicosis in cattle fed chicken litter containing 620 mg copper/kg DM. It can be concluded that, presently, copper toxicosis due to the consumption of broiler litter by sheep should not be a serious problem in South Africa.

Arsenic

Arsenicals are used for the treatment of specific diseases but when used at low levels may have growth promoting properties (Calvert, 1971). Drugs and growth promotants containing arsenic such as arsanilic acid or sodium arsanilate, arsenobenzene, 3-nitro-4-hydroxyphenylarsonic acid and 4-nitrophenylarsonic acid are included sometimes in broiler diets (Calvert, 1971). This can result in the excretion of arsenic residues in the manure (Calvert, 1974). Except for manure samples from free-range poultry, Van Ryssen *et al.* (1993) did not measure high arsenic concentrations in poultry excreta collected in South Africa. The average concentration for the South African samples was 4.9 mg/kg DM. Westing *et al.* (1985) reported a concentration of 76 mg arsenic /kg DM in broiler litter.

Feeding of arsenical has been reported to increase liver arsenic concentration in cattle. However, the levels were lower than the accepted minimum safe levels (Webb & Fontenot, 1975). Calvert (1973) observed that most of the arsenic was excreted by sheep with minimal retention in the body when 14 percent chicken manure containing 42 mg/kg arsenic was included in a sheep ration. Calvert & Smith (1972) observed no increase of arsenic in milk from cows consuming 40 mg arsenic per cow per day through the consumption of broiler manure. No detectable arsenic could be found in the liver, heart, spleen, 12th rib, kidney, kidney fat or brain tissue of lambs fed poultry litter supplemented with 3-nitro-4-hydroxyphenylarsonic acid (Brugman *et al.*, 1968). Arsenic in drinking water (5 ppm) prevents selenium toxicity (Lloyd *et al.*, 1978).

Selenium

Relatively high concentrations of selenium have been recorded in poultry manure. In the South African sources Van Ryssen *et al.* (1993) reported concentrations of 0.62 and 0.24; 0.47 and 0.25; 0.42 and 0.22 mg selenium /kg DM in broiler litter, pure laying hen manure and pullet litter, respectively. Similarly, high concentrations were measured elsewhere, e.g. 1.09 mg selenium (Westing *et al.*, 1985) and 0.95 mg selenium (Ben-Ghedalia *et al.*, 1996) /kg dry poultry litter. However, it is claimed that selenium in animal excreta is relatively unavailable to plants and animals (Allaway, 1973; Stowe & Herdt, 1992; Ullrey, 1992). Whether this is true for the selenium in poultry excreta, has not been established.

Iron

Broiler litter has been reported to contain 1335 mg iron /kg DM (Van Ryssen, 1993). Similar iron concentrations were reported by other researchers (Essig, 1975; Westing *et al.*, 1985, Ruffin & McCaskey, 1990). Van Ryssen *et al.* (1993) pointed out that the level of iron in the survey samples was well above the requirement of the ruminant. Although iron is necessary in biological systems, it is a potent oxidant or pro-oxidant that can adversely affect cell function (Pitzen, 1994). Pitzen (1994) concluded that the rancid off-flavour observed in milk from cows was as a result of high iron intake. Cows on a high iron diet tended exhibit silent heat, soar feet and uterine infection (Pitzen, 1994). Furthermore, Valdivia *et al.* (1982) indicated the main toxic effect of iron and aluminium to be induced deficiencies of other minerals.

Ash content

According to Brosh *et al.* (1998) the commercial value of poultry litter is based on its crude protein and ash content. Ash is diluting the concentration of other nutrients in broiler litter. Broiler litter high in ash content has the possibility of a notable amount of litter remaining in the rumen by settling to the bottom (Brosh *et al.*, 1998). It has been suggested that a high quantity of ash rich organic matter complex would probably sink to the bottom of the rumen thus interfere with normal rumen motility and the movement of particles to the rumen omasum orifice (Brosh *et al.*, 1998). Consequently, rumen particulate emptying and dry matter intake would be reduced and mean retention time (MRT) extended (Brosh *et al.*, 1998). The main factor that limits intake of a high ash diet

is the ability to mobilise and dispose of the complex. No serious health problems have been attributed to high ash content in diets for livestock.

1.4.2 Gastro-intestinal impaction

Problem of bloat

The physical and chemical nature of broiler litter, e.g. small particle size, high solubility and high density of insolubles is conducive to lack of ruminal stimulation with a low saliva flow and a low voluntary intake (Patil *et al.,* 1995; Rossi *et al.*, 1996). A consequence of this is the occurrence of bloat in cattle on high litter diets (Ruffin & McCaskey, 1998). A standard recommendation in the USA is that long hay must be supplied when cattle are fed diets high in broiler litter (Fontenot, 1991; Ruffin & McCaskey, 1998).

1.4.3 Transmitting of drug residues

Fontenot & Webb (1975) and McCaskey & Anthony (1979) have reviewed the health aspects of feeding poultry wastes or animal wastes and regulatory considerations in the use of animal wastes as feedstuffs. Poultry waste, just like any other animal feedstuff, is a potential source of bacteria, fungi, viruses, parasites and chemical residues (mycotoxins, pesticides, hormones, toxic minerals and medicinal drugs). Thus, precautions when utilisation of poultry wastes as feedstuffs should be taken to eliminate the potential health problems that may result from using poultry wastes as feedstuff.

Parasites

Internal parasites are not transmitted from poultry to ruminants (Wuethrich, 1978). They can be transmitted from poultry to poultry if unprocessed manure is included in poultry diets. Kitching (1986) mentioned a case where the carcasses of cattle that received broiler litter were infested with measles. It turned out that the litter was contaminated with human excreta because farm labourers used the poultry house as a toilet.

Fungi, bacteria, pathogens and toxins

Poultry litter is an ideal medium for the development of fungi. Lovett *et al.* (1971) reported 17 different types of fungi in poultry litter from commercial poultry enterprises. The most abundant of these fungi included *penicillum, aspergillus*, *scopulariopsis* and *candida*. Mycotoxins produced by *Aspergillus* species are most likely to be a problem, especially if the litter fed to animals is damp. Presence of aflatoxins in poultry feed, poultry litter samples and the livers of chickens has been reported in South Africa (Westlake & Dutton, 1985).

According to Bhattacharya & Taylor (1975) poultry are potential carriers of several human pathogens, which have been found in poultry waste. These include the following: viruses of New Castle disease and Chlamydia which, respectively, cause conjunctinitas and pneumonia in human; *Erysipelothrix rhusiopathia*, which produces erysipelas; *Listeria monocytogenes*, the agent causing listerosis; *Mycobacterium avium*, one of the agents that occasionally produces human tuberculosis or causes tuberculin sensitivity without disease; *Candida albicans*, the causative agent of a fungal disease, candidiasis, with symptoms of oral lesions, vaginitis, skin lesions and bronchopulmonary infection;

Aspergillus fumigatus, which causes rhinitis, asthma and chronic pulmonary disorder; *Clostridium botulinum*, which produces food poisoning and *Salmonella* spp., which causes enteritis infection in man.

Ogonowski *et al.* (1984) analysed 813 South African fresh poultry manure and litter samples for the presence of micro-organisms. The micro-organisms found included *Clostridia* species in 0.37 percent, E. coli in 0.49 percent, *Staphylococcus* in 0.25 percent and *Salmonella* in 12.3 percent of the samples. The *Clostridia* species produces botulism causing toxins. Botulism is a common problem in ruminants eating unsterilised poultry litter. The source of the *Clostridia* species is dead rodents, chicks, partly hatched eggs, etc. found in the manure/litter (Oosthuizen, 1979). The *Clostridia botulinum* produces a deadly toxin which easily contaminates the litter (Oosthuizen, 1979). It is important that animals be vaccinated twice against botulism before they are fed litter, five weeks and one week before the start of feeding the litter (Van der Lugt *et al.*, 1996).

Products of animal origin can be a source of *Salmonella* infection. However, the pathogen is destroyed by heat and dehydration and should not be a problem if the litter fed, is dry (Wuethrich, 1978).

Processing of the litter destroys pathogens and improves the keeping quality and palatability of the litter (McClure & Fontenot, 1987; Lober *et al.*, 1992; Chaudhry *et al.*, 1996). Fontenot & Webb (1974) indicated that pathogens such as *Arizona* spp., *Salmonella pullorum, S. typhimurium* and *Escherichia coli* were destroyed by mild heat

treatment. Jacob *et al.* (1998) demonstrated that pathogenic bacteria intentionally added to litter at levels higher than normally encountered in infected litter were killed when litter was deep stacked for 5 days. Knight *et al.* (1977) showed that deep stacking of broiler litter increased the litter temperature by over 60^0 C and thus destroyed *coliform, mycobacterium* and *clostridia* bacteria. Hovatter *et al.* (1979) reported that pathogens were eliminated by deep stacking the litter alone. A similar result was indicated by Caswell *et al.* (1977) when the litter was ensiled at different moisture levels alone or in combination with high moisture grain. Carter & Poore (1998) recommended that the litter be deep stacked for at least three weeks.

1.4.4 Carry-over of drugs

Pesticides

Pesticides are sometimes used in poultry houses or are applied on the litter to combat insects in the manure. Messer *et al.* (1971) reported the presence of DDT and DDE in 10 poultry litter samples. Fontenot *et al.* (1971) found negligible amounts of pesticides in broiler litter and suggested that the feeding of rations containing 25 or 50 percent broiler litter did not have a substantial effect on pesticide accumulation in the liver or omental fat of cattle. Similar results were reported by El-Sabban *et al.* (1970) when steers were fed processed hen manure. It seems from the literature that pesticide residues in the litter do not seriously handicap the use of poultry waste as a feedstuff.

Drugs and residues

Drugs are used for medicinal purposes and improvement of growth and feed efficiency (Fontenot & Jurubescu, 1980). Webb & Fontenot (1975) observed that medicinal drugs were present in broiler litter when broiler diet composition included medicinal drugs. Elmund *et al.* (1971) reported as much as 75 percent of chlortetracycline in the diet being excreted in the manure by steers. Messer *et al.* (1971) found levels ranging from 10.2 to 25.1 mg/kg of furazolidone and 4.5 to 26.7 mg/kg nitrofurazone in litter samples taken from different poultry farms. However, the residues (chlortetracycline, micarbazin and amprolium) have not been reported to accumulate in edible tissue of finishing steers slaughtered after a five-day withdrawal period (Webb & Fontenot, 1975). This suggests that at least a five-day withdrawal period is required before slaughter when poultry waste is fed to finishing steers. In USA a 15 day withdrawal period before slaughter is required on animal waste containing drug residues if it is destined for feeding, and must carry a label to that effect (Ruffin & McCaskey, 1998). Since these nitrofurans do not accumulate in body tissue, there is a possibility that these compounds may appear in fairly large quantities in poultry manure (Calvert, 1971). However, what effect they might have on the animal consuming the manure is not known. Bare *et al.* (1964) studied low levels of bacitracin and penicillin and found that after continuous feeding of 11 mg/kg of bacitracin and 44 mg/kg penicillin there was a marked difference in the amount of these two compounds in the intestine, with the level of bacitracin remaining unchanged. It appeared that bacitracin was more resistant to deactivation compared to penicillin. From these results it would appear that some antibiotics are excreted in fairly large quantities and

others are not. If poultry waste is fed to cattle, sheep and goats the carry-over effect of these antibiotics contained in broiler litter needs to be understood.

Compounds like quaternary ammonium, sodium propionate and nystatin are added to feeds to prevent mould growth (Calvert, 1971). However, the amounts are small and it is unlikely that they may present problems to the animals eating the litter.

Broad spectrum, absorbable antibiotics are the same as mentioned above, but they are used at higher levels for short periods. They are used for treatment of diseases and are not fed continuously. However, they may end up in the litter thus posing a potential problem to the animals consuming the litter.

Worming drugs used to treat parasite infections in poultry may include sulphur drugs, sulfaquinoxaline and sulfanitran. According to Calvert (1971) not much is known about these compounds once they leave the gut. They may, however, pose a problem if found in litter fed to animals.

Coccidiostats

Feeding of broiler litter has been associated with mortalities due to botulism, copper toxicity and salmonellosis (Fourie *et al.,* 1991). Mortalities that could not be ascribed to any of the above causes were reported between 1986 and 1990 in South Africa in cattle and sheep fed poultry litter (Bastianello *et al.*, 1995). The problem could be traced to broiler litter containing a coccidiostat, maduramicin, which was added to broiler feed

(Fourie *et al.*, 1991). Upon consumption of diets containing such litter, cattle and sheep become intoxicated and the symptoms of the toxicity included dilated cardiomyopathy with congestive heart failure and mild to severe skeletal muscle lesions (Bastianello *et al.*, 1995). Nel (1989) observed that the coccidiostat became a problem when more than 20 percent broiler litter containing 5 mg/kg (5ppm) maduramicin was included in a stock ration.

Phelps (1990) pointed out that a coccidiostat may not all be absorbed from the broiler digestive system, resulting in some of it being voided with the faeces. Since the same drug may also be included in a ruminant's diet as a ionophore, the inclusion of high levels of litter containing the drug may result in the consumption of dangerously high levels of the drug (Phelps, 1990).

Van Ryssen (1991) studied the effect of monensin and its metabolites in broiler litter on sheep consuming the litter. He concluded that residues of this coccidiostat in broiler litter did not seem to cause a problem in ruminants consuming the litter.

Hormones

Hormones are not widely used in poultry feed (Calvert, 1971), available information seems to be published up to the early 1970's. On occasion some hormones may be added for specific purposes in poultry diets. Iodinated casein has been used to simulate the action of thyroxin (Calvert, 1971). Thyrouracil, though not a hormone, may be added to diets to suppress thyroid activity and increase fertility in hens (Marks, 1968). Dinesterol

diacetate is added to finishing broiler feeds (Calvert, 1971). This compound has oestrogenic activity (Calvert, 1971). If it appears in the manure it may pose problems for the animals eating the litter. Abortion has been reported in cows fed broiler litter (Griel *et al.*, 1969). The litter was indicated to have had oestrogenic activity of 10 mg per 100 g as compared to 1 mg per 100 g in forage crops (Griel *et al.* 1969). The effect, in this case, was suspected to be due to the incorporation of dienesterol diacetate in roaster feed mixed to contain 150 to 250 mg/kg of a premix containing 14 percent dienesterol diacetate (Bhattacharya & Taylor, 1975). Presence of oestrogenic hormones in hen faeces has been reported (Hertelendy *et al.*, 1965). According to Oosthuizen (1979) litter/faeces containing oestrogenic activity must be from sexually mature fowls and the reported abortions may be due to hormonal imbalance. Although the fact of poultry litter causing abortion in animals fed the litter is not substantiated it cannot be ignored as a possible danger (Oosthuizen, 1979). Abortion may also be of fungal origin. According to Lowry (1992) broiler litter is a good source of cheap protein. However, abortion cases caused by a fungus, *Ospergillios* spp, which occurs in most poultry litter, could be encountered when broiler litter is fed to ruminants.

A high incidence of abortion was reported in cows fed low levels of poultry litter in their wintering ration and grazing pasture in summer which had been fertilised with poultry litter (Fontenot & Jurubescu, 1980). Abortions were suspected to be due to dienoestrol acetate fed to birds and resulted in oestrogenic activity in the litter (Fontenot & Jurubescu, 1980). However, the cause of the abortion was not established, but blamed on a hormonal imbalance.

1.4.5 Conclusion

In conclusion, it has been demonstrated conclusively that poultry litter can be used as a feedstuff for ruminant animals. However, most of the research on poultry litter as a feedstuff for ruminants has demonstrated only a potential hazard in sheep fed poultry waste with high levels of copper (; Drake *et al.*, 1965; Fontenot *et al.*, 1966; Fontenot *et al.*, 1971 Webb *et al.*, 1973; Cullison *et al.*, 1976; Olson *et al.*, 1984). No transmission of toxic effects from livestock to man has been demonstrated as a result of feeding of poultry litter (Fontenot & Webb, 1975).

Pugh *et al.* (1994) stated that the feeding of poultry litter is associated with a few health problems, hypocalcaemia, salmonellosis, copper toxicosis and gastrointestinal impactions.

1.5. LEGAL ASPECTS REGARDING THE FEEDING OF POULTRY LITTER

1.5.1 South African situation

South African Act 36 of 1947 states very clearly that no product originating from animals can be sold as an animal feed unless it has been registered as an animal feed. The Act stipulates that a registered farm feed, such as poultry manure, must be sterilised (Ogonowski *et al.*, 1984). This requires the product to meet certain nutritional and hygienic standards. The Act specifies that broiler litter should have a moisture content of 120 g/kg (maximum), crude protein 240 g/kg (minimum), crude protein from uric acid 600 g/kg (maximum), fat 15 g/kg (minimum), fibre 150 g/kg (maximum), ash 150 g/kg

(maximum), feathers 10 g/kg (maximum), calcium 35 g/kg (maximum), phosphorus 15 g/kg (minimum), sodium 5 g/kg (maximum), silica 5 g/kg (maximum) and copper 50 mg/kg (maximum). Twenty thousand micro-organisms /g is deemed pathogen free according to the Act. The requirements for layer manure are similar to those of broiler litter except for the crude protein (220 g/kg), ash (250 g/kg), calcium (80 g/kg) and phosphorus (20 g/kg) concentrations. Feed suppliers have to comply with this law. Feed consultants are legally not permitted to recommend the feeding of unregistered litter (Government Gazette, 1980). However, legislation does not prevent farmers from buying poultry litter as a fertiliser or have it available on the farm and use it as an animal feed.

1.5.2 Legal aspects elsewhere in world

Besides South Africa the use of poultry manure as a feed has been reported in Canada (Anonymous, Feedstuffs, 1967) and Australia (McInnes *et al.*, 1968). In England, poultry manure was marketed as TOPLAN (Zindel & Flegal, 1971). The British Agricultural Research Council suggested that poultry manure be fed at the rates of 50 percent TOPLAN to 50 percent barley for cattle and sheep production and for dairy cattle at the rate of 25 percent TOPLAN to 75 percent barley (Smith, 1971). The use of poultry manure as feed for animals has since been completely banned in the United Kingdom and Europe. In USA a 15-day withdrawal period before slaughter is required on animals that were fed poultry manure diets (Fontenot, 1991).

1.6. MOTIVATION

Disaster droughts have a frequent occurrence in Southern Africa. On top of this, devastating veld fires are often destroying huge areas of grassland during the dry winter periods following a good rainy summer. Therefore, stock farmers frequently have to resort to emergency feeding measures to maintain their animals, i.e. following survival feeding strategies, amongst others by making do with what feed is available such as poultry litter.

Poultry farming is one of the livestock enterprises which is very successfully conducted in rural areas. Although poultry manure can be used as a fertiliser, these products are available during droughts and can be used as animal feed. Furthermore, most larger poultry units have an abundance of litter material. The product can often be obtained free of charge or at least at a very reasonable price compared to other feed ingredients.

Under survival feeding conditions farmers will resort to feeding of chicken litter quite often as the only feed (Bishop *et al.*, 1971). Chicken litter is not an ideal feed, being classified as a bulky protein concentrate. It is low in energy; high in some minerals; it may contain coccidiostats, antibiotics and drugs, hormones etc. and therefore it is assumed that feeding of the litter as the sole feed may have harmful consequences to the animals. In the investigations reported in this document it is assumed that it is a *de facto* fact that farmers will use the unregistered product. The product used is usually stored outdoors, under high temperatures and dry atmospheric conditions.

(i) Because of its low energy content, feeding of the litter would result in increased levels of ammonia in the rumen thus increasing the amount of ammonia absorbed from the rumen resulting in an increased burden on the liver.

(ii) The utilisation of the increased ammonia level in the rumen can be improved by feeding the litter together with easily available energy sources (molasses or starch).

(iii) Because of its high mineral content, feeding of the litter could lead to accumulation of toxic minerals in animal body and also affect carcass characteristics.

Based on practical observations it is hypothesised that broiler litter can constitute a high proportion of a ration. However, attention needs to be paid to many possible health problems related to the feeding of litter. It is argued that instead of condemning the use of broiler litter as feed, it must be accepted that farmers in South Africa are feeding it to their livestock. Therefore, although an animal scientist in South Africa is prohibited by law to recommend the feeding of unregistered broiler litter, he must have the knowledge to advise farmers using it. This series of trials were thus conducted to elucidate:-

(1) The health aspects of feeding broiler litter as a survival feed, i.e. the effects of feeding high broiler litter levels on health aspects in the body of sheep.

(2) The metabolism and utilisation of the chicken litter by microbes in the rumen and in the rest of the digestive track and methods to modify it.

(3) The effect of broiler litter feeding as a survival feed on carcass characteristics as some farmers may respond to a drought situation by reducing their stock numbers and culled animals may end up in the abattoir.

CHAPTER 2

2.0 THE EFFECT OF HIGH BROILER LITTER DIETS AS SURVIVAL RATION ON THE HEALTH OF SHEEP

2.1 INTRODUCTION

Drought occurs frequently in southern Africa and devastating veld fires often destroy vast areas of grassland during the dry winter periods. Consequently, livestock farmers often have to resort to emergency feeding measures to sustain their animals, utilising whatever feed is available. Such conditions have prompted farmers to resort to feeding poultry manure/litter (Fourie *et al.*, 1991) as the sole feed for their livestock.

Sugarcane molasses is an available energy source for the rumen micro-organisms (Yan *et al.*, 1996), readily accessible in many parts of Southern Africa and not consumed by humans. It is often mixed with broiler litter to complement the high nitrogen content of litter with available energy in a ruminant's diet.

Although poultry manure / litter has been used successfully as a ration ingredient in ruminant diets (Bosman, 1973; Kargaard & Van Niekerk, 1977), many potential problems exist. Problems of nutrients imbalances and the effects of potentially toxic component such as pathogens, dietary copper, medicinal compounds, mycotoxins, ionophores and botulinum toxin (Fontenot, 1991; Fourie *et al.*, 1991) will be accentuated when the product is fed as a sole feed. Silanikove & Tiomkin (1992) reported liver damage in beef cows when overwintered on high poultry litter diets in Israel. The authors attributed the

damage to high ruminal ammonia concentrations due to fermentation of the litter in the rumen. In South Africa, this report of liver damage seems to have prompted warnings against the use of poultry litter as a ruminant feed at any rate of inclusion. However, liver damage is not usually observed in cattle when poultry litter is fed, except when it contains high concentrations of copper (Rankins *et al.,* 1993). The objective of the present study was to investigate the effect of high levels of broiler litter on the health of sheep. Since broiler litter contains excessive levels of non-protein nitrogen, improving the dietary nitrogen to energy balance to improve the product as a survival feed was evaluated as well.

2.2 MATERIALS AND METHODS

2.2.1 Experimental procedure

Eighteen South African Mutton Merino wethers (*ca.* 2 years old and *ca.* 42 kg body mass) were assigned randomly to 3 treatments, namely pure broiler litter and broiler litter mixed with 7.5 or 15.0 percent molasses. It would have been preferred to have a negative control, however, this was not possible due limited availability of facilities. Sun-dried broiler litter with wood shavings as bedding material was used. The litter was sifted to remove lumps and foreign material. Before the onset of the trial the sheep were vaccinated twice against botulism and dosed with a broad-spectrum anthelmintic. During a 14-day adaptation period the sheep received broiler litter and grass hay. The sheep were fed individually in slatted-floor feeding pens with free access to water. Feed refusal was measured daily, the sheep weighed once a month. Feed samples were collected

throughout the trial for chemical analyses. Blood samples collected (before and during experimental period) by venipuncture in heparinised vacutainers and spot urine samples were obtained 4 times during the experimental period. A spot urine sample was collected in a clean plastic bag tied to the stomach of the wether. The urine was preserved in 10% HCl.

After an average of 83 days the wethers were slaughtered over a period of 10 days. The warm carcasses, livers and kidneys were weighed. Liver, heart and kidney samples were taken and preserved in 10% buffered formalin for histopathological examination. Liver samples were also dried at 80^0C for Cu analysis. Backfat thickness at the 13^{th} rib was measured on the cold carcass.

2.2.2 Laboratory Analyses

The concentrations of haemoglobin in whole blood, glucose and bilirubin in plasma, and the activities of the following plasma enzymes: aspartate aminotransferase (AST, EC 2.6.1.1), creatine kinase (CK, EC 2.7.3.2), alanine aminotransferase (ALT, EC 2.6.1.2) S-glutamyltransferase (SGT, EC 2.3.2.2) and sorbitol dehydrogenase (SDH, EC 1.1.1.14) were measured using Boehringer Mannheim analytical kits (Boehringer Mannheim GmbH Diagnostica, Germany). An analytical kit was used to determine the concentration of Beta hydroxybutyrate in plasma (Sigma Diagnostics). Packed cell volume in whole blood was determined by microhaematocrit. The method described by De Villiers *et al.* (1977) was used to determine free fatty acid concentration in plasma, that of Tietz (1976) for plasma albumin and the Bertelot method (Anonymous, 1974) for plasma urea nitrogen

concentrations. Total allantoin concentration in urine was measured (Borchers, 1977) to estimate urinary purine concentration. The creatine concentration in urine was read on an auto-analyser using the alkaline picrate method.

Atomic absorption spectrophotometry was used to determine the calcium, copper, magnesium, sodium, potassium, manganese and zinc concentrations in the respective samples. The fluorometric method of Koh & Benson (*1*983) was used to determine selenium concentrations. Standard reference samples (bovine liver 1577b and peach leaves 1547; National Bureau of Standards, Gaithersburg, MD, USA) were used to verify the accuracy of the mineral assays. Crude protein, ash, phosphorus, ether extract, neutral detergent fibre and acid detergent fibre concentrations in each sample were obtained using standard laboratory techniques. The litter was screened with a thin-layer chromatography for the presence of ionophore antibiotics and quantified colorimetrically (Golab *et al.*, 1973).

Pathology

Tissues were fixed in 10% formalin, sectioned and stained with haematoxylin and eosin according to standard methods. Myocardial lesions were scored according to a histological classification system applied by Bastianello *et al.* (1995).

2.2.3 Statistical analysis

Data were subjected to analyses of variance and correlation coefficients were calculated using Minitab statistical software (Minitab, State College, Pennsylvania).

2.3 RESULTS

The DM content of the pure litter was 923 g/kg, and the addition of molasses decreased it to 917 and 870 g/kg for the 92.5 and 85 percent litter treatments respectively. The chemical composition of the experimental diets is presented in Table 2.1. The crude protein concentration of the pure litter was 182 g/kg DM. The inclusion of molasses decreases the crude protein concentration to 169 and 168 g/kg DM for the 92.5 percent and 85 percent broiler diets respectively. The copper concentration in the diets varied between 22 and 27 mg/kg DM. The calcium to phosphorus ratio in all the diets was approximately 2:1. The sheep in the 15 percent molasses group consumed significantly more feed ($P<0.01$) than the sheep on the 7.5 percent molasses and the pure litter groups (Table 2.2). This was associated with significantly higher ($P<0.01$) final body mass of the sheep in high molasses treatment compared to the other treatments. In the 15 percent molasses group, intakes reached an optimum after 3 weeks on the diet while those on the other 2 diets reached optimum intake at about 6-7 weeks. Carcass mass and fat cover at the last rib area of the carcass tended to be higher in the molasses-supplemented groups than in the control, but differences were not significant (Table 2.2).

Throughout the trial the concentrations of free fatty acid, β-hydroxybutyrate and glucose in plasma showed no differences among treatments (Table 2.3). Plasma urea nitrogen concentrations at the last collection of the trial were 298, 286, and 276 mg/l for the 100, 92.5 and 85 percent broiler litter treatment respectively, versus a quoted normal range of 80-200 mg/l (Kaneko, 1989) (Table 2.3).

Table 2.1: Chemical composition of broiler litter and litter with molasses (Dry matter basis)

Broiler litter (%):	**100**	**92.5**	**85**
Molasses (%):	**0**	**7.5**	**15**
Dry matter (g/kg)	923	917	870
Ash (g/kg)	97	110	124
Crude protein (g/kg)	182	169	168
Ether extract (g/kg)	11.2	9.4	8.2
NDF[a] (g/kg)	540	520	460
ADF[b] (g/kg)	395	355	334
Calcium (g/kg)	15.0	16.0	16.0
Phosphorus(g/kg)	8.1	8.4	7.4
Sodium (g/kg)	2.90	2.75	3.35
Potassium (g/kg)	9.9	11.9	12.7
Magnesium (g/kg)	4.71	4.79	4.77
Copper (mg/kg)	22	27	22
Manganese(mg/kg)	214	241	231
Selenium (mg/kg)	0.68	0.66	0.66

[a]NDF = neutral detergent fibre.

[b]ADF = acid detergent fibre.

Table 2.2: Average feed intake, body mass gain, body mass at slaughter, fresh liver, kidney and carcass mass and fat thickness at the last rib area of the carcass (means ± SD)

Broiler litter (%)	**100**	**92.5**	**85**
Molasses (%)	**0**	**7.5**	**15**
Feed intake (kg/d)	$1.3^{a*} \pm 0.08$	$1.5^{a} \pm 0.15$	$2.1^{b} \pm 0.07$
Final body mass (kg)	$44^{a} \pm 3.6$	$48^{ab} \pm 3.6$	$52^{b} \pm 2.4$
Gain/d (g)	26 ± 23	63 ± 32	101 ± 10
Carcass mass (kg)	20 ± 0.9	22 ± 1.3	23 ± 0.9
Liver:			
Mass (fresh) (g)	610 ± 40	592 ± 41	668 ± 23
as % body mass	1.4 ± 0.19	1.2 ± 0.18	1.3 ± 0.03
Kidney:			
As % carcass mass	3.0 ± 0.33	2,8 ± 0.15	2.9 ± 0.12
Kidney mass (g)	108 ± 6.0	134 ± 5.4	134 ± 6.5
Subcutaneous fat			
Fat thickness (mm)	1.8 ± 0.21	2.6 ± 0.52	2.8 ± 0.68

*Values within a row with different superscripts differ significantly at $p < 0.05$.

Table 2.3: Concentration of various plasma metabolites and activity of enzymes in plasma at the last collection (mean ± SD)

Broiler litter (%)	**100**	**92.5**	**85**	
Molasses (%)	**0**	**7.5**	**15**	**Norm***
Free fatty acids (mmol/l)	0.6 ± 0.16	0.35 ± 0.05	0.47 ± 0.08	0.55**
β-hydroxybutyrate (mmol/l)	0.3 ± 0.03	0.19 ± 0.02	0.21 ± 0.02	0.55
Glucose (mmol/l)	3.55 ± 0.1	3.35 ± 0.1	3.47 ± 0.12	2.8 – 4.4
Urea nitrogen (mg/l)	293 ± 17	267 ± 14	257 ± 16	80 – 200
AST[a] (U/l)	58 ± 3.9	56 ± 2.5	61 ± 8.5	61
δ-GT[b] (U/l)	39 ± 1.9	37 ±4.1	39 ± 3.5	20 – 50
CK[c] (U/l)	63 ± 10.6	56 ± 22.6	40 ± 3.6	8 – 13
SDH[d] (U/l)	1.6 ± 0.2	1.8 ± 0.16	1.4 ± 0.19	8 – 16
ALT[e] (U/l)	16.5 ± 1.94	13.3 ± 3.15	16.5 ± 2.3	30

[a]AST = aspartate aminotransferase.

[b]δGT = gamma glutamyltransferase.

[c]CK = creatine kinase.

[d]SDH = sorbitol dehydrogenase.

[e]ALT = alanine aminotransferase.

*Kaneko (1989)

**De Villiers *et al.* (1977)

Differences between treatments were not significant

However, high concentrations were measured from the onset of the trial. The average ± standard deviation (SD) plasma albumin (35.3±4.14 g/l), plasma globulin (24.9±4.79 g/l), bilirubin (30.4±6.2 g/l), pack cell volume (0.78±0.048) and haemoglobin (164±13.9 g/l) concentrations remain relatively constant throughout the trial, showed no treatment effects and were within the normal range for sheep (Kaneko, 1989). Copper concentrations in the livers did not differ significantly among treatment group and were 387, 383 and 338 mg/kg DM for the 100, 92.5 and 85 percent broiler litter treatment respectively.

No significant differences in the activity of any of the plasma enzymes were observed between the different group (Table 2.3). Activities were within the normal ranges for sheep with the exception of plasma CK, where the activity was higher than the expected normal values. At the final blood collection CK activities were recorded at 62.9±10.6, 56.1±22.6 and 40.0±3.6 U/l for the pure litter, 92.5 and 85 percent litter diet, respectively. However, these values were within a similar range throughout the trial. The activity of plasma AST was randomly distributed and did not show any correlation with pathological lesions in the liver or heart.

The purine:creatinine $(W^{0.75})^{-1}$ (PD:C) ratios during the trial are presented in Table 2.4. At 28 days after the onset of the trial these ratios were lower than at other stages, although differences were not statistically significant.

Mineral concentrations in the plasma did not reflect any treatment effect. Average concentrations ± SD (mmol/l) over the experimental period were: 2.15±0.12 calcium; 2.48±0.394 inorganic phosphorus; 12.6±2.49 copper; 0.987±0.076 magnesium; 145±3.6 sodium; 5.2±0.29 potassium; 16.8±1.66 zinc. The calcium to phosphorus ratio in urine varied widely and did not show any consistent pattern. However, in many of the sheep, irrespective of treatment, the concentration of phosphorus in urine was higher than its respective calcium concentration.

Myocardial pathology was mild and similar for all the treatment groups (Table 2.5). The hepatic pathology was mild and consisted of hyaline degeneration and single-cell necrosis, considered to be none specific, and triaditis, an incidental finding usually associated with parasites. Renal pathology was restricted to one case of tubular degeneration and 11 intertubular congestion. When myocardial pathology was observed, the litter was screened for ionophores. Narasin, at a concentration of 10 mg/kg, was measured in the broiler litter.

Table 2.4: Purine: creatine ratio ($W^{0.75})^{-1}$ in urine from spot samples taken during the trial (mean ± SD)*

	Day of collection			
Litter (%)	**1**	**28**	**63**	**81**
100	27 ± 10.7	16 ± 4.8	24 ± 6.5	24 ± 7.2
92.5	28 ±24.6	13 ± 6.1	27 ± 6.0	25 ± 5.7
85	31 ± 29.0	24 ± 9.5	32 ± 4.3	26 ± 3.2

*Differences among means not significant.

Table 2.5: Number of sheep fed broiler litter with or without molasses with histopathological lesions in the myocardium (n = 6/treatment)

Broiler litter (%)	**100**	**92.5**	**85**
Molasses (%)	**0**	**7.5**	**15**
Myofibre hypertrophy	5	3	4
Myofibre atrophy	5	3	4
Hyaline degeneration	3	3	4
Hyaline necrosis	3	2	4
Attempted regeneration	3	3	4
Interstitial fibrosis	1	2	4
Incidental lesions:			
Sarcocysts	4	1	3
Congestion	2	2	5

2.4 DISCUSSION

The crude protein concentration of 180 g/kg DM, although less than average South African value, was well within the levels of crude protein in litter fed to animals. However, this was substantially lower than 300 g dietary protein/kg feed that reportedly caused the liver damage in cows (Silanikove & Tiomkin, 1992). A direct comparison of results is therefore not possible. The high selenium concentrations of the diets indicate a potential selenium oversupply if selenium in broiler litter is available. The plasma urea nitrogen in the present trial is well above the normal range of 80-200 mg/l (Kaneko, 1989), indicating that excess ammonia must have been absorbed from the rumen. The high plasma urea nitrogen observed in the first collection was probably due to feeding of litter during the preliminary period. The normal concentrations of plasma albumin, bilirubin and hepatic enzyme activity in plasma indicate negligible hepatic pathology. Rankins *et al.* (1993) questioned the observation of Silanikove & Tiomkin (1992), and suggested that the observed liver damage might have been due to copper toxicity. Unfortunately Silanikove & Tiomkin (1992) did not report the copper concentrations in the broiler litter used or in the livers of their cows. In the present study the copper concentration in the litter was 22 mg/kg DM. Copper concentration in the livers of our sheep (< 400 mg/kg) was well below toxic levels (Howell *et al.*, 1987). Van Ryssen *et al.* (1993) concluded from the survey of mineral concentrations in poultry manure that copper sulphate is at present not included in broiler rations in South Africa. Consequently, in South Africa, copper toxicosis due to ingestion of litter is unlikely, contrary to the situation in the USA (Rankins *et al.*, 1993). Angus *et al.* (1978) reported

serious liver damage in sheep consuming diets containing up to 60 percent manure from laying hens. Their findings included an accumulation of fluid in the abdomen and marked histological changes in the liver. No explanation could be given and the presence of a toxic substance was suggested. They also described kidney damage in sheep on high intakes of broiler litter, again of unknown cause (Angus *et al.*, 1978). The possibility of copper toxicity was considered and ruled out. The causes of the above lesions were obviously not present in our experimental diets.

The elevated plasma CK activity may indicate muscle damage. However, elevated activity was measured throughout the trial and may be unrelated to the broiler litter treatments. Although the myocardial lesions resembled those of ionophore-associated litter toxicity, as described by Bastianello *et al.* (1995), they were considered very mild in this batch of sheep. The ionophore antibiotic, narasin, which was present in the broiler litter, is not registered in South Africa as an ionophore for ruminants. However, our findings suggest that the level of narasin in the feed (10 mg/kg) was not high enough to induce severe myocardial pathology or influence the animals' ability to survive on the particular diet. Since the purpose of feeding high levels of litter was to keep the animals alive, i.e. at a maintenance or even sub-maintenance level of nutrition, these histological findings were probably of minor significance.

The inclusion of molasses in the diets resulted in a significant increase in feed intake. This increased intake was reflected in improved daily mass gains and a higher final body mass in the respective groups. The higher body mass in the molasses-fed sheep must have

been due partly to higher gut content in these groups, because differences in carcass mass between treatments were less pronounced. If the objective is to keep the sheep alive, the inclusion of molasses may be unnecessary, except if the intake of the pure litter is unsatisfactory. In fact, lower litter intakes than recorded in the present trial should be sufficient for the survival of the sheep. Where litter with a crude protein concentration higher than that in the present study is used, the addition of molasses may have a more pronounced effect, e.g. in detoxifying ammonia.

The ratio of PD:C in urine can be used as an indication of relative rumen microbial protein synthesis in the animal (Chen *et al.*, 1995). Although this ratio increased slightly with an increase in molasses inclusion in the diet, variations within treatments were wide and differences were not significant. From urinary PD:C ratios, Chen *et al.* (1995) estimated rumen microbial nitrogen productions in sheep of less than 5 to more than 20 g nitrogen /d. At PD:C ratios of between 15 and 30, Chen *et al.* (1995) estimated a rumen microbial nitrogen production of 6 – 12 g/d. In the current trial a PD:C ratio of *ca.* 23 was measured, indicating a relatively low microbial production of less than 12 g/d. The low PD:C ratios observed at 28 days may reflect incomplete adaptation of the microbes to the diets at that stage. This was evident in relatively low initial DM intakes which showed an increase for the first 6 weeks in the 100% litter diet. It should be noted however, that uric acid not digested may influence the purine content of urine thus inflating the rumen microbial nitrogen production estimated through the PD:C ratios. Further studies are required to confirm this apparent long adaptation period required by the sheep or the rumen micro-organisms before they can utilise broiler litter effectively.

The concentrations of minerals in the broiler litter were lower than the means for South African samples, but well within the range of variation measured (Van Ryssen *et al.*, 1993). The cows used by Silanikove & Tiomkin (1992) were hypocalcaemic and hyperphosphataemic when they consumed broiler litter and reacted positively to calcium borogluconate injections. The authors suggested that the apparent imbalances in calcium and phosphorus metabolism were due to the severe liver damage in the cows. Although the dietary calcium to phosphorus ratio in the present study was normal at 2:1, the phosphorus was well above requirement for sheep (NRC, 1985). The high concentration of phosphorus in urine relative to that of calcium signifies that the high phosphorus intake through litter could cause urinary calculi in wethers.

It is concluded that the feeding of dry broiler litter of the quality used in the present investigation did not affect the health of the sheep when fed for a period of *ca.* 80 days. Therefore, in an emergency feeding situation of limited duration, it seems feasible to feed broiler litter to ruminants, even at restricted levels of intake. However, the necessary precautions must be taken because broiler litter has many potential problems as an animal feed (Fontenot, 1991; Fourie *et al.*, 1991).

CHAPTER 3

3.0 SITE AND EXTENT OF DIGESTION OF BROILER LITTER FED WITH OR WITHOUT MOLASSES AS A SURVIVAL FEEDING STRATEGY IN SHEEP

3.1 INTRODUCTION

In arid countries with long dry seasons and frequent occurrence of droughts, poultry litter is used often as a feedstuff for ruminants (Silanikove & Tiomkin, 1992; Deshck *et al.*, 1998). It sometimes constitutes the main source of nutrients for the animals (Silanikove & Tiomkin, 1992). Similar situations exist in Southern Africa in particular during protracted droughts or when devastating veld fires have destroyed vast areas of natural grazing. Farmers then have to resort to emergency feeding measures, which would prompt them to feed any available product such as poultry manure to keep their livestock alive (Chapter 2).

The potential problems with poultry manure or litter as a feedstuff have been investigated extensively. These studies emphasised the precautionary measures required in the feeding of such a nutritionally unbalanced group of products which may possess numerous potential health risks to the animal (Caswell *et al.*, 1997; Fontenot & Jurubescu, 1980; Fontenot, 1991; Rankins *et al.*, 1993; Ruffin & McCaskey, 1998).

Broiler litter has a high crude protein content, mainly non-protein nitrogen, and is deficient in available energy (Fontenot, 1991). The high crude protein and low available energy content in the litter could impair the efficient utilisation of the ammonia by ruminal micro-organisms and thus by the animal. To investigate the utilisation of the nutrients in broiler litter under such a situation, the partition of digestion in the gut was studied with sheep fed broiler litter alone or mixed with molasses.

3.2 MATERIALS AND METHODS

3.2.1 Animals and treatments

Six mature SA Mutton Merino wethers (*ca.* 54 kg body weight) fitted with ruminal and T-type abomasal and terminal ileal cannily were adapted to a 100% broiler litter diet. At the onset of the trial the wethers were randomly allocated to three treatments: pure broiler litter and the litter mixed with 7.5% or 15% molasses. Sun-dried broiler litter with wood shavings as bedding materials was used. The litter was sifted through a 2.5 cm sieve to remove lumps and foreign material. Experimental diets were prepared by mixing the litter with 0, 7.5 and 15 percent liquid molasses (by weight) in a vertical feed mixer. A 3 x 3 Latin square design was used, giving two wethers per treatment per period and six animals per treatment at completion of the trial. Three weeks prior to the trial the sheep were vaccinated against botulism and dosed with a broad spectrum anthelmintic. Between each collection period a 14-days adaptation period on the next experimental diet was allowed before the sheep were placed in metabolism crates and fitted with harnesses for

faecal collection. The sheep received the diets *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.

The double marker technique was used in the partial digestion study (Faichney, 1975) with chromium-EDTA (Downes & McDonald, 1964) and ytterbium - acetate (Siddons *et al.*, 1985) as liquid phase and particulate phase markers respectively. The chromium-EDTA and ytterbium-acetate were prepared according to the methods described by Morgan *et al.* (1976). The concentrated chromium solution contained approximately 16000 mg chromium/l and the concentrated ytterbium solution 7750 mg ytterbium/l. The actual concentration of chromium and ytterbium in the solutions were determined by atomic absorption spectrophotometry. At the onset of the infusion period a priming dose of each of the concentrated solutions (20 ml of the chromium and 10 ml of the ytterbium solutions) were introduced directly into the rumen; thereafter, the concentrated solutions (15 ml chromium-EDTA and 10 ml ytterbium per day) diluted with distilled water (2000 ml) were infused with the aid of an electrical peristaltic proportioning pump. This ensured that about 240 mg chromium and 77.5 mg ytterbium were infused per sheep per day. From day five of infusion, ruminal, abomasal and ileal contents were collected over a period of four days. This was done according to a predetermined schedule to avoid unduly disturbance of the animals and flow of digesta, but ensured the collection of a ruminal, abomasal and ileal sample every three hours of a 24-hour period. Sampling times on day 5 were at 9:00 and 21:00; on day 6 at 12:00 and 24:00; on day 7 at 15:00

and 03:00; and on day 8 at 18:00 and 06:00 hours. Immediately after collection of ruminal samples, pH was measured. Thereafter, ruminal content was strained through six layers of cheese cloth. Twenty five ml of the rumen liquor were preserved with 25% ortho-phosphoric acid (1 ml to 9 ml of sample) for volatile fatty acid (VFA) analyses (Grimaud & Doreau, 1995) and another 25 ml with 50% (v/v) sulphuric acid (1ml to 9 ml of sample) for an ammonia nitrogen assay. Fifty ml each of abomasal and ileal digesta were collected at each sampling and frozen at -20^{0}C. Faeces were collected twice a day and 10% aliquot per collection was stored at -20^{0}C.

3.2.2 Analytical procedures

After thawing, composite samples (20 ml each) of abomasal and ileal digesta were centrifuged and the supernatant stored at -20^{0}C pending chromium, ytterbium, and ammonia nitrogen analysis. Chromium, ytterbium and ammonia nitrogen concentrations in broiler litter (chromium only), supernatant, composite abomasal and ileal samples were determined with an auto analyser (Technicon Auto Analyser II; Industrial method No. 334- 74A). Concentrations of VFA in the ruminal fluid were assayed using a gas chromatograph with a FFAP column (25m X O.53mm), injector and detector temperatures 230^{0}C and 250^{0}C, respectively, and nitrogen flow set at 15 ml/minute). The DM, organic matter and nitrogen concentrations in the feed, composite abomasal, ileal and faecal samples were obtained using the standard A.O.A.C. (1990) procedures. The uric acid was extracted from the litter using the method of Eiteman *et al.* (1994) and then determined by the capillary zone electrophoresis method of Shihabi *et al.* (1995). Based on the 100% recovery of samples spiked with uric acid, it was concluded that this method

was successful in measuring the uric acid concentration in litter. However, the method appeared unsuitable for the abomasal content because only a 20% recovery of spiked uric acid could be achieved on those samples. True protein concentration was obtained with a protein precipitation method using trichloroacetic acid (Faichney & White, 1983; Marais & Evenwell, 1983). However, the method states that uric acid will precipitate with the protein. Amino acid composition of the litter was read on an amino acid analyser (Hewlett Packard 3D CE capillary electrophoresis). Neutral detergent fibre and acid detergent fibre concentrations in the diets were determined according to the procedure of Robertson & Van Soest (1981). The abomasal samples were assayed for purine-nitrogen according to the procedure of Zinn & Owens (1986). Calcium, phosphorus, magnesium, copper, sodium, manganese, potassium and zinc concentrations in the diets were obtained as described in Chapter 2. Total non-structural carbohydrate (TNC) concentrations in the litter were determined according to the procedure of Harris (1970). A hydride generator attached to an atomic absorption spectrophotometer was used in the assay for selenium concentration 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.

3.2.3 Calculations

The abomasal and the ileal digesta flows were calculated by reference to chromium as liquid phase marker and ytterbium as particulate marker (Faichney, 1975). Total digesta were reconstituted according to marker concentrations in fractionated and unfractionated

digesta. Large intestines digesta flow was calculated by difference between ileal and faecal digesta flows and nutrient disappearances by difference for the rumen, small and large intestines. Microbial nitrogen flow was estimated from the purine nitrogen flow in the abomasum (Zinn & Owens, 1986). A factor, 0.3133, was developed from the purine nitrogen: total nitrogen ratio in isolated rumen bacteria, collected from sheep on a 100 percent broiler litter diet. To estimate the purine nitrogen flow 1200 ml rumen fluid was collected from separate ruminally cannulated sheep (50 ml per collection) at 6.00 hours, 9.00 hours, 12.00 hours, 15 hours, 18.00 hours, 21.00 hours and 24.00 hours staggered to avoid unduly disturbance of the animals over 12 days with two collections per day. Thawed samples were centrifuged at 2000 rpm for 5 minutes and supernatant harvested. The supernatant was centrifuged at 8000 rpm for 30 minutes and supernatant decanted. The remaining solid was washed with distilled water, centrifuged (as above) and supernatant decanted. This procedure was repeated two times. The remaining microbes were washed into a container, freeze dried and then analysed for purine and total nitrogen. The efficiency of microbial nitrogen synthesis was estimated from the microbial nitrogen flow in the abomasum per kg of organic matter apparently digested in the rumen. Non-ammonia nitrogen represents a true protein concentration and is the difference between total nitrogen and ammonia nitrogen flows at a specific site.

3.2.4 Statistics

Statistical analyses were conducted according to the Latin square design using the Statistical Analysis System (1994) and a Tukey test to test the significance of differences. Due to the inherently large variations encountered with marker technique as in partial

digestion studies (Titgemeyer, 1997) total faecal recoveries of nitrogen and organic matter were compared with recoveries calculated from marker concentrations in faeces. When obvious out-liers in the latter were excluded, the nitrogen and organic matter recoveries between marker and total faecal collections corresponded well (Titgemeyer, 1997). Results from these sheep were omitted also in calculations based on data from the abomasal and ileal collections.

3.3 RESULTS

The chemical composition of the diets is presented in Table 3.1. The addition of molasses did not change the composition of the litter substantially, except for slight increases in TNC and potassium concentration with the addition of molasses. The chromium concentration in the litter was negligibly low and therefore not subtracted in the calculations of flow rate of the liquid phase. The particle size of 41 percent of the pure litter was > 2mm and 52 percent > 1 mm. The composition of the nitrogen fraction in the pure litter is presented in Table 3.2. The true protein concentration represented 47.6 percent of total nitrogen in the litter. The total amino acid and total true protein concentrations were 95.9 and 104.8 g/kg DM respectively. The uric acid concentration in the pure litter was 9.69 g/kg DM, equivalent to 9.2 percent of total nitrogen.

The DM intake increased ($p < 0.05$) with molasses addition (Table 3.3) and constituted 1.9, 2.4 and 3.0 percent of the sheep body weight for the 100, 92.5 and 85 percent litter treatment respectively. The intakes were reflected in higher ($p < 0.05$) flow rates of

digesta through the abomasum and ileum of the high molasses treatment, but not in faecal output (Table 3.4). Despite the increased intakes, the average pH of the ruminal contents and the VFA and ammonia-nitrogen concentration in ruminal fluid did not differ among treatments (Table 3.3).

Although total nitrogen intake was higher at 15 percent molasses inclusion than in the other treatments, differences were not statistically significant (Table 3.5).

Table 3.1: The chemical composition of broiler litter containing diets (Dry matter basis)

Broiler litter(%)	**100**	**92.5**	**85**
Molasses (%)	**0**	**7.5**	**15**
Dry matter (g/kg)	850	880	830
Organic matter (g/kg)	820	830	820
Crude protein (g/kg)	190	210	200
NDF (g/kg)	410	410	400
ADF (g/kg)	280	250	230
TNC (g/kg)	120	140	190
Calcium (g/kg)	13	18	14
Phosphorus (g/kg)	13	13	12
Magnesium (g/kg)	2	2	3
Potassium (g/kg)	11.2	13.5	15.1
Sodium (g/kg)	2.4	2.2	2.7
Manganese (mg/kg)	290	267	250
Copper (mg/kg)	58	49	51
Selenium (mg/kg)	0.94	0.97	1.07
Zinc (mg/kg)	222	253	252

NDF = Neutral detergent fibre; ADF = Acid detergent fibre;

TNC = Total non-structural carbohydrates

Table 3.2: Composition of nitrogen fractions in pure broiler litter (Dry matter basis)

Nitrogen fraction	g/kg
Crude protein	220.0
True protein	104.8
True crude protein (of total N)	476.0
Uric acid	9.69
Uric acid nitrogen	3.23
Total amino acids	94.9
Alanine	7.3
Arginine	4.0
Aspartic acid	7.9
Glutamic acid	14.1
Glycine	8.3
Histidine	1.5
Isoluecine	4.7
Leucine	8.0
Lysine	5.3
Methionine	1.7
Phenylalanine	4.9
Proline	7.0
Serine	6.8
Threonine	5.2
Tyrosine	2.2
Valine	6.0

Table 3.3: Feed intake, pH of ruminal content and ammonia and volatile fatty acid (VFA) concentrations in ruminal fluid*

Broiler litter(%)	**100**	**92.5**	**85**
Molasses(%)	**0**	**7.5**	**15**
Dry matter intake (g/d)	858.4[a]	1123.1[a]	1365.9[b]
Nitrogen intake (g/d)	31.3	44	52
Ruminal fluid pH	6.8	6.9	6.7
Ruminal fluid NH_3 –N (mg/100 ml)	51.4	56.4	51
Volatile fatty acids			
Total VFA (mMOL/100ml)	17.4	22.7	23.02
Acetic acid (Molar)	0.652	0.666	0.657
Propionic acid (Molar)	0.235	0.199	0.206
N-butyric acid (Molar)	0.075	0.095	0.106
Iso-butyric acid (Molar)	0.015	0.013	0.008
N-valeric acid (Molar)	0.009	0.009	0.009
Iso-valeric acid (Molar)	0.014	0.011	0.009

*Means within a row with different superscripts are statistically different at $P<0.05$

Table 3.4: Digesta flow at various sites of the gastrointestinal tract*

Broiler litter(%)	**100**	**92.5**	**85**	**MSE**	**p<**
Molasses(%)	**0**	**7.5**	**15**		
Abomasum(l/d)	9.9[a]	11.3[a]	20.1[b]	5	0.05
Ileum (l/d)	3.5	4.2	4.2	1.1	NS
Faecal output(g/d)	518.5	568.2	559	123	NS

*Means in the same row with different superscripts are different P<0.05

The flow rates of total nitrogen, non ammonia nitrogen and microbial nitrogen through the abomasum were higher ($p<0.05$) in the 85 percent ($p<0.05$) litter treatment compared to the other two treatment (Table 3.5). This trend was not evident in the ileum. A smaller ($p<0.05$) percentage of nitrogen (24 percent) disappeared from the rumen when the 85 percent litter diet was fed compared to when 100 (55%) and 92.5 (59%) percent litter treatments were given. In the small intestine a higher ($p<0.05$) percentage of total dietary nitrogen disappeared from the 85 percent litter diet than from the other two diets, viz. 40 versus 18 and 11 percent, respectively. Apparent digestibility of total dietary nitrogen in the whole tract was between 72 and 73 percent with no significant differences among treatments (Table 3.5). When the 85 percent litter diet was fed, microbial nitrogen flow in the abomasum was 16.2 g/day which was significantly higher ($p<0.05$) than in the 100 and 92.5 percent treatments (8.5 and 10.4 g nitrogen/day) respectively. The quantity of ruminal microbial nitrogen apparently synthesised per kg of organic matter digested in

the rumen was 27.8, 16.1 and 75.3g for the 100, 92.5 and 85 percent litter diets respectively.

Table 3.5: Intake, flow, non ammonia (NAN) and ammonia nitrogen flows and apparent digestion of nitrogen (N) in the gastrointestinal tract*

Broiler litter(%)	**100**	**92.5**	**85**	**MSE**	**p<**
Molasses (%)	**0**	**7.5**	**15**		
N-intake (g/d)	31	44	52	16	NS
Nitrogen flow (g/d)					
At abomasums	14^{a}	18^{a}	39^{b}	11	0.05
At ileum	6	11	15	6	NS
NAN flow (g/d)					
At abomasums	11^{a}	15^{a}	34^{b}	10	0.05
At ileum	5	6	6	1	NS
Microbial-N flow (g/d)					
Abomasum	8.5^{a}	10.4^{a}	16^{b}	4	0.05
Apparent digestion (g/d)					
Rumen	17^{ab}	26^{a}	13^{b}	5	0.05
Small intestine (NAN)	6^{a}	9^{a}	28^{b}	5	0.05
Digestion coefficients (%)					
Rumen	55^{a}	59^{a}	24^{b}	12	0.05
Small intestine (NAN)	18^{a}	11^{a}	40^{b}	14	0.05
Total track nitrogen	72	72	73	4	

*Means on the same row with different superscripts are significantly different.

Table 3.6: Intake, flow and apparent digestion of organic matter in the gastrointestinal tract*

Broiler litter(%)	**100**	**92.5**	**85**	**MSE**	**p<**
Molasses (%)	**0**	**7.5**	**15**		
Organic matter intake (g/d)	730[a]	988[a]	1134[b]	290	0.05
Total flow (g/d)					
At abomasums	458[a]	531[a]	901[b]	342	0.05
At ileum	341[a]	450[a]	509[b]	148	0.05
Faecal output	269	379	421	86	NS
Apparent digestion (g/d)					
In rumen	272[a]	457[b]	233	419	NS
In small intestine	117[a]	81[a]	392[b]	288	0.05
In large intestine	42[a]	71[a]	88[b]	52	0.05
In total tract	431[a]	609[a]	731[b]	354	0.05
Site of digestion (% of total)					
Rumen	63[a]	75[a]	32[b]	13	0.05
Small intestine	27[b]	13[b]	54[a]	11	0.05
Large intestine	10	12	12	8	0.05
Digestibility coefficients (%)					
Rumen	37[a]	46[a]	21[b]	10	0.05
Small intestine	16[a]	8[a]	35[b]	16	0.05
Large intestine	6	7	8	6	NS
Total tract	59	62	64	26	NS

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

The total quantity of dietary organic matter (Table 3.6) that disappeared in the rumen differed ($p < 0.05$) between treatment: a lower ($p<0.05$) percentage (21%) of dietary organic matter disappeared in the rumen from the 85 percent litter compared to 37 and 46 percent from the 100 and 92.5 percent litter diets respectively Table 3.6). On the other hand, a higher ($p<0.05$) percentage (35%) of organic matter was apparently digested in the small intestines when the sheep received the 85 percent litter than the 16 and 8 percent when the 100 and 92.5 percent litter diets were fed respectively (Table 3.6). However, the apparent digestibility of organic matter in the total digestive tract did not differ among treatments and ranged from 59 to 64 percent.

3.4 DISCUSSION

The litter used in the present study contained 20 percent crude protein. This is relatively low in comparison with the concentrations usually quoted for the product in other countries, e.g. 30 percent in Israel (Silanikove & Tiomkin, 1992), 30 to 32 percent in the USA (Bhattacharya & Fontenot, 1966; Rude & Rankins 1997). However, it corresponded with crude protein concentrations recorded in South Africa (Van Ryssen *et al.*, 1977). The 48 percent true protein in crude protein in the present study corresponded well with the value of 45.4 percent reported by Bhattacharya & Fontenot (1966) and 50 to 60 percent reported by Van Ryssen *et al.* (1977). The amino acid composition of the pure broiler litter sample agreed well with analyses quoted by Bhattacharya & Fontenot (1966)

and Wuethrich (1978). However, the uric acid (nitrogen x 6.25) constituting 9.2 percent of total crude protein in the litter is substantially lower than the 28.8 to 30.5 percent reported by Bhattacharya & Fontenot (1966), the 45.7 percent calculated from data presented by Wuethrich (1978) and the 36.5 percent calculated from the data of Zinn *et al.* (1996). It is usually assumed that poultry excreta nitrogen contains a high proportion, up to 87 percent, of uric acid (Oltjen & Dinius, 1976). In our assay the uric acid-spiked samples gave a 100 percent recovery of added uric acid. The true protein concentration which includes uric acid (Faichney & White, 1983) was very similar to the sum of the amino acids in the sample. This supports the result of a low uric acid concentration in our litter. According to Oltjen & Dinius (1976) uric acid in wet droppings tends to decompose rapidly to urea and ammonia with the consequent wide variation in uric acid concentration in poultry waste. In the present study the relative slow drying of the litter in the sun could have decreased the uric acid as well as total crude protein concentrations.

The crude protein, calcium and phosphorus concentrations of the molasses diets were recorded as above that of the pure litter diet. This was possibly due to experimental error in the case of crude protein concentration. Calcium and phosphorus concentrations tended to increase when molasses was added to the diets in the experiments reported in this document. This suggests that the molasses used contained these minerals.

Voluntary DM intake increased with increasing addition of molasses to the broiler litter. This agrees with results from our previous study (Chapter 2). In Israel, Silanikove *et al.* (1987) observed a high intake of litter by beef cows relative to the low digestibility of the

diet. They concluded that the small particle size of broiler litter resulted in its easy escape from the rumen, and suggested that this characteristic of poultry litter would probably add to the relatively high intake capacity they noted. However, the general contention in the USA seems to be that the physical and chemical nature of broiler litter, e.g. small particle size, high solubility and high density of insolubles is conducive to lack of ruminal stimulation with a low saliva flow and a low voluntary intake (Patil *et al.*, 1995; Rossi *et al.*, 1996). A consequence of this is the occurrence of bloat in cattle on high litter diets (Ruffin & McCaskey, 1998), a problem not observed in our series of trial, using sheep (Chapter 2 and unpublished results). Patil *et al.* (1995) postulated that the passage rate of ruminal digesta of diets high in broiler litter (viz. 50%) might be slow when dietary roughage levels are low, with an accompanying low feed intake. The physical characteristics of broiler litter digesta in the rumen (e.g. buoyancy) may not be conducive to rapid ruminal outflow of digesta and moderate to high dietary levels of roughage would be essential to avert this. Patil *et al.* (1995) reported an increase in ruminating time with the increase of level of hay inclusion in diets high in broiler litter. A standard recommendation in the USA is that long hay must be supplied when cattle are fed diets high in broiler litter (Fontenot, 1991; Ruffin & McCaskey, 1998). Although the DM intake in our 100 percent litter treatment was only 1.9 percent of body weight, which is relatively low for sheep, no signs of bloat were noticed. A possible explanation could be that the average particle size of our broiler litter was higher and would thus stimulate rumination more than the litter in the USA. In the present study 41 percent of the litter was >2mm in size, while Rossi *et al.* (1996) reported average particle sizes of 1.53, 1.05, 0.85 and 0.79 mm for litter in the USA. These differences in particle size could be the

result of the practice in the USA to rear five to six batches of broilers in a house before the litter is removed (Park *et al.*, 1995; Patil *et al.*, 1995; Rude & Rankins, 1997), while in South Africa a broiler house is cleaned after each batch of birds.

It seems unlikely that the dramatic increase in broiler litter intake with the addition of molasses could be due to improved conditions in the rumen. Ruffin & McCaskey (1998) pointed out that when broiler litter contains less than 12 percent moisture, the ration may be dusty and thus unpalatable to cows. The litter in the present study contained 15 percent moisture. For lack of a better explanation for the increased intake, it is suggested that the molasses might have reduced the dustiness of the litter which made it more acceptable to the sheep.

There seems to be very little information in the literature on nutrient utilisation of broiler litter fed at very high intakes, as investigated in the present study. Therefore, direct comparisons with information from other research were often not possible. In the present study the magnitude of ruminal pH changes was small and never dropped below 6, reflecting the alkaline nature of broiler litter (Harmon *et al.*, 1974; Silanikove *et al.*, 1987) and its high buffering capacity. These pH values agreed with readings taken by Caswell *et al.* (1977), Silanikove & Tiomkin (1992), Patil *et al.* (1995) and Chaudhry *et al.* (1996) on diets containing lower concentrations of litter than the current trial. In the present study the total VFA concentrations in the ruminal fluid varied between 174 and 230 mmol/l which seems high in comparison with other published values. In diets containing between 56 and 69 percent litter, Rossi *et al.* (1996) measured total VFA

concentrations of 84 and 101 mmol/l, Patil *et al.* (1995) reported a concentration of 90 mmol/l in diets containing low levels of broiler litter while Chaudhry *et al.* (1996) recorded 44 mmol VFA/l on diets containing 50 percent litter silage. The proportion of individual VFA's on a molar percentage basis compared well with those in other studies (Caswell *et al.*, 1977; Rossi *et al.*, 1996). Inclusion of litter into diets has reportedly altered rumen fermentation towards increased propionic acid production (Fontenot & Jurubescu, 1980; Rossi *et al.*, 1996), though according to Patil *et al.* (1995) this would vary depending on the dietary characteristics of the rest of the diet. In the present study high proportions of acetic acid were measured, corresponding to the molar proportion for individual VFA's in the ruminants on high roughage diets (Bath & Rook, 1965).

The apparent digestibility of dietary nitrogen was relatively constant at 72 percent for the different treatments. This agreed with estimates (calculated by difference) of 72 and 74 percent reported by Bhattacharya & Fontenot (1966), 67 to 73 percent by Patil *et al.* (1995), 61 to 71 percent by Chaudhry *et al.* (1996) and 84 percent by Zinn *et al.* (1996). The ammonia nitrogen concentrations in ruminal fluid of above 50 mg/100ml in the present study corresponded with the results of Silanikove & Tiomkin (1992) when their beef cows consumed 6 kg of poultry litter with a small quantity of wheat straw per day. These high ammonia nitrogen concentrations imply that large quantities of ammonia would be absorbed through the ruminal wall, requiring an energy consuming process to detoxify the ammonia in the liver (Silanikove & Tiomkin, 1992). This would result also in an overestimation of the crude protein from litter available to the animal and implies an apparent loss of nitrogen from the rumen as ammonia nitrogen (50%) of intake quantities.

Since a large proportion (50%) of the nitrogen in our litter was in the form of non-protein nitrogen, some might have escaped ruminal degradation. In the present study the chemical form of the non-protein nitrogen is largely unknown. Rate of ruminal degradation of uric acid was found to be slow (Oltjen *et al.*, 1968), though Zinn *et al.* (1996) estimated that 96 percent of uric acid is degraded in the rumen. Previously, Jacobs & Leibholz (1977) could not detect uric acid in the digesta leaving the abomasum of the calves fed diets containing uric acid, but speculated that undetected uric acid or allantoin might have accounted for a high nitrogen absorption in the lower digestive tract of their calves. If non-amino acid-non protein nitrogen escaped ruminal degradation, its absorption in the lower digestive tract would be of little value to the animal (Smith & McAllan, 1971).

The total apparent digestibility of organic matter was similar for all treatment diets, ranging from 59 to 64 percent. These values compared well with reported organic matter digestibilities of 64 percent (Fontenot & Jurubescu, 1980), 44 and 47 percent (Patil *et al.*, 1995), 56 and 58 percent (Chaudhry *et al.*, 1996) and 42 to 46 percent (Rossi *et al.*, 1996). If the higher proportion of organic matter digested in the lower digestive tract at the high molasses intake contained non-protein sources, it would benefit the animal compared to the other two treatments. However, there would be less energy available for microbial growth in the rumen. The rate of organic matter digestion in the rumen was lower (32 percent) for the 15 percent litter diet compared to other treatment diets. Organic matter disappearance in the small intestine for the 15 percent molasses diet was higher than in the rumen and other diets organic matter disappearances. It may be concluded that increased litter intakes may lead to increased rate of rumen passage of nutrients thus

resulting in a shift in organic matter digestion towards the lower tract. This was due probably to the increased dry matter intake for the 85 percent litter diet. Molasses contains a high percentage of water-soluble carbohydrates which is fermented rapidly in the rumen (Yan *et al.*, 1996). Since the quantity of ruminal microbial synthesis is controlled by the quantity of the fermentable metabolisable energy (FME) in the organic matter digested in the rumen (AFRC, 1992), proportionally less microbial nitrogen per unit organic matter intake should have been formed at the high than at the lower molasses intakes. Because of the differences in intake, the effect of molasses on ammonia nitrogen utilisation in the rumen could not be established. However, in the present trial substantially more microbial nitrogen (75 g) was apparently synthesised per kg of organic matter digested in the rumen in the 15 percent molasses diet than from the 28 and 16 g/kg organic matter from the other treatments, respectively. According to Titgemeyer (1998) high microbial yields may indicate inaccuracy in the partial digestion study. This was apparently the case in the high molasses treatment. An attractive alternative explanation would have been to suggest that the uric acid escaping ruminal degradation added to the high concentration of purine in the abomasum. However, this could not be the case if a low concentration of uric acid was present in the litter in this trial.

Apparent DM digestibilities of broiler litter of between 65 and 68 percent measured in the present study compared well with the calculated values of 69 to 74 percent reported by Bhattacharya & Fontenot (1966), 50 percent by Rankins *et al.* (1993) and 57 to 58 percent by Rude & Rankins (1997).

The shift in digestion site of organic matter away from the rumen towards the lower tract in this trial appears abnormal and biologically unlikely. However, the increased litter intake per day suggests the possibility of an increased rate of passage from the rumen which may have resulted in the shift in the organic matter site of digestion. Furthermore, the litter particle size leans towards easy rumen passage which would, possibly, be increased by high feed intakes.

The main effect of an addition of molasses to the pure litter was a significant increase in litter intake and consequently a change in site of digestion of the components in the litter away from the rumen to the lower digestive tract. Whether this would be beneficial to the animal is questionable. If a large proportion of the non-protein nitrogen escapes ruminal degradation, such an increased litter intake would be of little value to the animal. In a previous study (Chapter 2) sheep put on more weight when molasses was added to broiler litter than when fed as the sole feed. This was due mainly to the higher DM intake. In a drought feeding situation where a shortage of energy is the primary problem and protein requirements of the animal should be supplied by the microbial protein synthesised in the rumen, it is debatable whether a high intake of litter which is digested in the lower digestive tract, should be aimed for. Therefore, the addition of molasses may be feasible under drought conditions only if litter intake can be restricted or if voluntary litter intake is unacceptably low.

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

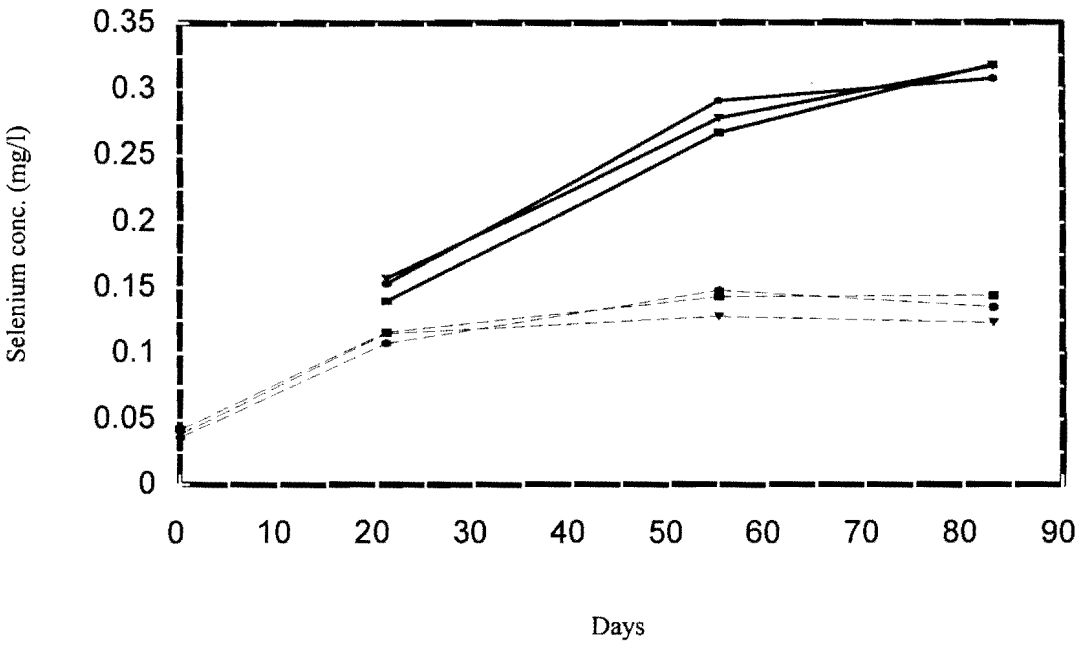


Figure 4.1: Selenium concentration in whole blood (——) and plasma in sheep (— —) receiving 100% broiler litter (▼) 92.5% litter and 7.5% molasses (■) and 85% litter and 15% molasses (●) for 83 days.

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.

CHAPTER 6

6.0 DIFFERENT LEVELS OF BROILER LITTER IN DIETS OF SHEEP ON WEIGHT GAINS AND CONDITIONS IN THEIR DIGESTIVE TRACTS

6.1 INTRODUCTION

Despite the fact that broiler litter is sold in South Africa as a fertilizer, an estimated 50 percent of the annual sales of broiler litter in Natal is used as a ruminant feedstuff (Kitching, 1986). In feedlot rations the inclusion rate of broiler litter is usually up to 25 percent (Kitching, 1986). Under survival feeding conditions considerably higher proportions of litter are included in the diets of ruminants. Information on the effects of high levels of litter in the diet on carcass parameters and conditions in the digestive system is limited. However, the results of some investigations have been reported on rumen fermentation of diets containing broiler litter (Harmon *et al.*, 1974; Silanikove & Tiomkin, 1992; Patil *et al.*, 1995; Chaudhry *et al.*, 1996). The objectives of the present studies were to investigate the effect of different levels of including broiler litter in diets of sheep on weight gain, digestion, conditions in the rumen and tensile characteristics of the carcass. The latter is reported in the next chapter.

6.2 MATERIALS AND METHODS

6.2.1 Experimental procedure

Experiment 6.1

Thirty six (36) South African Mutton Merino wethers (*ca.* 2years old and ca. 41 kg body mass) were randomly allocated to four treatment diets containing 0, 28, 56 and 85 percent broiler litter. The rations were compiled to represent the situation as is practiced under both normal and drought conditions in South Africa. The control diet contained 60 percent concentrate and 40 percent roughage, representing a normal feedlot finishing diet for sheep. The 28 percent litter diet is representative of a feedlot diet containing broiler litter. The 56 and 85 percent litter diets are representative of survival feeding situations.

The composition of the treatment diets is shown on Table 6.1. Urea was included in the finishing diets to increase the crude protein concentrations. However, these diets could not be formulated on a isonitrogenous basis, and still represent the feeding situations as aimed for, because of the high crude protein concentration of broiler litter.

The preparation of the sun dried broiler litter with wood shavings as bedding material and the pre-experimental treatment of the sheep were similar to those described in Chapters 2 and 3. During the adaptation period and most of the experimental period the sheep were group fed and had free access to water. On two occasions the sheep were placed in individual feeding pens for two-week periods to measure digestibility of diets. During these periods individual feed intake, faecal excretion and feed refusals were measured daily. Feed samples were collected throughout the trial for chemical analyses. Blood

samples were collected on days 0, 38 and 75 of trial following the method as reported in Chapter 2. Initially the sheep were weighed at two week intervals. When the groups were approaching target slaughter weight, they were weighed every week. The wethers were slaughtered on an individual basis when they reached a weight of 55 kg the week before slaughter. The pre-determined fixed slaughter weight was implemented to ensure that the carcass evaluation was done on a comparative weight basis. After slaughter by exsanguination, the individual sections of the digestive tract were tide off and the weights of the full reticulo-rumen, omasum, abomasum, small and large intestines (caecum only) were taken. These sections were then rinsed with running water until clear, drip-dried and weighed to obtain an empty weight. The warm carcasses, livers and kidneys were weighed as well. Representative samples of the digestive tract sections and livers were taken and dried to obtain their DM content. The various measurements conducted on the cold carcasses are described in Chapter 7.

Table 6.1: Composition of the diets fed to sheep in both trials (g/kg)

	Broiler litter (%)			
Ingredients	**0**	**28**	**56**	**85**
Broiler litter	-	280	560	850
Oats hay	400	325	166	-
Maize meal	311	230	124	-
Molasses	150	150	150	150
Sunflower meal	114	-	-	-
Urea	10	5	-	-
Dicalcium phosphate	10	5	-	-
Salt	5	5	-	-

Experiment 6.2

Four mature SA Mutton Merino wethers (*ca.* 60 kg body weight) fitted with ruminal cannulas were allocated in a 4 x 4 Latin square arrangement to the same dietary treatments as in Experiment 6.1. Between collection periods a 21 days adaptation to the next diet was allowed before sampling. During this period sheep received the diets *ad libitum* and had free access to water. Over a period of seven days of sampling, the sheep were fed 1kg of their diet and 500 ml water through ruminal cannulas. The measuring of the pH of rumen content and the sampling of rumen liquor were done at before (0) and 2, 4, 6, 8, 10 and 12 hours after feed introduction into the rumen. To avoid unduly disturbance of the animals, the pH measurement and sampling of the rumen content were done over a period of seven days according to a pre-determined schedule, which ensured a collection from the rumen every two hours of a 12-hour period. Sampling on day 22 was before feeding (0 hour), day 23 at 2 hours, day 24 at 4 hours, day 25 at 6 hours, day 26 at 8 hours, day 27 at 10 hours and day 28 at 12 hours from feeding time. The pH of the rumen content was measured by inserting the pH meter probe into the rumen. Readings were taken at three locations in the rumen. Rumen content was sampled and strained through six layers of cheese cloth. The liquor was treated as reported in Chapter 3 for VFA and ammonia nitrogen determinations.

6.2.2 Laboratory analysis

The following chemical analyses were done according to the techniques referred to in Chapters 2 and 3: free fatty acid concentrations and ß-hydroxybutyrate, aspartate amino transaminase (AST, EC 2.6.1.1) and creatine kinase (CK, EC 2.7.3.2) activities in

plasma; DM, organic matter, crude protein, neutral detergent fibre and acid detergent fibre concentrations in the feed and faeces; the minerals, reported in Table 6.2, in the feed and ammonia nitrogen and VFA concentrations in ruminal fluid. The nonstructural carbohydrate concentration in a diet was calculated by subtracting the crude protein, neutral detergent fibre, acid detergent fibre and fat concentration from the organic matter content of the diet.

6.2.3 Statistical analysis

Data from Experiment 6.1 were subjected to analysis of variance using the Quatro Pro for Windows statistical software (Borland International, 1993). Data from Experiment 6.2 was analyzed according to the Latin Square design using the Statistical Analysis System (1994) and Tukey test was employed to test for significance of differences.

6.3 RESULTS

The chemical composition of the four diets fed in both experiments is presented in Table 6.2. The crude protein concentration of the diets increased with increasing broiler litter levels in the feed. The broiler litter used in the trial contained 240 g crude protein / kg DM. The organic matter and total nonstructural carbohydrate concentrations of the diets tended to decline with increasing levels of the litter in the diets while the mineral concentrations of the diets increased with increasing inclusion rates of the broiler litter.

Table 6.2: Chemical composition of diets fed to sheep on both trials

	Broiler litter (%)			
	0	**28**	**56**	**85**
	g/kg DM			
Dry matter	870	860	860	850
Organic matter	930	910	890	860
Crude protein	140	130	160	210
Neutral detergent fibre	420	370	370	400
Acid detergent fibre	230	210	220	220
Total nonstructural carbohydrates	370	360	300	210
Ether extract	24	23	24	24
Calcium	-	6.6	8.1	13.3
Phosphorus	-	5.4	6.8	10
Magnesium	-	1.4	1.7	2.5
Sodium	-	2.5	1.9	2.1
Potassium	-	12.7	13.7	14.2
	mg /kg DM			
Copper	-	16	29	50
Manganese	-	144	196	245
Selenium	-	0.36	0. 62	1.11
Zinc	-	70	154	244

***Experiment* 6.1**

The first animals reached the slaughter weight at 84 days while the average number of days for the groups up to slaughter was 106, 115, 112 and 155 days for the 0, 28, 56 and 85 percent litter treatments (Table 6.3). Average daily feed intake per sheep over the experimental period for the 28 and 56 percent litter diets was higher ($p < 0.05$) than that of other treatments, but reached the same level during the the second period tested (days 38 to 74). The apparent digestibility of the nutrients in the diets decreased with icreasing levels of broiler litter inclusion, with the exception of crude protein (Table 6.4)

During the first 37 days of the experiment the 85 percent litter group showed very little gain in weight compared to the other treatments, though in the second 37 days gained as well as the other groups (Table 6.4). This is demontrated in Figure 6.1, which depicts the cumulative weight gains of sheep over the first 84 days of the trial. The efficiency of feed conversion followed the same trend as growth with a very low efficiency in the 85 percent litter group during the first 37 days, but an efficiency very similar to that in the other treatments during the second 37 days.

Table 6.3: Average daily feed intake calculated at different experimental periods for the sheep*

	Broiler litter (%)			
	0	**28**	**56**	**85**
Days to slaughter	106	115	112	155
Feed intake (kg/day)				
Entire period	$1.9^{ab} \pm 0.12$	$2.1^{a} \pm 0.23$	$2.1^{a} \pm 0.24$	$2.0^{b} \pm 0.413$
Day 1 to day 37	$1900^{a} \pm 214$	$2035^{b} \pm 314$	$1934^{a} \pm 291$	$1514^{c} \pm 121$
Day 38 to day 74	$1924^{a} \pm 221$	$2104^{b} \pm 326$	$2340^{c} \pm 332$	$2274^{c} \pm 328$

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

Table 6.4: Body weight at slaughter, total and daily weight gains and feed conversion for sheep on trial 1

	Broiler litter (%)			
	0	**28**	**56**	**85**
Weight at slaughter (kg)	56 ± 5	54 ± 3	55 ± 6	51± 4
Total weight gain (kg)				
Entire period	13.1^{a} ± 2	10.2^{a} ± 3	12.3^{a} ± 1	6.4^{b} ± 1
1 to 37 days	7.8^{a} ± 3	7.1^{a} ± 4	5.3^{a} ± 2	0.4^{b} ± 0.2
38 to 74 days	5.3^{a} ± 2	3.6^{a} ± 2	6.9^{b} ± 4	6.0^{b} ± 3
Daily weight gain (g)				
Entire period	176^{a} ± 110	162^{a} ± 100	167^{a} ± 100	144^{b} ± 110
1 to 37 days	210^{a} ± 130	194^{a} ± 110	143^{b} ± 100	100^{c} ± 10
38 to 74 days	147^{a} ± 120	100^{b} ± 80	192^{c} ± 110	168^{c} ± 120
Feed conversion				
Entire period	9.24	11.14	12.33	16.51
1 to 37 days	9.0	10.4	13.6	152.0
38 to 74 days	13.06	21.26	12.07	13.39
Apparent digestibility %				
Dry matter	66^{a} ± 2.0	60^{ab} ± 2.3	58^{b} ± 3.6	50^{c} ± 5.1
Organic matter	72 ± 3.1	67 ± 2.4	66 ± 2.8	60 ± 3.1
Crude protein	71 ± 3.0	62 ± 4.1	68 ± 1.6	71 ± 2.3
Neutral detergent fibre	61^{a} ± 3.4	52^{b} ± 3.5	52^{b} ± 3.4	48^{b} ± 5.9
Acid detergent fibre	51^{a} ± 8	42^{a} ± 6	39^{a} ± 7	24^{b} ± 6

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

Fresh carcass weights did not differ among treatments. The fresh liver and kidney weights of the two high litter diets were higher ($p < 0.05$) than those of the lower litter treatments (Table 6.5), However, expressed as a percentage of carcass weight these differences were not significant.

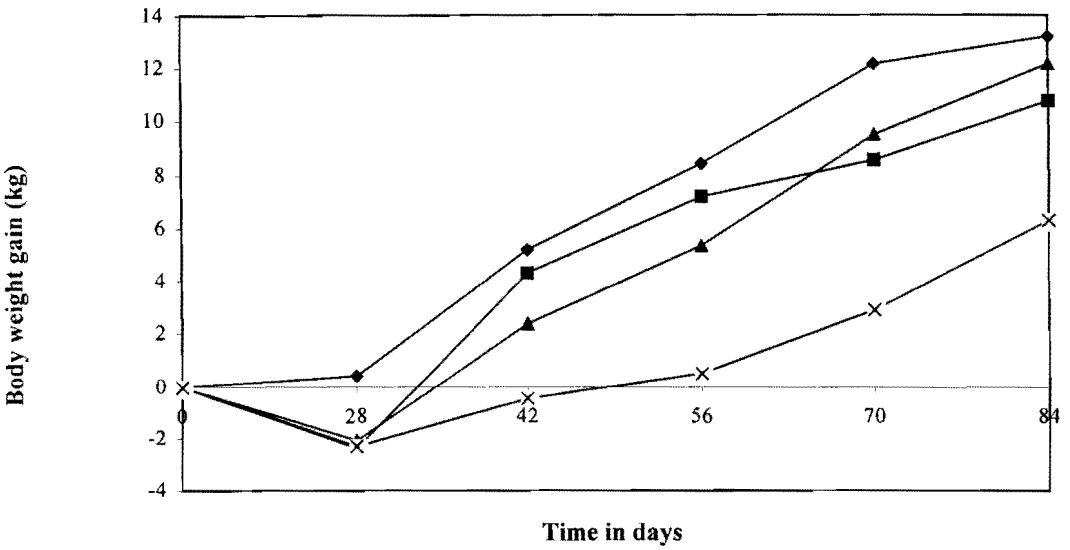


Figure 1: Cumulative weight gain of sheep fed 0% broiler litter (◆), 28% broiler litter (■) 56% broiler litter (▲) and 85% broiler litter (✕) for first 84 days

Table 6.5: Carcass, liver and kidney weights and dressing percentage of sheep fed broiler litter based diets*

	Broiler litter (%)			
	0	**28**	**56**	**85**
Carcass weight (kg)	26 ± 3	27 ± 5	26 ± 7	25 ± 4
Dressing %	48 ± 2	49 ± 3	48 ± 6	47 ± 4
Liver weight (g)	671^{a} ± 25	679^{a} ± 28	758^{b} ± 32	792^{b} ± 39
as % carcass wt.	2.7 ± 0.2	2.7 ± 0.4	3.1 ± 0.3	3.4 ± 0.4
Kidney weight(g)	131^{a} ± 15	120^{a} ± 18	142^{b} ± 23	149^{b} ± 28
as % carcass wt.	0.5 ± 0.03	0.4 ± 0.02	0.6 ± 0.1	0.6 ± 0.3

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

Table 6.6: Full and empty weights of rumen, omasum, abomasum, small and large intestine and their weights expressed as percent of carcass weight*

	Broiler litter (%)			
Parameter	**0**	**28**	**56**	**85**
Rumen (g)				
Full	7428 ± 122	7844 ± 127	8267 ± 127	6450 ± 118
Empty	1132 ± 142	1130 ± 136	1125 ± 128	1076 ± 97
as % carcass wt	4.4	4.2	4.3	4.3
Omasum (g)				
Full	304 ± 58	352 ± 84	340 ± 61	333 ± 33
Empty	131 ± 17	134 ± 27	134 ± 21	127 ± 13
as % carcass wt	0.50	0.50	0.52	0.51
Abomasum (g)				
Full	579^{a} ± 148	697^{b} ± 209	643^{b} ± 175	896^{c} ± 345
Empty	286^{a} ± 39	235^{b} ± 28	268^{ab} ± 58	303^{c} ± 35
as % carcass wt	1.10	0.87	1.03	1.2
Small intestine (g)				
Full	1328 ± 235	1267 ± 330	1540 ± 411	1503 ± 300
Empty	659 ± 76	614 ± 82	507 ± 74	590 ± 60
as % carcass wt	2.53	2.27	2.00	2.36
Large intestine (caecum) (g)				
Full	903 ± 165	928 ± 165	1035 ± 168	1094 ± 187
Empty	224 ± 42	196 ± 49	302 ± 51	198 ± 36
as % carcass wt	0.86	0.73	1.16	0.79

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

The weights of the full and empty sections of the digestive tract did not differ among treatments, except for the abomasum (Table 6.6), where the weight of this section increased ($p < 0.05$) with increasing broiler litter content in the diet. At slaughter it was observed that soil had accumulated in the abomasums of the sheep on the high litter diets.

At that stage of the trial, when many of the animals in the other treatment groups were already slaughtered, it did not seem worth quantifying the amount of soil.

No significant differences were observed in the activity of the plasma enzymes measured. Plasma AST activity before and after 74 days into the feeding period for the control, 28, 56, and 85 percent litter diets was 29±2 and 41±3; 25±3 and 45±5; 24±2; 53 ± 5 and 36±3 and 40±6 µmol/l respectively. Plasma CK activity was measured at 21±2 and 50±8; 19±1 and 45±8; 22±2 and 24±1; and 30±6 and 27±4 µmol/l for the control, 28, 56 and 85 percent litter diets, respectively before and after 74 days of experimental period. Plasma ß-hydroxybutyrate activity measured before and after 74 days into the experimental period was noted as 1.6±0.2 and 1.9± 0.1; 1.6±0.1 and 1.9±0.1; 1.9±0.2 and 2.7±0.01; and 1.6±0.2 and 2.2±0.3 mmol/l for the control, 28, 56 and 85 percent litter diets, respectively. Free fatty acids concentration in plasma were indicated as 0.08±0.01 and 0.09±0.01; 0.07 ± 0.01 and 0.09 ±0.01; 0.01±0.01 and 0.13±0.003 and 0.07 ± 0.01 and 0.01 ± 0.01 mmol/l for the control, 28, 56 and 85 percent litter diets, respectively; before and after 74 days of experimental period.

***Experiment* 6.2**

The sheep received an average of 870, 860, 860 and 850 g DM per day for the control, 28, 56 and 85 percent broiler litter diets, respectively. Crude protein intakes for the respective groups were 137, 125, 257 and 210 g/day. Ruminal ammonia nitrogen concentrations for the control, 28 and 56 percent litter diets peaked 2 hours after introduction of feed, while the 85 percent litter group peaked 6 hours from feeding time

(Figure 6.2). The pH of the rumen content (Figure 6.3) remained well above 6.66 throughout the 12 hour period in the 56 and 85 percent litter diets, while that of the control and 28 percent litter diets declined to below pH 6.00 after 6 hours from feed introduction. Total volatile fatty acid production information is presented in Figure 6.4.

Total volatile fatty acid concentration and the concentration of individual volatile fatty acids in the rumen fluid tended to peak at 6 hours for all diets. These peaks were higher in the 56 and 85 percent litter diets than in the low litter diets (Figures 6.5; 6.6; 6.7 and 6.8). In general it appears as if the peaks were more pronounced in the 85 percent litter diet than in the other ones.

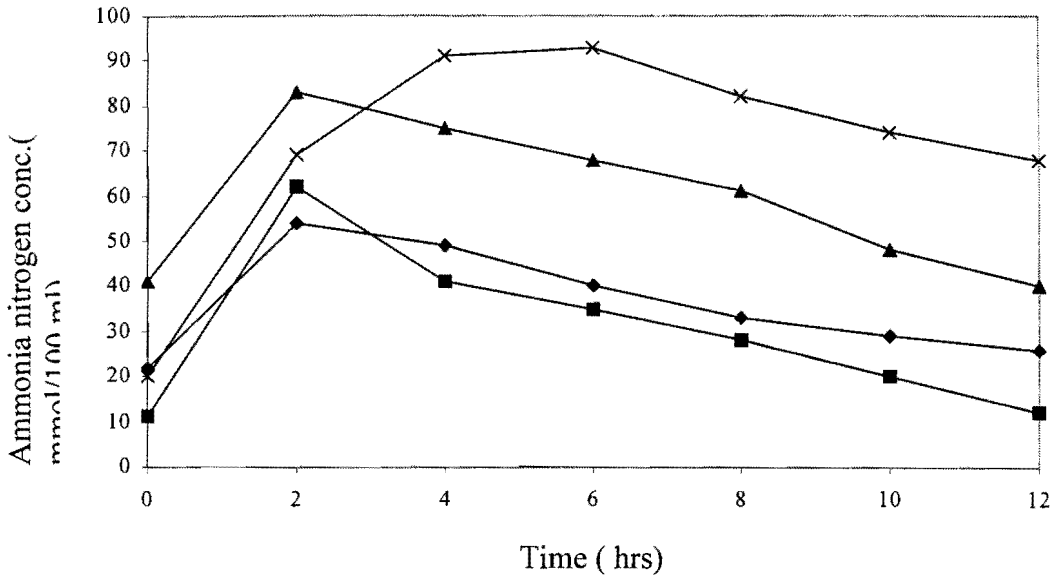


Figure 6.2: Rumen ammonia nitrogen concentrations in sheep fed concentrate and survival diets based on broiler litter: **0% litter (♦), 28% litter (■), 56% litter (▲), 85% litter (✕)**

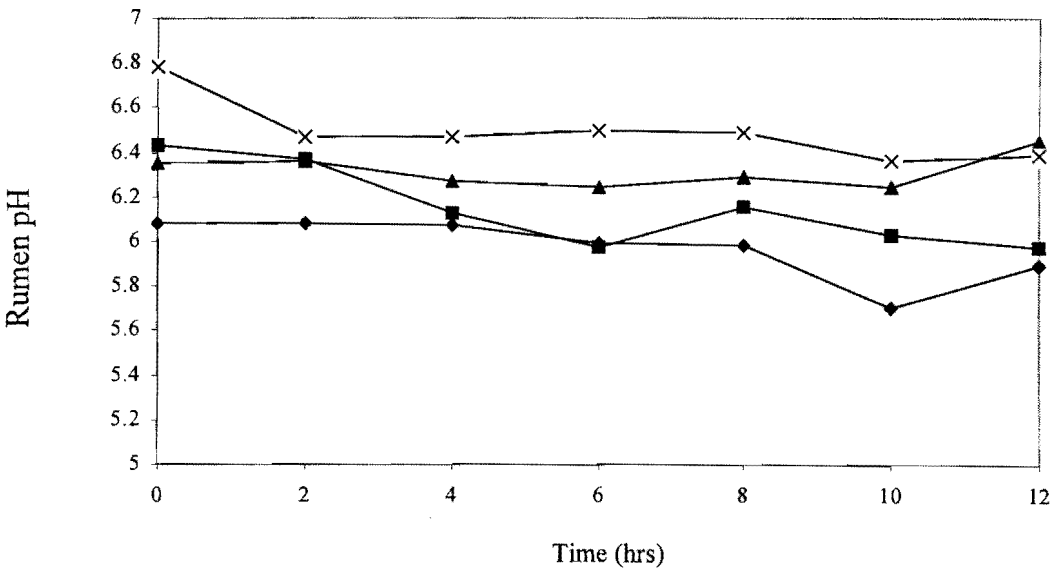


Figure 6.3 : Rumen pH in sheep fed various levels of broiler litter diets

0% broiler litter (◆), 28% litter (■), 56% litter (▲), 85% litter (✕)

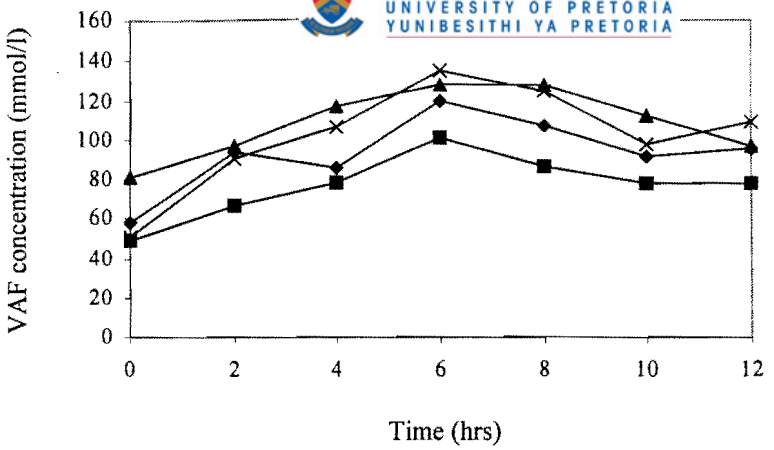


Figure 6.4 : Rumen VFA concentrations in sheep fed diets containing various broiler litter levels: **0% litter (◆), 28% litter (■), 56% litter (▲), 85% litter (✕)**

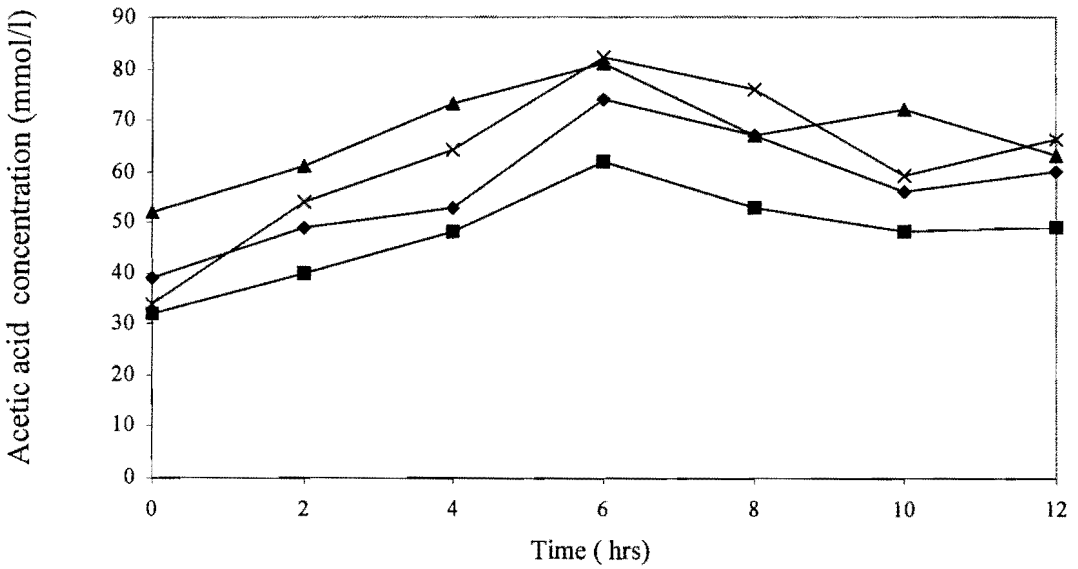


Figure 6.5 : Rumen acetic acid concentrations in sheep fed diets containing 0, 28, 56 and 85 percent litter diets: **0% litter (◆), 28% litter (■), 56% litter (▲), 85% litter (✕)**

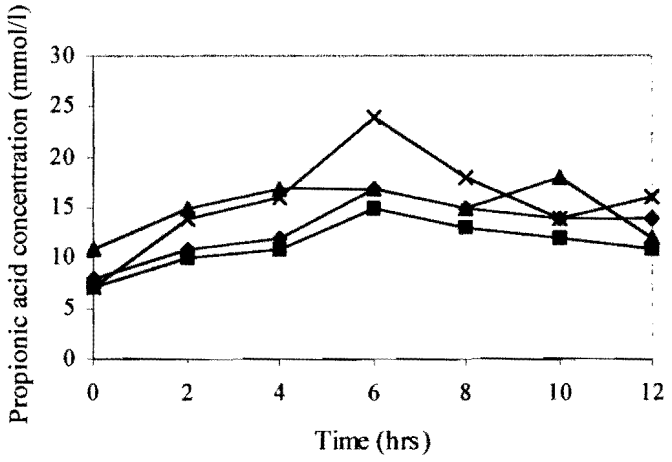
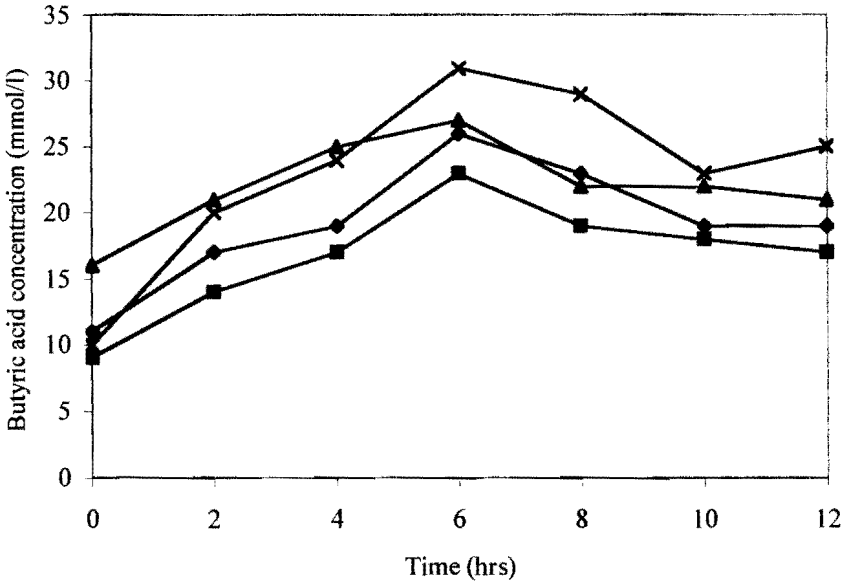


Figure 6.8 : Propionic acid concentrations in the rumens of sheep fed concentrate and survival diets based on broiler litter. 0% litter (◆), 28% litter (■), 56% litter (▲), 85% litter (✖)



Time (hrs)

re 6.7: Rumen butyric acid concentrations in sheep fed diets containing broiler litter at various levels. **0% litter (◆) 28% litter (■) 56% litter (▲) 85% litter (✕)**

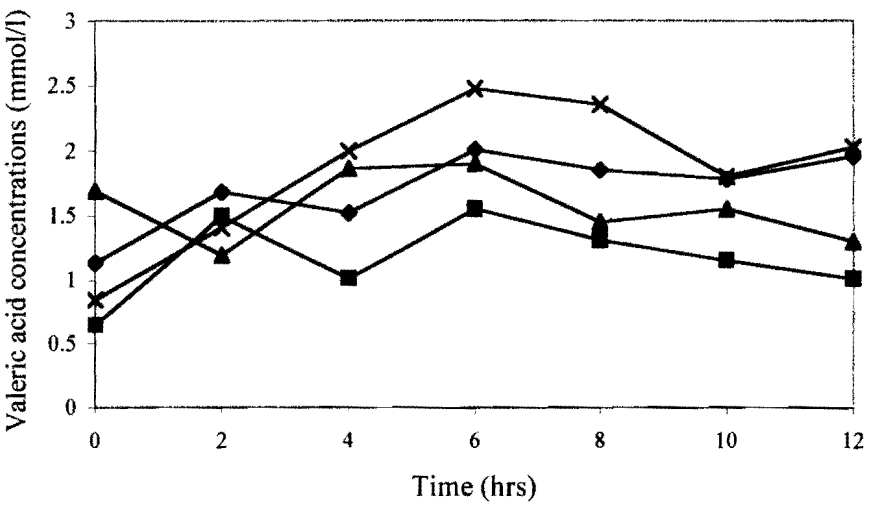


Figure 6.8: Rumen valeric acid production over a period of 12 hour by sheep fed broiler litter based diets: **0% litter (◆), 28% litter (■), 56% litter (▲), 85% litter (✕)**

6.4 DISCUSSION

Experiment 6.1

Up to inclusion of 56 percent broiler litter in the diet, weight gains and efficiency of feed conversions of the sheep were very similar. Bearing in mind that these wethers were two years of age, average daily gains of 0.160 to 0.176 kg could be considered as good. Smith & Calvert (1976) reported the best feed conversion in sheep when their diets contained 14 percent broiler litter, while Borgioli & Tocchini (1969) observed the highest daily weight gains from a diet containing 25 percent poultry litter. Likewise, Tagari *et al.* (1976) found that feed intake of steers was higher on broiler litter containing diets but feed efficiency was impaired when the proportion of litter exceeded 25 percent. Pelleting had a beneficial effect in terms of higher digestibility of crude protein and organic matter when a diet containing 40 percent litter was fed to calves, compared to lower litter inclusion rates (Kumanov *et al.*, 1969). Kargaard & Van Niekerk (1977) and Hadjipanayiotou (1984) reported that high levels of poultry excreta inclusion in high energy diets tended to depress animal performance. They attributed the depressed performance to the dilution of the energy content of the diets due to a low metabolisable energy value of poultry excreta. Whether the inclusion of broiler litter in a finishing diet of sheep or steers will affect the performance of the animals will obviously depend on the available energy value of the broiler litter relative to that of the rest of the diet. Broiler litter is quoted to have a low metabolisable energy value of 9.13 MJ/kg DM (Bhatacharya & Fontenot, 1966). This is probably low relative to an energy source such as maize meal. The Total Digestible Nutrient (TDN) content of the litter (+ 15% molasses) should be close to 60 percent that of organic matter (Table 6.3). This is lower than the TDN content of maize

meal of 75 percent (Bredon *et al.*, 1987), but probably not what could be described as low in available energy. Therefore, a lower weight gain can be expected if litter replaces a high energy concentration such as maize meal in a finishing diet. Financial considerations will thus determine whether it will be economical to include the litter in a finishing diet or not.

During the first 37 days of the trial the sheep on the 85 percent litter diet put on very little weight and consumed less of their diet than the other groups. However, both feed intake and average daily gain improved dramatically during the second 37 days to be comparable to those of the other treatments. Although less pronounced, this same trend was evident for the 56 percent litter group. The average daily gains of 0.168 kg in the 85 percent litter group during the second 37 days was better ($p < 0.05$) than the gains of 0.147 and 0.100 measured in the 0 and 28 percent litter groups respectively. However, it must be accepted that the sheep were probably in different stages of finishing, and compensatory growth might have played a role in the high weight gain in the high litter treatment.

The lack of growth of the sheep on the 85 percent litter diet during the first 37 days of the trial and the rapid growth there-after, suggest that rumen microorganisms required quite a long period to adapt to the high broiler litter diet, much longer than the 15 to 20 days that is normally accepted. It seems as if this observation is supported by the observation in the first trial (Chapter 2) where an initial low rumen microbial growth was estimated based on urinal purine concentrations of the sheep on the high broiler litter diets. If that is the

case, abnormal and incorrect measurements of digestibility and ruminal flow rates would be obtained if the period of adaptation was insufficient.

Considerable evidence has shown that a large proportion of an animal's maintenance energy requirements can be attributed to the visceral organs especially the liver and the digestive tract (Ferrel & Jenkins, 1985; Fluharty & McClure, 1997). The metabolic activity of the visceral organs is a function of the metabolic activity and size of the organ which is affected by level of nutrition (Fluharty & McClure, 1997). In the present study the liver and kidney weights of the sheep on the high litter diets were higher than those on the other diets. Weights of the different sections of the digestive tract did not differ among treatments, except for the abomasum. It can be speculated that this was due to the soil in the abomasums of the sheep on the high litter diets. One of the mechanisms which helps an animal to survive in a drought situation, is the reduction in visceral organ weights and thus in maintenance energy requirements (Fluharty & McClure, 1997). Heavier visceral organs as measured in the present study with the sheep on the high litter diets are therefore contrary to what should be aimed for under drought feeding conditions. This suggests that, under drought feeding conditions, it may be advisable to restrict broiler litter intake and thus reduce maintenance energy requirements.

The soil contamination of the broiler litter was probably the result of mechanical collecting of the litter. This is clearly an undesirable state of affairs and a risk that is run when unregistered broiler litter is fed to ruminants. As such, it would probably not have serious consequences to the animal.

Based on the activity of the plasma enzymes measured, no abnormal tissue catabolism has taken place in the sheep's bodies in any of the treatments. This supports the results obtained in the first trial (Chapter 2).

Experiment 6.2

The different crude protein concentrations of the experimental diets restrict direct comparison between diets. Rumen ammonia nitrogen concentrations for all diets were high, well above the optimum required for rumen microbial growth of between 2 and 20 mmol / 100 ml (Ørskov & Miller, 1988). It emphasizes that it would be wasteful to feed high levels of litter under drought feeding conditions because of the extra drain on energy in the body to detoxify the ammonia (Silanikove & Tiomkin, 1992). The ruminal ammonia nitrogen concentrations of the sheep that received the diets containing urea (control and 28 percent litter) peaked within two hours after feeding, while those on the 85 percent litter diet peaked at 4 to 6 hours after feeding. This probably supports the slower rate of degradation of other sources of nitrogen versus urea.

Over the 12 hours from feeding time the magnitude of ruminal pH (Figure 6.3) changes was small for the 56 and 85 percent litter diets compared to the control and 28 percent litter diets. The pH levels for the 56 and 85 percent litter treatments remained well above pH 6.00, reflecting the alkaline nature of broiler litter (Harmon *et al.*, 1974; Silanikove *et al.*, 1987) and its high buffering capacity. The pH values for the 56 and 85 percent litter diets are in agreement with those reported by Caswell et al. (1977), Silanikove &

Tiomkin (1992), Patil et al. (1995) and Chaudhry et al. (1996) on diets containing lower concentrations of litter than the present investigation. The control and 28 percent litter treatments showed pH reductions down to below pH 6.00 but higher than pH 5.5 at 6 hours from feeding. The introduction of 1 kg of feed directly into the rumen of the sheep would be less than what a sheep of 60 kg would consume voluntary per day. However, the rumen content pH should not be different from when *ad libitum* feed intake was allowed. This should be especially applicable for the finishing diets, the Control and 28 percent litter treatments.

Total VFA (Figure 6.4) peak concentrations were reached 6 hours from feeding time. The 85 percent litter diet recorded the highest concentrations followed by the 56 percent litter diet. In the present study, although not so pronounced, the pH negatively related to the VFA production. The proportion of individual VFA as on a molar percent basis compare well with those reported by Caswell *et al.* (1974) and Rossi *et al.* (1996) for diets containing lower levels of broiler litter. It may be noted that acetic acid (Figure 6.5) concentration for the 56 percent litter diet is higher than that of the other treatment diets in the first 6 hours from feeding time and is about the same as that of the 85 percent litter diet after 6 hours from feeding time. Propionic acid (Figure 6.6) concentrations show the same trend in the first 4 hours from feeding, thereafter, propionic acid concentration for the 85 percent litter diet is higher compared to other treatment diets. The difference between the 56 and 85 percent litter diets composition is that the 56 percent litter diet contains hay and maize meal. This may imply that the broiler litter used in this trial had enough energy in the form of chicken feed. The higher acetic acid production by sheep on

the 56 percent litter treatment compared to other treatment diets may be due to the inclusion of hay in the diet. Butyric acid (Figure 6.7) and valeric acid (Figure 6.8) concentrations showed the same trends as for acetic and propionic acid concentrations. It may be noted though that the control diet valeric acid concentration peaked at a higher concentration compared to the 56 percent diet and remained higher than that of the 56 percent litter diet over the remaining time to 12 hours.

6.5 CONCLUSIONS

This investigation demonstrated that broiler litter can be used in diets for sheep at levels above the recommended 25 percent. However, increasing the litter levels in the diets should be weighed against the desired time to slaughter as the inclusion of broiler litter may increase the adaptation time of the sheep to the feed. Feeding of broiler litter did not have any adverse effects on rumen conditions even when it was fed at very high levels. Because of its high nitrogen content, the inclusion of broiler litter in sheep diets may result in heavier livers and kidneys because of the increased ammonia burden on these organs. Silt content of the litter may result in an increase in the size of the abomasum as it tends to accumulate in this organ. However, the effect of silt in the litter remains to be tested.

CHAPTER 7

7.0 SENSORY CHARACTERISTICS OF MEAT AND SUBCUTANEOUS FAT COMPOSITION OF SHEEP FED DIFFERENT LEVELS OF BROILER LITTER

7.1 Introduction

In South Africa strict legislative control exists over the trading with litter as an animal feed. However, it does not preclude the farmer from feeding litter produced by himself or obtained as a fertiliser, to his livestock. During periods of feed shortage high levels of litter are sometimes fed (Chapter 2). In such emergency situations, farmers are often desperate to reduce stock numbers on the farm. Consequently, cattle and sheep which were fed high levels of poultry litter may end up in the abattoir and in the human food chain. The presence of drug residues in the litter which may contaminate the meat seems to be minimal, provided certain precautionary measures have been taken e.g. ensuring that the poultry did not receive any antibiotics or by enforcing a 15 day withdrawal period from the litter containing diet before slaughter (Fontenot, 1991). Taste panels could not detect any sensory effect in the meat of steers consuming diets containing up to 50% broiler litter (Fontenot *et al.*, 197; Smith *et al.*, 1979; Ben-Ghedalia *et al.*, 1988).

The composition of the ruminant diet may influence the flavour (Melton, 1990; Shand *et al.*, 1998) and fatty acid composition (Webb *et al.*, 1994 ; Shand *et al.*, 1998) of red meat. High energy grain diets were found to produce a more intense flavour in red meats than in low energy diets (Shand *et al.*, 1998). The composition of fatty acid in meat affects the taste of meat (Webb *et al.*, 1992; Shand *et al.*, 1998). Offer & Offer (1994) associated the

reduction in the degree of saturation of tissue and milk fat to the feeding of distillery by-products. Similarly, changes in the fatty acid composition of both bovine and ovine tissues were attributed to components in the diet and the end-products in the digestive tract originating from them (Mills *et al.*, 1992; Rule *et al.*, 1994; Webb *et al.*, 1994b). The effect on carcass properties has not been investigated when very high levels of litter, typical that of an emergency drought feeding situation, were fed to ruminants. In the present study the sensory characteristics and fatty acid composition of mutton were studied when broiler litter constituted up to 85 percent of the sheep's diet.

7.2 MATERIALS AND METHODS

7.2.1 Animals and Treatments

Thirty six SA Mutton Merino wethers, *ca.* 18 months of age with an initial weight of 41 kg, were randomly allocated to four dietary treatments, viz. diets containing 0, 28, 56 or 85 percent broiler litter (Table 6.1). Sun-dried broiler litter was sifted and wethers vaccinated and dewormed as described in Chapter 6. The diets were fed as indicated in Chapter 6 and sheep had free access to water. Feed intake was recorded daily. The sheep were weighed at two week intervals. Wethers were slaughtered at 55 kg body weight to eliminate fatness as a factor in observed difference in sensory characteristics. On reaching a target weight of at least 55 kg the wethers were slaughtered by exsanguination and severing the spinal cord. Carcasses were electrically stimulated (21 V, 60 Hz, 120 sec.) and chilled overnight (4^0C) before samples were collected.

Subcutaneous fat was sampled (5g) from the left side of each carcass, at a point over the 13th rib, 25 mm from the midline (Webb *et al.*, 1994b) and stored in a polyethylene bag at -20^{0}C, pending fatty acid analyses (Webb, 1992; Casey *et al.*, 1988). A three-rib sample was cut from the left side at ribs 8, 9 and 10 for dissection and estimation of the carcass composition. The ventral extremity of the sample was on a line drawn from the pubic symphysis to the middle of the first rib (Webb *et al.* 1994b).

7.2.2 Sensory evaluation

The left loin (M. *Longissimus thoracis et. Lumborum*) was removed from each carcass, vacuum packed and stored at –20^{0}C pending sensory evaluation. A trained sensory panel evaluated these samples on a 10 cm unstructured scale for aroma, juiciness, tenderness flavour and overall acceptability (Webb *et al.*, 1994b). Taint, fat to muscle ratio and fat firmness of the loins were measured according to the techniques described by Webb *et al.* (1994b). The panel used mutton and lamb as standard samples.

7.2.3 Chemical analysis

Extraction of lipids was done according to the procedure described by Ways & Hanahan (1964) as modified by Webb *et al.* (1994a). Methyl esters of the fatty acid component were prepared according to the NaOH / methanol method (A.O.A.C., 1975). The fatty acids were separated on a polar phase SP2330 column (2m x 3mm, packed with Silar 10c coated on Gas chrom Q) fitted to a Varian 3700 gas chromatograph with a flame ionisation detector (Webb *et al.*, 1994a). The DM, organic matter and crude protein concentrations in feed were obtained using standards A.O.A.C. (1990) procedures.

Neutral detergent fibre and acid detergent fibre concentrations in the diets were determined as described in Chapter 2.

7.2.4 Statistical analysis

Data emanating from laboratory analysis and panel testing were subjected to multifactor analysis of variance and detected by Duncan's multiple range test using the General Linear Models (GLM) procedure of SAS (SAS Institute, 1992).

7.3 RESULTS

Chemical composition of the feed and average daily feed intakes per sheep are reported in Tables 6.2 and 6.3. Wethers on the 85 percent broiler litter treatment required 155 days to reach the target slaughter weight compared to the 106, 112 and 115 days required by the 0, 28 and 56 percent litter treatment groups, respectively.

Carcass mass, carcass composition, dressing percentage and subcutaneous fat thickness did not differ significantly ($p < 0.05$) among treatments (Table 7.1). Subcutaneous fat thickness was 2.22, 2.47, 3.26 and 2.84 mm for the 0, 28, 56 and 85 percent litter diets, respectively. The fatty acid composition of the subcutaneous fat of the wethers is presented in Table 7.2. Significant differences ($p < 0.03$) were observed for myristic acid (C 14:0) which was recorded at 2.97, 2.58, 2.26 and 2.38 percent and margaric acid (C 17:0) ($p < 0.04$) at 2.136, 2.356, 2.081 and 1.914 percent for the control, 28, 56 and 85 percent litter diets, respectively. Differences between treatment diets ($p < 0.0001$) were also observed when linolenic acid (C 18:3) results were considered. Linolenic acid

concentrations were 3.296, 3.117, 3.107 and 4.658 percent for the control, 28, 56 and 85 percent litter diets, respectively.

Sensory score results are presented in Table 7.3. Juiciness, tenderness, flavour and overall acceptability showed significant differences ($p < 0.05$) between treatment. Firmness, fat : muscle ratio and taint of the loin scores are found in Table 7.4. Significant differences in fat firmness ($p < 0.05$) were noted between treatment groups. Fat firmness tended to decline with increasing litter in the diet. Fat : muscle ratio was recorded at 56, 22, 22, and 22 for the control, 28, 56 and 85 percent litter treatment groups, respectively. An atypical taint was observed when mutton from sheep fed the 85 percent litter diet was tasted.

Table 7.1: Dressing percentage, carcass mass and carcass composition of mutton from wethers fed broiler litter based diets

	----------Broiler litter (%)----------			
Parameters	**0**	**28**	**56**	**85**
Dressing (%)	48±2	49 ± 3	48 ± 6	47 ± 4
Carcass mass (kg)	26 ±3	27 ± 5	26 ± 7	25 ± 4
Carcass composition (9-10-11th rib cut)				
% lean	43 ± 0.8	46 ± 0.82	45 ± 0.83	45 ± 1.05
% fat	33 ±1.9	30 ± 0.75	32 ± 1.5	32 ± 1.63
% bone	24 ±3.2	24 ± 0.39	23 ± 0.65	23 ± 0.71
Subcutaneous fat thickness (mm)	2.22	2.47	3.26	2.84

Table 7.2: Influence of different levels of broiler litter diets on subcutaneous fat composition (molar %) of wethers

	----------Broiler litter (%)----------				
Fatty acid	**0**	**28**	**56**	**85**	**Significance**
C 14:0	3.0^{a}	2.6^{ab}	2.3^{b}	2.4^{b}	P = 0.03
C 15:0	0.28	0.36	0.27	0.36	NS
C 16:0	25.1	25.2	26.2	25.8	NS
C 16:1	2.6	2.9	2.7	2.6	NS
C 17:0	2.1^{ab}	2.4^{a}	2.1^{ab}	1.9^{b}	P = 0.04
C 18:0	20.0	18.4	18.0	18.5	NS
C 18:1	42.4	43.9	44.2	42.2	NS
C 18:3	3.3^{a}	3.1^{a}	3.1^{a}	4.7^{b}	P = 0.0001
C 20:1	1.2	1.3	1.2	1.6	NS

*Means on the same row with different superscripts are different

Table 7.3: Sensory characteristics of carcass samples from wethers fed high broiler litter levels

	----------Boiler litter (%)----------			
Parameters	**0**	**28**	**56**	**85**
Aroma intensity	7.61 ± 0.46	7.58 ± 0.38	7.52 ± 0.57	7.41 ± 0.52
Juiciness	7.78^{a}± 0.50	7.66^{a} ±0.56	7.58^{a}± 0.65	7.24^{b}± 0.60
Tenderness	7.48^{ab}± 0.67	7.61^{a}± 0.71	7.70^{a} ±0.78	7.27^{b} ±0.93
Flavour	7.71^{a} ± 0.43	7.64^{a} ±0.45	7.58^{ab}±0.45	7.45^{b}± 0.52
Overall acceptability	7.65^{a}± 0.44	7.61^{a} ±0.53	7.55^{a} ± 0.59	7.23^{b} ±0.57

*Means on the same row with different superscripts are different at $p < 0.05$
Scale : 0 - 10

Table 7.4: Loin sample characteristics of wethers fed different levels of broiler litter

	----------Broiler litter (%)----------			
Parameters	**0**	**28**	**56**	**85**
Fat firmness (%)				
Firm	89[a]	67[b]	67[b]	78[c]
Soft	11	33	33	22
Fat : muscle ratio (%)				
Little	56[a]	22[b]	22[b]	22[b]
Medium	44	67	78	56
Abundant	0	11	0	22
Taint (%)				
Typical	100	100	100	93.7
Atypical	0	0	0	6.3

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

7.4 DISCUSSION

Carcass mass, carcass composition, dressing percentage and subcutaneous fat thickness did not differ among treatments. Since all sheep were slaughtered at reaching 55 kg body weight, this had the advantage that the degree of fatness could be excluded as a reason for differences in the sensory characteristics due to diet composition. Fatty acid composition of the subcutaneous fat of the wethers was negatively affected by the litter inclusion. Inclusion of broiler litter in the diets reduced myristic acid (C 14:0) concentration from 2.97 mol (%) in the control to 2.38 mol (%) in the 85 percent litter treatment. Similarly, the margaric acid (C 17:0) was lower and the linolenic acid (C 18:3) concentration higher in the carcass fat of the wethers consuming 85 percent broiler litter diet, compared to the other treatment groups. It is well established that composition of the diet can change the

fatty acid composition of the ruminant tissues (Mills *et al.*, 1992; Rule *et al.*, 1997; Webb *et al.*, 1994b). This has been attributed to the effect of the diet on changes in proportion and peak concentrations of volatile fatty acids produced in the rumen (Duncan *et al.*, 1974). High sensory scores (7 on a scale of 1 to 10) were obtained for all treatments. These corresponded well with sensory scores obtained for wethers finished on normal feedlot diets (Webb *et al.*, 1994b; 1997). Aroma intensity did not differ among treatments but tended to decrease with increasing inclusion of litter in the diets. The juiciness score of the loin samples from wethers fed the 85 percent litter diet was lower than the scores in other treatments. Ilian *et al.* (1988) recorded juicier meat when sheep received up to 40 percent poultry litter in their diets compared to the meat of sheep receiving no litter. However, increased juiciness was associated with an increased carcass fat content (Ilian *et al.*, 1988). In the present study carcass fat content did not differ among treatments and therefore could not have contributed to a decreased juiciness with the increase in litter inclusion in the diets.

The tenderness of *M. longissimus thoracis* samples from sheep on the 85 percent litter diet was lower ($p < 0.05$) than those of sheep on the 28 and 56 percent litter diets but did not differ from the control samples. Ilian *et al.* (1988) reported more tender meat when up to 40 percent poultry litter was included in diets of sheep than when no litter was included. Inclusion of 85 percent litter in the diet decreased the flavour of the sensory samples compared with the flavour in meat from the other diets. Webb *et al.* (1997) found that a higher proportion of carcass fat and a thicker subcutaneous fat depth were associated with lower flavour scores in the loin samples. They calculated that 31 percent

of the variability in the flavour of the samples was due to the proportion of fat in the carcass. Again, fat thickness did not differ among treatments in the present study. However, this difference in flavour could be related to the lower proportions of the C 14:0 and C 17:0, and the higher proportion of C 18:3 fatty acids in the carcass fat of the 85 percent litter treatment compared to other treatments. Another factor, which is related to lower flavour scores, is a high level of arsenic in the diet (Westing *et al.*, 1985). Although the concentration of arsenic can be high in broiler litter (Westing *et al.*, 1985), arsenic concentrations were not measured in the diets used in the present study.

The overall acceptability of the loin samples tendered to decrease with increasing litter levels in the diets with an overall acceptability in the 85 percent litter treatment being lower then acceptability in the other treatments. A higher proportion of carcass fat and increased thickness of subcutaneous fat were found to be associated with a decline in overall acceptability of the loin samples (Webb *et al.*, 1997). Although in the present study the thickness of the subcutaneous fat tendered to increase with litter inclusion in the diets, these differences were not statistically significant. Furthermore, the degree of fatness was not related to type of diet, but rather to the fatness of the sheep at slaughter, which was done at a body weight of at least 55 kg.

The carcass of the wethers receiving the broiler litter diets tended to have lower fat firmness scores compared to the control diet. A decline in fat firmness scores was observed when wethers consumed high energy diets (11.8 MJ ME /kg DM) which is associated with a high propionic acid concentration in the ruminal fluid, compared to

diets lower in energy concentration (10.2 MJ ME /kg DM) (Webb *et al.*, 1997). Likewise, processing of cereals which is associated with an increase in the proportion of propionic acid in the ruminal fluid was found to decrease the firmness of the subcutaneous fat in sheep (Ørskov *et al.*, 1974). In general, an increase in the broiler litter component of the diet tended to decrease the energy concentration of the diet. However, because the physical properties of litter which is a combination of the manure powder and coarse bedding material, the ratio of these component can vary. Consequently, the effect of litter inclusion in a diet on volatile fatty acid composition in the rumen seems to be inconsistent. Fontenot & Jurubescu (1980) and Rossi *et al.* (1996) reported that the inclusion of litter diets altered rumen fermentation towards increased propionic acid production. Such a change towards a higher propionic acid concentration in the ruminal fluid was not observed (Chapter 6) when diets high in litter were fed to sheep.

The taint of all meat from the 0, 28 and 56 percent broiler litter treatments was classified as "typical", while 6.3 percent of the samples from the 85 percent litter diet was classified as "atypical". The taint of these samples was described as "sour". According to Melton (1990) and Shand *et al.* (1998) the composition of the ruminant diet may influence the flavour of red meat. Webb *et al.* (1994b) and Shand *et al.* (1998) observed that the composition of the ruminant diet also affected the subcutaneous fatty acid composition. The "atypical" taint observed in the study may be due to the composition of the litter, which had a higher mineral content. However, the magnitude and true cause of the flavour has to be confirmed in further studies.

From the present study it is concluded that the inclusion of broiler litter at levels of more than 56 percent might induce slight detrimental effects on the sensory quality of the meat. This seems to be mainly because of changes in the fatty acid composition of the carcass fat and an acquisition of an off flavour in the meat. However, in the event of an emergency feeding situation, mutton producers could include up to 56 percent broiler litter in the diet without affecting the eating quality of the mutton.

CHAPTER 8

8.0 THE NUTRITIONAL VALUE OF BROILER LITTER AS A FEED SOURCE FOR SHEEP DURING PERIODS OF FEED SHORTAGE-

CONCLUSIONS

It must be accepted that most people will probably find the feeding of animal excreta to other animals revolting and offensive. An even worst reaction could be expected if it should be known that such a product is not registered as an animal feed. Such a reaction can be anticipated, considering the total ban in Europe on the feeding of animal products to other animals. However, any farmer watching his livestock waning away because of lack of food, be it during a protracted drought which is frequently occurring in Southern Africa or the result of veld fires that destroyed vast areas of grassland, would be desperate to help his animals and would resort to desperate means of achieving that. Farmers' financial resources would seldom be adequate to simply buy in feedstuffs, which usually have to be transported over long distances, thus adding to their cost. The feeding of poultry manure during such periods of food shortage is therefore both a humane act towards the animal and an attempt of the farmer to survive financially. This present investigation was therefore not intended to disprove the concerns of opponents to the feeding of poultry excreta to animals, nor to justify the feeding of unregistered poultry manure to ruminants. The objective was to evaluate the effects on the animal of feeding high levels of broiler litter as an emergency nutrient resource and to be able to advise farmers on the safe use of broiler litter under these conditions. The hypothesis

was that broiler litter could be fed successfully to overcome such a crisis situation, provided certain basic precautions are taken.

In the study, the feeding and management practices on the farm during a drought were followed as far as possible. The broiler litter was not sterilised but sun-dried, usually containing a moisture content of less than 15 percent. The product was sifted to remove lumps and dead chickens and the animals were vaccinated twice against botulism, at five and one weeks before the starting of a trial. It is accepted without further verification that the botulism toxin is frequently present in broiler litter and that the animals must be vaccinated. The litter in different trials was obtained from different sources, therefore representing litter from a variety of broiler production enterprises. In most of the trials a maximum voluntary intake of the litter was allowed in an attempt to solicit a worst possible response or reaction in the sheep.

The sun-dried broiler litter available in South Africa is usually low in moisture (< 12%) and according to Weuthrich (1979) a medium unsuitable for microbial growth. Therefore, a basic requirement if unsterilised litter is used as a survival feed, is that the litter must be dry and be kept dry. The dry Southern African climate with its abundance of sunshine has probably the advantage that the litter used by farmers is usually dry, probably containing few if any pathogens. This may explain why farmers in Southern Africa who are feeding broiler litter to their livestock usually experience minimal destinct problems related to pathogens. Based on plasma enzyme activities and the histopathological evaluation of tissues, no evidence of tissue damage or a health problem

in the sheep could be related to their high broiler litter intakes in the present study. Despite these observations, plenty of evidence and an active field of research, mainly in the USA, demonstrated that there are different cheap methods of sterilizing poultry litter for animal consumption. These include the ensiling of litter with other crops or alone, deep stacking, etc. (Carter &Poore, 1998).

The nitrogen concentration of Southern Africa litter seems to be low compared to similar products in the USA and other countries. Fontenot & Jurubescu, (1980) reported a crude protein concentration of 300 g/kg DM for USA litter. Compared to that the average South African samples contain ±200 g /kg DM (Van Ryssen *et al.*, 1977 and present study). This difference could be due to the method of drying the litter. Sun-drying could result in a substantial loss of ammonia causing the low crude protein in South African samples. Furthermore, the local practice of keeping birds on bedding material for only one production cycle before the house is cleaned, compared to five to six cycles in the USA would reduce the proportion of manure to bedding material and thus the crude protein concentration in the local material.

Despite the relatively low crude protein concentration in the litter used in the present study, very high concentrations of ammonia in the rumen fluid (51.4 mmol/100ml) and urea in the blood (293 mg/l) were recorded in the sheep consuming the litter. Results from the partial digestion study showed that as much as 50 percent of the nitrogen in the pure litter diets did not reach the abomasum of the sheep, and was apparently lost through the rumen wall. Such high blood urea and ammonia concentrations could be harmful to

animals in terms of fertility and production (Polmann et al., 1981; Erb et al., 1976; Jordan & Swanson, 1979). No immediate detrimental effect on the sheep was recorded in the present study. A high concentration of ammonia was expected in the rumen. This prompted the decision to add molasses to some experimental diets to encourage a more efficient microbial conversion of the ammonia to protein in the rumen. However, the addition of molasses increased the rate of passage of the ingesta through the rumen, making it impossible to measure the effect of molasses *per se* on protein synthesis by the microorganisms in the rumen. Despite the higher rate of flow with the addition of molasses, the total quantity of nitrogen lost from the rumen was approximately the same, with or without the addition of molasses. The risks associated with high ammonia concentrations in the rumen and body with the feeding of high levels of litter could therefore not be eleviated through the inclusion of molasses to the diet. At a restricted litter plus 15 percent molasses intake, the response might have been different. However, this was unfortunately not tested in the study.

From this study it appears as if the uric acid concentration in the South African litter is very low. This may indicate a possible loss of ammonia during sun-drying. It would be interesting to verify this observation on local litter samples in a more extensive survey.

The available energy in broiler litter is claimed to be low (Bhattacharya & Fontenot, 1966; Bhattacharya & Taylor, 1975; Bull & Reid, 1971; Tinnimit *et al.*, 1972). However, although the ME is not as high as a pure energy source such as maize meal, the quoted values of 10.21 MJ ME / kg DM are not low, nor the digestibility of the organic matter

measured in the present study. Therefore, it may be questioned if the addition of 15 percent molasses to litter could have substantially improved the supply of available energy to rumen microbes. It could only be speculated why the addition of 15 percent molasses increased the dry matter intake as observed in the present study. Even more relevant is the question of whether the addition of the 15 percent molasses was benefitial or not to the animal in a survival feeding situation. The addition of molasses resulted in a drastic increase in feed intake, though did not reduce the demand on the energy resources in the body to metabolize the surplus ammonia absorbed from the rumen. Furthermore, the high feed intake resulted in an increase in weight of visceral organs, and thus in energy requirements to sustain these heavier tissues. It is suggested that the intake of broiler litter in a survival feeding situation should be restricted and molasses should be added only if litter intake is unsatisfactorily low. The sheep consuming the litter at a rate of 1.9 % of their body weight, still gained weight. This suggests that litter consumption for survival does not have to be more than approximately 1.5 percent of body weight.

With the addition of 15 percent molasses a change in the site of disappearance of organic matter towards the lower digestive tract was recorded. Whether the animal is benefiting at all from that is not certain, though, under drought feeding conditions, does not seem to be desirable. This again supported the suggestion that the addition of molasses is not required in a survival ration.

From the two growth trials it was clear that broiler litter even at a 100 percent litter diet contained enough energy to give weight gains and improved body condition of the sheep. This may be an added bonus under survival feeding conditions if the farmer can sell his animals. However, since there is no guarantee that there are no drug residues present in the litter, such a practice of introducing these animals into the human food consumption chain cannot be recommended.

World-wide, pressure is on animal feed manufacturing companies to produce animal feeds that are environmentally friendly, i.e. resulting in the lowest possible excretion of substances that can pollute the environment. This is to the advantage of the livestock producer using broiler litter because potential drug and mineral residues in litter would be less of a problem. In South Africa, copper sulphate and the coccidiostat, highly toxic to ruminants, maduramicin, are not included in broiler diets and therefore not a problem when the litter is fed to ruminants. A potential problem of litter as a feed for ruminants is the high calcium and phosphorus concentrations. Phosphorus can precipitate urinary calculi in sheep, and the calcium can be a problem causing milk fever in beef cows. The feeding of broiler litter to pregnant beef cows close to calving therefore cannot be recommended. Selenium in broiler litter is readily bio-available, making broiler litter a good source of selenium. Iron concentrations in broiler litter are well above the requirements for ruminants, posing a potential problem of iron toxicity.

In the present investigation it appeared as if the sheep consuming high levels of broiler litter took a long time to adapt to the diet. It is not clear if that was due to a slow

adaptation of rumen microorganisms to broiler litter diet or for some other reason. This will obviously not be desirable in a survival feeding situation, nor in experiments where a statistical design such as a Latin square is used. Further studies are required to clarify this.

Broiler litter consists of a mixture of faeces, litter material and sometimes apparently soil. Soil contamination of the litter was evident in one batch of litter used, though its effect on the animal and production seems to be relatively small (Brosh *et al.*, 1998). However, it would be advisable to ensure that soil contamination is restricted to a minimum because of its diluting effect on the litter and the tendency of the soil to accumulate in the rumen and abomasum. The local litter is coarser than the USA product, probably explaining the absence of bloat in South African livestock on high levels of litter compared to the USA situation.

It can be concluded that broiler litter can be used successfully as a survival diet for ruminants. However, it was clear that there are potential health problems to the animal and certain precautions must be taken. Results in this study suggested that it may be desirable to feed to litter at a level well below optimal intake. A level of approximately 1.5 percent body weight is suggested.

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