Effect of dietary molasses on the site and extent of digestion of nutrients in sheep fed broiler litter

D.T. Mavimbela and J.B.J. van Ryssen[#]
Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa

Abstract

The aim of this experiment was to determine the site and extent of digestion of nutrients in sheep fed broiler litter alone (100% litter treatment), broiler litter plus 7.5% sugarcane molasses (92.5% litter treatment) and broiler litter plus 15% molasses (85% litter treatment). Voluntary intake was increased by molasses, apparently due to an increased rate of passage of digesta through the digestive tract. This resulted in a shift in the site of disappearance of organic matter (OM) from the rumen towards the lower digestive tract. For the 100 and 92.5% litter treatments, 0.37 and 0.46 of dietary OM disappeared in the rumen respectively, compared to 0.21 for the 85% litter treatment, while 0.16, 0.08 and 0.35 of dietary OM disappeared in the small intestine for the 100, 92.5 and 85% litter diets respectively. In the case of the 85% litter treatment, 0.26 of dietary nitrogen (N) disappeared in the rumen and 0.45 in the small intestine, compared to 0.55 and 0.62 in the rumen and 0.18 and 0.11 in the small intestine for the 100 and 92.5% litter diets respectively. There were no differences between treatments for total tract apparent digestibility of N (0.73) and OM (0.65-0.73), rumen degradability of N (71-87%) or concentration of ammonia-N in rumen fluid (53 mg/100 ml). It was concluded that the addition of molasses might be advantageous when the intake of litter is restricted or when voluntary intake of litter is unacceptably low.

Keywords: broiler litter, sheep, nutrition, molasses, digestion
[#]Author to whom correspondence should be addressed. E-mail: jvryssen@postino.up.ac.za

Introduction

Many farmers in southern Africa use poultry manure as a livestock feed during protracted droughts or after the destruction of forage resources by fire (Mavimbela *et al*., 1997). The potential problems associated with the use of poultry manure or litter as a feedstuff have been investigated extensively. Many studies have emphasised that precautionary measures should be employed when feeding this product, which may be nutritionally unbalanced or pose a health-risk to the animal (Fontenot & Jurubescu, 1980; Fontenot, 1991; Rankins *et al*., 1993; Mavimbela *et al*., 1997; Ruffin & McCaskey, 1998).

According to Fontenot (1991), broiler litter has a high crude protein concentration, consisting mainly of non-protein nitrogen (NPN), and is deficient in available energy. When high levels of litter are fed, molasses is often added as a source of energy that is readily available to the rumen microbes to complement the high nitrogen (N) concentration of litter (Mavimbela *et al*., 1997). Little information has been published on the digestion of nutrients when litter constitutes all or most of the diet. The aim of this experiment was to determine the site and extent of digestion of nutrients in sheep fed broiler litter alone, broiler litter plus 7.5% sugarcane molasses and broiler litter plus 15% molasses.

Materials and Methods

Six mature South African Mutton Merino wethers (54 kg mean body weight) were used. The sheep were equipped with rumen, abomasal and terminal ileal cannulae. The wethers were randomly allocated to treatments consisting of pure broiler litter or litter mixed with 7.5% sugarcane molasses or 15% molasses in a 3 x 3 Latin square design, i.e. two wethers per treatment per period; six animals per treatment. The broiler litter that was used had been sun-dried and contained wood shavings that had been included as bedding material. The litter was passed through a 2.5 cm sieve to remove lumps and foreign material. The sheep were vaccinated against botulism and treated with a broad-spectrum anthelmintic three weeks prior to the trial. Sheep were allowed to adapt to the diets for 14 days between dietary treatments. Diets were offered *ad libitum*, and animals had free access to water. Feed intake was recorded and representative feed samples were taken. The experiment was conducted with the approval of the Ethics Committee for Animal Experimentation of the University of Pretoria.

The double marker technique (Faichney, 1975) was used for estimation of partial digestibility, with

chromium (Cr-EDTA; Downes & McDonald, 1964) and ytterbium (Yb-acetate; Siddons *et al*., 1985) as liquid and particulate phase markers respectively. The Cr-EDTA and Yb-acetate were prepared according to the methods described by Morgan *et al*. (1976), and predetermined daily doses were infused continuously into the rumen using a peristaltic pump. From day five of infusion, ruminal, abomasal and ileal contents were collected over a period of four days. A discontinuous sampling schedule was followed to minimise disturbance of the normal flow of digesta. Samples of rumen, abomasal and ileal digesta were collected as follows: at 9:00 and 21:00 on day 5; at 12:00 and 24:00 on day 6; at 15:00 and 03:00 on day 7; at 18:00 and 06:00 hours on day 8.

Rumen samples were strained through six layers of cheesecloth, and the fluid fractions were preserved with 50% (v/v) sulphuric acid for ammonia nitrogen (NH_3-N) assay. Abomasal and ileal digesta samples were frozen at -20^{o}C. Faeces were collected twice daily and aliquots were stored at -20^{o}C. After thawing, composite samples of abomasal and ileal digesta were centrifuged and the supernatant stored at -20^{o}C pending Cr, Yb and NH_3-N analyses. Digesta and faecal samples were dried at 60^{o}C and ground. Cr and Yb concentrations in abomasal and ileal samples (total and supernatant) were determined by atomic absorption spectrophotometry. The NH_3-N concentrations in ruminal and composite abomasal and ileal samples were determined with an auto analyzer (Technicon Auto-Analyzer II; Industrial method No. 334-74A). The ash and N concentrations of feed, faeces and composite abomasal and ileal samples, and dietary phosphorus content were determined using standard AOAC (1990) procedures. Neutral detergent fibre and acid detergent fibre concentrations in the diets were determined according to the procedure of Robertson & Van Soest (1981). The purine method (Zin & Owens, 1986) was used to determine the microbial N concentration of abomasal contents. The ratio of purine-N to total N in microbes was estimated from analysis of rumen bacteria collected from sheep consuming only broiler litter. Atomic absorption spectrophotometry was used to determine the calcium, magnesium, sodium, potassium, copper, manganese and zinc concentrations of the diets. A hydride generator was attached to the atomic absorption spectrophotometer for assay of selenium 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.

Abomasal and ileal digesta flows were calculated using Cr as liquid phase marker and Yb as particulate marker (Faichney, 1975). Total digesta flows were reconstituted according to marker concentrations in fractionated and unfractionated digesta. Organic matter (OM) and N disappearance in the various regions of the digestive tract was calculated as the difference in digesta flow (or intake/excreted) before and after the specific section. Non-ammonia nitrogen (NAN) was assumed to represent the N in true protein and was calculated as the difference between total N and NH_3-N flows at a specific site.

Statistical analyses appropriate for a latin square design were conducted using SAS (1994), and a Tukey test was used to determine the significance of differences. Treatment, animal and period effects were included in the analysis.

Results

The chemical composition of the broiler litter is presented in Table 1. The addition of molasses did not change the composition substantially except for slight increases in the concentration of potassium. Particles greater than 2 mm in diameter constituted 41% of the litter, and particles less than 1 mm in diameter constituted 52%.

Dry matter intake increased ($P < 0.05$) with an increase in molasses inclusion in the diet, *viz*. (mean ± s.e.) 858 ± 251, 1123 ± 342 and 1366 ± 413 g/d, constituting 1.9%, 2.4% and 3.0% of body weight for the 100%, 92.5% and 85% litter treatments respectively. This trend was also evident for OM intake, and a higher flow rate of digesta through the abomasum and ileum was observed for the high molasses treatment (Table 2). Apparent OM digestibility was lower ($P < 0.05$) in the rumen and higher ($P < 0.05$) in the small intestine for the 85% litter treatment than for the other treatments. Consequently, a larger proportion of dietary OM disappeared in the small intestine (0.35) than in the rumen (0.21) with the 85% litter diet - a trend not observed with the other two treatments. However, total apparent OM digestibility did not differ significantly between treatments ($P > 0.05$). Faecal DM concentration for the 85 % litter treatment (mean ± s.e.: 40.8 ± 3.5%) was lower ($P < 0.05$) than that for the 100% (49.5 ± 2.7) or 92.5% (47.3 ± 4.8%) litter treatments.

Table 1 Chemical composition of broiler litter (dry matter basis)

	g/kg
Dry matter	850
Organic matter	820
Crude protein	190
Neutral detergent fibre	410
Acid detergent fibre	280
Calcium	130
Phosphorus	130
Magnesium	20
Potassium	11.2
Sodium	2.4
	mg/kg
Manganese	290
Copper	58
Selenium	0.94
Zinc	222

Table 2 Means (± s.e.) for intake, flow and apparent digestion of organic matter (OM) in various segments of the digestive tract of sheep fed diets containing 100, 92.5 or 85% broiler litter

Broiler litter (%)	100	92.5	85
Molasses (%)	0	7.5	15
OM intake (g/d)	732 ± 241	986 ± 329	1133 ± 397
Total OM flow (g/d)			
At abomasum	459 ± 286	532 ± 634	901 ± 308
At terminal ileum	341 ± 215	450 ± 401	509 ± 171
OM apparently digested (proportion of OM intake)			
Rumen	0.37 ± 0.187[a]	0.46 ± 0.102[a]	0.21 ± 0.109[b]
Small intestine	0.16 ± 0.067[a]	0.082 ± 0.046[a]	0.35 ± 0.152[b]
Large intestine	0.062 ± 0.029	0.073 ± 0.016	0.08 ± 0.029
Total tract	0.59 ± 0.145	0.62 ± 0.091	0.64 ± 0.106

Means within rows with different superscripts differ significantly ($P < 0.05$)

The inclusion of 15% molasses in the diet resulted in a higher, though non-significantly different ($P > 0.05$) N intake compared to the other two treatments. However, this resulted in significantly higher ($P < 0.05$) flow rates of total N, NAN and microbial N through the abomasum for the 85% litter treatment compared to the other treatments (Table 3). The NH_3-N concentrations in ruminal fluid did not differ between treatments. Microbial N constituted 62-72% of abomasal NAN. The rumen degradability of N in broiler litter, as estimated from these results, was between 71 and 86% (Table 3). Nitrogen disappearance was higher ($P < 0.05$) in the rumen and lower in the small intestine ($P < 0.05$) for the 100% and 92.5% litter diets than for the 85% litter treatment, although apparent N digestibility for the digestive tract as a whole did not differ significantly between treatments (Table 3). Microbial N apparently synthesized per kg of OM digested in the rumen was 27.8, 16.1 and 75.3g for the 100, 92.5 and 85% litter diets respectively.

Table 3 Mean (± s.e.) nitrogen (N) intake, flow and apparent digestion in various segments of the digestive tract of sheep fed diets containing 100, 92.5 or 85% broiler litter

Broiler litter (%)	100	92.5	85
Molasses (%)	0	7.5	15
N intake (g/d)	31.3 ± 12.3	43.8 ± 15.5	52.0 ± 25.7
Total N flow (g/d)			
Abomasum: Total N	14.1 ± 8.9 [a]	17.8 ± 8.8 [a]	39.3 ± 20.8 [b]
Abomasum: NAN	12.0 ± 3.1 [a]	15.1 ± 3.2 [a]	34.3 ± 21.3 [b]
Abomasum: Microbial N	8.6 ± 2.5 [a]	10.4 ± 2.0 [a]	15.9 ± 2.2 [b]
Terminal ileum: NAN	5.1 ± 2.6	6.0 ± 1.7	6.2 ± 2.6
Indicators of the apparent fate of N in the rumen			
NH_3-N (mg/100 ml)	51 ± 11.5	56 ± 12.1	51 ± 12.5
Degradability (%)	86.7 ± 8.71	86.5 ± 10.65	71.4 ± 28.17
Microbial N as % of:			
Abomasal NAN*	72.4 ± 15.4	70.1 ± 13.4	62.8 ± 34.6
N intake	30.8 ± 12.5	26.1 ± 8.8	38.6 ± 21.6
N apparently digested (proportion of N intake)			
Rumen (N)	0.55 ± 0.19[a]	0.62 ± 0.14[a]	0.26 ± 0.17 [b]
Small intestine (NAN)	0.18 ± 0.06 [a]	0.11 ± 0.02 [a]	0.45 ± 0.095 [b]
Total tract (N)	0.72 ± 0.073	0.72 ± 0.042	0.73 ± 0.044

Means within rows with different superscripts differ significantly ($P < 0.05$); *NAN = Non-ammonia N

Discussion

The apparent DM digestibility (total digestive tract) of broiler litter varied between 0.65 and 0.68. This compares well with published values (calculated by difference) of 0.69-0.74 (Bhattacharya & Fontenot, 1966), 0.50 (Rankins *et al*., 1993) and 0.57-0.58 (Rude & Rankins, 1997). Similarly, the total tract apparent digestibility of OM ranged between 0.54 and 0.64, and compared well with reported OM digestibilities of 0.64 (Fontenot & Jurubescu, 1980), 0.44 and 0.47 (Patil *et al*., 1995), 0.56 and 0.58 (Chaudhry *et al*., 1996) and 0.42-0.46 (Rossi *et al*., 1996). The apparent digestibility of N in litter was 0.72 in the present study. This agrees with estimates of 0.72 and 0.74 (Bhattacharya & Fontenot, 1966), 0.67-0.73 (Patil *et al*., 1995), 0.61-0.71 (Chaudhry *et al.*, 1996) and 0.84 (Zinn *et al*., 1996). Considering the digestibility of OM in litter, the statement that broiler litter is deficient in available energy (Fontenot, 1991) is only correct in the sense that it is low relative to the high crude protein concentration of the product.

The increase in voluntary DM intake observed with increasing additions of molasses to the broiler litter is in agreement with the findings of a previous study (Mavimbela *et al*., 1997). Silanikove *et al*. (1987) observed a high intake of litter by beef cows and concluded that the small particle size of broiler litter resulted in fast escape from the rumen and a relatively high intake. However, others are of the contention that the physical and chemical nature of broiler litter is conducive to a lack of rumen stimulation with low saliva flow and voluntary intake (Patil *et al*., 1995; Rossi *et al*., 1996), and to bloat in cattle (Ruffin & McCaskey, 1998). Patil *et al*. (1995) suggested that the passage rate of ruminal digesta of diets containing high levels of broiler litter (*viz.* 50%) is low when dietary roughage levels are low, resulting in low feed intake. No signs of bloat were noticed in our study although DM intake for the 100% litter treatment was only 1.9% of body weight, which is low for sheep. A possible explanation for this disparity could be that the average particle size of litter used in the present study was higher (41% of particles were greater than 2 mm in diameter) than that used in the other studies; this would have stimulated rumination more than in the other studies. Rossi *et al*. (1996) recorded average particle sizes for litter samples collected in the USA of 1.53, 1.05, 0.85 and 0.79 mm. The difference between the particle size of litter used in this study (representative of the South African product) and the USA samples could be the result of different broiler rearing practices. In the USA five to six batches of broilers are commonly reared in a house before the litter is removed (Park *et al*., 1995; Patil *et al*., 1995; Rude & Rankins, 1997), while in South Africa broiler houses are usually cleaned after each batch of birds.

According to Ruffin & McCaskey (1998), broiler litter tends to become dusty and unpalatable for cattle when it contains less than 12% moisture. The addition of molasses in the present study might have decreased the dustiness of the litter, and thus improved intake. To what extent the 15% molasses had a laxative effect and thus increased the rate of passage of the digesta through the digestive tract, is not clear. Although the DM concentration of the faeces was significantly lower for the 15% molasses treatment than for the other two treatments, this was probably not caused by a laxative effect of the molasses. Blaxter *et al*. (1956) observed differences in faecal DM concentration when the rate of passage of diets through the digestive tract differed. They concluded that a high rate of passage of digesta through the colon limits the time available for water absorption from the digesta. This results in a higher water concentration in the faeces, compared to faeces from digesta moving slowly through the colon. In a previous study (Mavimbela *et al*., 1997), lambs gained more weight when broiler litter plus 15% molasses was fed than at lower inclusion levels of molasses. This was suggested to be due mainly to the higher DM intake of the molasses supplemented group. Molasses inclusion at 15% was thus beneficial to the animals.

The addition of molasses to the litter resulted in a shift in the site of disappearance of OM away from the rumen towards the small intestine. The disappearance of a higher proportion of dietary OM in the small intestine than in the rumen seems abnormal and biologically unlikely. The AFRC (1998) states that 0.55-0.70 of the digestible energy in a roughage diet typically disappears from the rumen and 0.20-0.35 from the small intestine. To what extent a change in site of digestion would be beneficial or undesirable for animals consuming broiler litter is unclear.

For optimal utilization of dietary N, all N should be absorbed as amino acids from the small intestine. Oltjen *et al*. (1968) reported that the rate of ruminal degradation of uric acid was slower than that of urea, and Zinn *et al*. (1996) estimated that 96% of uric acid is degraded in the rumen. Previously, Jacobs & Leibholz (1977) could not detect uric acid in the digesta entering the abomasum of calves, but speculated that undetected uric acid or allantoin might escape rumen degradation. In the present study rumen degradability of N in broiler litter was estimated to be between 71 and 87%. These values corresponded well with estimates of 85-93% obtained, using the *in situ* polyester bag technique (Erasmus, 1990). The smaller loss of dietary N (0.26) in the rumen with the 15% molasses treatment compared to the other two treatments (0.55 and 0.62) may be indicative of improved conversion of dietary N to microbial N. The microbial-N yield per g NAN in the abomasum and per unit N intake increased with the addition of 15% molasses to litter. However, this was probably not only due to the effect of molasses on microbial growth, but also because of the higher rate of passage of feed through the rumen. It is well documented that a higher rate of passage of feed through the rumen increases the efficiency of microbial protein synthesis in the rumen (AFRC, 1992). It should, however, be stated that the microbial N yield value of 75.3 g per kg of OM digested in the rumen for the 15% molasses diet seems exceptionally high. Titgemeyer (1997) pointed out that the error factors in partial digestibility studies can be very high.

The NH_3-N concentrations in ruminal fluid recorded in this study (above 50 mg/100ml) correspond with the results of Silanikove & Tiomkin (1992) in which study beef cows consumed 6 kg of poultry litter and a small quantity of wheat straw per day. These concentrations are well above the range of 2 – 20 mg NH_3/100 ml, considered as the optimal for efficient utilization of NH_3 by rumen microorganism (Ørskov & Miller, 1988). A large proportion of dietary N (0.55 and 0.62 respectively) from the 100% and 92.5% litter diets must have been absorbed as ammonia through the rumen wall. This is in agreement with the results of Mavimbela *et al*. (1997) who reported high concentrations of urea in the blood of sheep fed diets containing 85-100% broiler litter. In a drought feeding situation, where a shortage of energy is the primary problem, the detoxification of excess NH_3 in the liver could put an additional strain on the energy and N metabolism of the body (Lobley *et al*., 1995). The concentration of NH_3 in the rumen did not decrease when 15% molasses was added, despite the proportional change in site of N disappearance towards the small intestines. This was probably because of the higher litter intake, and implies that the strain on the body to detoxify NH_3 absorbed from the rumen would not have been alleviated by the addition of molasses.

Conclusion

Considering the apparent improved efficiency of rumen microbial synthesis and a better growth performance of lambs, as observed in a previous trial (Mavimbela *et al*., 1997), the inclusion of molasses was beneficial to the sheep. However, during a period of drought, the feeding of high levels of litter to sheep might be extravagant and the addition of molasses may be unnecessary except if litter intake can be restricted, or if the voluntary intake of litter is unacceptably low.

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