

Short communication**Effects of fibre source on nutrient digestibility of diets for finishing lambs****J.F. Macdonald¹, O.B. Einkamerer^{1#}, A. Hugo², A. Lepori¹, G.C. Josling¹ & M.D. Fair¹**¹Department of Animal, Wildlife, and Grassland Sciences, P.O. Box 339, University of the Free State, Bloemfontein, 9300, South Africa²Department of Microbial, Biochemical and Food Biotechnology, P.O. Box 339, University of the Free State, Bloemfontein, 9300, South Africa

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Abstract

Inexpensive fibre sources might be used as an alternative to lucerne hay in diets for finishing lambs. Thus, effects of providing fibre from lucerne hay (LH), soyhulls (SH), maize stover (MS) and *Eragrostis tef* hay (ET) on the nutrient digestibility of diets of finishing lambs with comparable NDF and nutrient concentration were evaluated. Thirty-six individually housed Merino ram lambs (\bar{x} = 43.03, SD = 3.72 kg) were randomly allocated to four diets (n = 9 lambs/treatment). A digestibility study was conducted to determine the nutrient availability of these diets. Dry matter (DM) intake of SH (1436 g) was lower than ET (1716 g). No differences were recorded between treatments for digestibility of NDF (0.32 - 0.34), acid detergent fibre (ADF) (0.41 - 0.44), and ether extract (EE) (0.67 - 0.75), except that MS (0.23) had lower NDF digestibility. Digestibility of DM, organic matter (OM) and non-structural carbohydrates (NSC) were similar for the LH (0.72; 0.75; 0.96) and SH (0.70; 0.74; 0.95) diets, whereas digestibility of crude protein (CP) (0.71 vs. 0.68), metabolizable energy (ME) (9.49 vs. 8.90 MJ/kg DM), and the available ash fraction (0.39 vs. 0.28) were altered. The SH and ET (8.70 MJ/kg DM) treatments had similar ME concentrations, but ET had lower DM digestibility (0.68). The MS treatment had the lowest ME concentration (8.25 MJ/kg DM). The LH treatment resulted in overall better nutrient availability compared with SH, MS, and ET.

Keywords: *Eragrostis tef* hay, lucerne hay, maize stover, nutrient availability, soybean hulls#Corresponding author: einkamererob@ufs.ac.za

Feeding high-concentrate diets to finishing lambs generally improves lamb performance (Jabbar & Anjum, 2008; Shivambu *et al.*, 2011). However, lamb feedlot diets require a minimum amount of fibre to ensure normal rumen functioning, which differs according to the chemical and physical properties of the fibre source (Jeon *et al.*, 2019). Lucerne hay is usually the primary fibre source that is used in high-producing animals such as growing lambs, but it can be expensive and its quality varies. Furthermore, research is limited that compared the effect of fibre source on the nutrient availability of complete lamb finishing diets based on equivalent NDF concentration, especially those containing high levels of concentrate (>50% grain) (Flores-Mar *et al.*, 2018). This lack of information hinders the use of less expensive alternative sources in lamb finishing diets. The cell wall concentration (NDF fraction) of fibre sources has the biggest single influence on DM intake and thus on energy intake among forages (McDonald *et al.*, 2011; Tedeschi *et al.*, 2019). Therefore, the aim of the study was to evaluate the effect of lucerne, soyhulls, *Eragrostis tef* hay, and maize stover on the nutrient digestibility of high-concentrate (55% maize) finishing lamb diets with comparable NDF and nutrient concentration.

All procedures were approved by the Animal Ethics Committee for Animal Experimentation at the University of the Free State (Animal Experiment No. UFS-AED2018/0004). A digestibility study was conducted at Paradys Experimental Farm, University of the Free State, Bloemfontein, South Africa. Thirty-six Merino ram lambs were randomly allocated to four dietary treatments (n = 9 lambs/treatment) from wean to slaughter. Lambs were housed in individual pens, and water was provided ad libitum. A 15% feed refusal level, based on the average feed intake of the preceding three days, was maintained to ensure that feed weighed out daily for each animal allowed for ad libitum and consistent feed intake. Four diets were

formulated to be nutritionally comparable, but differed in fibre source, that is, lucerne hay (LH), soyhulls (SH), maize stover (MS) and *Eragrostis teff* hay (ET) (Table 1).

Table 1 Analysed chemical and physical composition of four dietary treatments that differed in fibre source

Raw materials (g/kg)	Primary source of fibre in diet			
	Lucerne hay	Soybean hulls	<i>Eragrostis teff</i> hay	Maize stover
Maize meal	550	550	550	550
Lucerne hay	350			
Soyhulls		229		
Maize stover				195
<i>Eragrostis teff</i> hay			216	
Soybean oil	0.3		2.4	2.9
Citrus pulp	69	177	179	201
Urea	6.6	14.3	19.1	20.7
Limestone	2.5	6.7	8.5	7.2
Ammonium chloride	7.5	7.5	7.5	7.5
Mono-calcium phosphate	7.0	8.5	9.2	8.5
Salt	5.0	5.0	5.0	5.0
Mineral and vitamin premix ¹	2.5	2.5	2.5	2.5
Nutrient composition (g/kg DM)				
Dry matter	926	924	933	931
Organic matter	923	916	906	908
Ash	78	84	94	92
Crude protein	153	156	154	151
Non-structural carbohydrates	487	493	455	486
Neutral-detergent fibre	245	232	265	240
Acid-detergent fibre	176	197	181	189
Ether extract	37	35	32	31

¹Vitamin A: 3 500 000 IU/ton, vitamin B1: 2.0 g/ton, cobalt: 1.5 g/ton, ferrous iron: 30.0 g/ton, iodine: 1 g/ton, manganese: 30.0 g/ton, selenium: 0.3 g/ton, zinc: 65.0 g/ton, salinomycin: 18 mg/ton, zinc bacitracin: 25.0 g/ton, Toxibind (Bitek Industries, Kempton Park, South Africa): 500.0 g/ton

It was essential to balance the treatments for dietary CP content because microbial protein synthesis is affected by the rumen concentration of nitrogen-containing compounds and organic matter fermentation (Soto-Navarro *et al.*, 2003). The NRC (2007) nutrient requirements for finishing ram lambs were used as guidelines to formulate the experimental diets (40 kg late maturing lambs growing at an average of 300 g/day). The diets were prepared with these fibre sources and citrus pulp in an attempt to equalize the NDF concentration of the treatments at approximately 245.5 g/kg (Bampidis & Robinson, 2006). The rationale for equalizing the NDF content of the diets was that it could affect animal voluntary DM intake, which is the major factor in energy intake (Decruyenaere *et al.*, 2009). Likewise, soybean oil was used to balance the lipid content between treatments. Therefore, the focal point of this study was the possible effect of fibre quality on DM intake (Lopes *et al.*, 2007) and available nutrient content (including energy) for the animal (Ball *et al.*, 2001). A synthetic antioxidant was included in all diets to prevent fatty acid oxidation. The treatment diets were presented to the lambs in pelleted form (5 mm diameter) to avoid selective feeding. At four months old (\bar{x} = 43.03, SD = 3.72 kg) lambs entered a digestibility trial. The digestibility study was conducted over seven days after adaptation (seven days) to the faecal bags that were fitted to the animals. Lambs were fed twice daily (07h00 and 16h00), and feed refusals were collected every morning before feeding. Total faeces were collected, dried, and weighed. Daily feed, feed refusal and faecal samples of each animal were composited. After thorough mixing, representative samples were taken, ground to pass through a 1 mm

sieve and stored pending chemical analyses. Milled feed, feed refusal and faecal samples were analysed for DM, CP, gross energy (GE), ash, NDF and ADF, and OM and NSC were calculated (AOAC, 2000; Van Soest *et al.*, 1991). The ME concentration was calculated from digestible energy (DE) values by multiplying DE by a factor of 0.81 (McDonald *et al.*, 2011) to compensate for energy losses in the urine and methane gas. Apparent digestible coefficients were calculated accordingly. Data were subjected to a Shapiro-Wilk test ($P \leq 0.01$) to test for deviations from normality (Shapiro & Wilk, 1965). Then, data were analysed with the one-way ANOVA procedure of SAS (SAS Institute Inc., Cary, North Carolina, USA) and Tukey's honest significant difference (HSD) test to identify significant differences between dietary treatments ($P < 0.05$).

Lambs had comparable DM intake between treatments with the exception of ET (1716 g), which had a higher ($P < 0.05$) DM intake than SH (1436 g). The DM digestibility coefficients of LH (0.72) and SH (0.70) were significantly higher than MS (0.66) and ET (0.68). For OM, digestibility ranged from 0.68 for MS to 0.74 for the LH treatment ($P < 0.05$). The availability of the ash fraction of LH (0.39) was significantly higher than the ET (0.29), MS (0.28) and SH (0.28) treatments. No differences were recorded between SH (0.68) and MS (0.68) for CP digestibility, but both were lower ($P < 0.05$) compared with LH (0.71) and ET (0.72). Digestibility of the NSC fraction was significantly higher for LH (0.96) and SH (0.95) compared with MS (0.92), whereas only LH differed ($P < 0.05$) from the ET (0.95) treatment. No significant difference was detected between ET and MS. Overall, the lowest ($P < 0.05$) NDF digestibility coefficient (0.23) was recorded for the MS treatment, with no notable differences between LH (0.34), ET (0.32) and SH (0.34). No significant differences were recorded between the treatment means for ADF and EE digestibility, which ranged from 0.41 to 0.44 and from 0.67 to 0.75, respectively. Finally, the fibre sources were ranked ($P < 0.05$) based on the ME (MJ/kg DM) of the treatments: LH (9.49) > SH (8.90) and ET (8.70) > MS (8.25). The effects of fibre source on DM intake, apparent digestibility and ME concentration of diets fed to Merino lambs are presented in Table 2. Data of all traits in Table 2 followed a normal distribution.

Table 2 Effects of fibre source in finishing diets for lambs on dry matter intake, digestibility and metabolizable energy

	Primary source of fibre in diet				P-value	SE
	Lucerne hay	Soybean hulls	<i>Eragrostis teff</i> hay	Maize stover		
Dry matter intake, g/day	1604 ^{ab}	1436 ^b	1716 ^a	1694 ^{ab}	0.0360	35.49
ME, MJ/kg DM	9.49 ^a	8.90 ^b	8.70 ^b	8.25 ^c	<0.0001	0.047
Digestibility						
Dry matter	0.72 ^a	0.70 ^a	0.68 ^b	0.66 ^b	<0.0001	0.003
Organic matter	0.75 ^a	0.74 ^{ab}	0.72 ^b	0.68 ^c	<0.0001	0.004
Ash	0.39 ^a	0.28 ^b	0.29 ^b	0.28 ^b	0.0008	0.014
Crude protein	0.71 ^a	0.68 ^b	0.72 ^a	0.68 ^b	<0.0001	0.003
NSC	0.96 ^a	0.95 ^{ab}	0.94 ^{bc}	0.92 ^c	0.0003	0.003
Neutral-detergent fibre	0.34 ^a	0.34 ^a	0.32 ^a	0.23 ^b	0.0002	0.009
Acid-detergent fibre	0.42	0.44	0.41	0.44	0.2948	0.008
Ether extract	0.75	0.71	0.72	0.67	0.4607	0.019

^{a,b,c} Within a row, means with a common superscript were not different with probability $P = 0.05$
ME: metabolizable energy, NSC: Non-structural carbohydrates

The dry matter intake of a fibre source can be influenced by factors such as NDF concentration, fill factor, rate of digestion and palatability (Ball *et al.*, 2001; Decruyenaere *et al.*, 2009). The cell wall concentration (NDF fraction) of fibre sources has the single biggest influence on DM intake (Tedeschi *et al.*, 2019). For this reason, these treatments were formulated to contain comparable levels of NDF (245.5 g/kg DM). However, NDF values ranged between 232 g/kg DM for SH and 265 g/kg DM for ET, effectively provoking a response in DM intake between these treatments. Lambs fed the ET diet compensated for the energy dilution effect of the higher cell wall concentration by increasing DM intake. Saylor *et al.* (2018) investigated the potential of replacing lucerne hay and maize silage in the diets of dairy cows with *Eragrostis teff* hay as the sole forage, and found no difference in DM intake or DM and NDF digestibility when diets

were balanced for DM, CP and NDF concentration. The lower DM digestibility coefficient of ET compared with LH and SH could not be ascribed to differences in digestibility of the CP, NDF, ADF, and EE fractions, but to the variations in the dietary NDF to NSC ratio and partly to the availability of the mineral and NSC fractions. Besides the higher NDF level, the ET diet had the highest ash concentration, which contributed to the lower ME value compared with LH.

The results on the DM intake of lambs fed the SH diet were similar to those of Cunningham *et al.* (1993), who reported a decrease in DM intake when soybean hulls replaced forage of dairy cows, with no effect on the DM and OM digestibility, but altered protein digestion. Similarly, Araujo *et al.* (2008b) found that CP digestibility decreased when SH was included in lamb diets, but reported an increase in DM intake. Although the negative effect on CP digestibility was not large enough to elicit an overall response in DM and OM digestibility, it contributed to the lower ME value of the SH diet alongside the lower DM intake. Cunningham *et al.* (1993) ascribed the decrease in DM intake and CP digestibility to the decrease in particle size of SH compared with forage. Ipharraguerre and Clark (2003) reported that the inclusion of more than 300 g/kg DM soybean hulls in high-grain diets ($\geq 50\%$) that lack long-length forage fibre may elevate the concentration of acids in the rumen, increase the ruminal passage rate (displacing fermentation of fibre from the rumen to the lower digestive tract) and decrease the DM intake of dairy cows. In contrast, Araujo *et al.* (2008a) replaced forage with SH (100%) in diets of lactating ewes and found an increase in DM intake, milk production and lamb weaning weight. Sheep generally spend more time eating and ruminating than cattle, which makes them less prone to digestive disorders (Mulvenna *et al.*, 2018). This brings into question the assumption that the same particle size limitations apply to cattle and sheep. However, there has been research into the replacement of forage fibre with non-forage fibre sources such SH in high-concentrate diets. Nevertheless, the current results indicated that there were negative associative effects in DM intake, CP digestibility and ME when soybean hulls were the sole fibre source in lamb diets containing 55% maize.

The collective lower digestibility of the NDF, NSC, CP, OM, and DM fractions of the MS treatment was typically related to the advanced maturity of the fibre source (Sun *et al.*, 2017) and could not be overcome by positive associative effects of a complete diet, despite the increased concentrate to roughage ratio. Maize stover is a by-product of a physiologically mature maize plant, which is associated with an increase in stem-to-leaf ratio, lignin content and lignification (Moore & Jung, 2001). Lignin covers the cellulose microfibrils and binds chemically to hemicellulose (in NDF fraction) and pectin (in NSC fraction). This binding negatively affects the digestibility of hemicelluloses and pectin to a greater extent than cellulose (Dryden, 2008). It explains the lower NDF and NSC digestibility of MS in the present study with no associated differences in ADF concentration and ADF digestibility compared with the other fibre sources. The current results agree with those of Harper and McNeill (2015), who reported that lignification has a greater influence on the digestibility of a mature fibre source than lignin content. Furthermore, when one considers the small contribution of maize stover to the total CP content of the MS diet, the lower ME could have contributed to the lower CP digestibility by limiting the efficiency of nitrogen capture from non-protein nitrogen (urea). In comparison, the CP digestibility of the ET diet with a similar urea inclusion level was not affected in the same way because of its higher ME concentration. The lower ME of the MS treatment was therefore ascribed largely to the inferior digestibility of the carbohydrate (NDF and NSC) fractions, which affected the digestibility of CP, OM, and DM, whereas the elevated ash concentration also contributed to the overall lower ME concentration. The results of the present study are in contrast to the results of Flores-Mar *et al.* (2018), who found that sorghum stover was superior to lucerne hay as a fibre source in lamb feedlot diet. However, the dietary NDF levels (maximum 90 g/kg) in their study were markedly lower than the present study.

Dry matter intake in the present study was comparable between the lucerne-based diet and other fibre sources. Poore *et al.* (1991), Cherney *et al.* (2004), and Flores-Mar *et al.* (2018) also observed no differences in the DM intake of dairy cows and growing lambs whether lucerne, wheat straw, orchard grass, tall fescue, or sorghum stover served as the source of fibre when dietary NDF was constant in the range of 60 to 300 g/kg DM. However, the absence of a positive response in voluntary DM intake with rapidly digestible fibre indicates that ruminal fill is not the main limiting factor of intake (Jung & Allen, 1995). Legumes are more susceptible to particle breakdown grasses when ground mechanically and pelleted (Paulson *et al.*, 2008), which might have resulted in the lack of physical fill of the LH and SH treatments in the present study. Although the higher ME value of LH compared with SH, MS and ET was ascribed partly to higher OM concentration, the better availability of the CP and NSC fractions played a role in improving OM digestibility, resulting in overall higher energy concentration of the LH diet. These results agree with those of Martin and Mertens (2005) and Scholtz (2009), who ascribed the advantage of lucerne as a fibre source to the rapid rate of digestion and available mineral component.

The results of the present study indicated that LH in finishing diets of lambs that contained high concentrate levels resulted in better overall nutrient availability compared with alternative fibre sources. Therefore, complete replacement of LH with SH, ET, or MS would probably result in a lower dietary energy

concentration when diets are balanced based on NDF. Future studies should investigate whether the differences in digestibility of alternative fibre sources affect the performance of finisher lambs, but should consider the cost of gain and should determine the effect of replacing graded levels of lucerne. Although long-term matrix values and grading systems were used to predict the nutrient composition of these fibre sources, the quality of the fibre sources should be analysed before experimental diets are formulated for research.

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Authors' Contributions

JFM and OBE designed the experiment and carried out the research trial. MDF completed the statistical analyses. JFM, OBE and GCJ structured the scientific content and drafted the manuscript. AH & AL assisted with the experimental design and research trial, while all authors provided editorial suggestions and approved the final manuscript.

Conflict of Interest Declaration

The authors declare that there is no conflict of interest.

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