The voluntary intake and digestibility of combinations of cereal crop residues and legume hay for sheep*

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Summary

TRIFOLIUM TEMBENSE *hay (TH) l was fed to adult male castrate sheep in proportions of approximately 15, 30 and 45% with each of four cereal crop residues (CCRs) in four separate experiments. Each CCR was also fed alone. In a fifth experiment, TH was fed alone. The CCRs used were maize stover (MS), oat straw (OS), wheat straw (WS) and teff* (Eragrostis tef) *straw (TS). The sheep were housed in metabolism cages; five sheep were fed each diet. Voluntary dry matter (DM) intake, digestibility of various chemical components and nitrogen retention were measured.*

The intake of OS was significantly higher than that of the other three CCRs. The apparent DM digestibilities of MS and OS were significantly higher than that of TS, and that of TS was significantly higher than that of WS. Higher digestibility was associated with higher metabolic loss. The addition of TH significantly reduced the consumption of each CCR but significantly increased total DM consumption. The extent to which this occurred differed among the CCRs and proportions of TH. TH also increased the apparent digestibilities of DM, crude protein (CP) and phosphorus (P) in each mixed diet, when compared with each CCR fed alone. The apparent digestibility of the cell wall fraction was increased in mixed diets based on MS and OS. The apparent digestibility of acid detergent fibre was also increased in OS-based diets. Nitrogen retention was increased in all cases. The magnitude and significance of differences varied among levels of TH supplementation and among CCRs but the average increase in digestibility was 17% when the ration contained about 35% TH.

The increases in nutritive value obtained from supplementing CCRs with legume hay were comparable to those expected from treating CCRs with strong alkalis. Using legumes to supplement CCR-based diets is more appropriate to the conditions encountered on small mixed farms in Africa.

Introduction

More than 340 million tonnes of fibrous crop residues are produced each year in Africa (Kossila, 1984), the great majority of which are from cereals. However, the utilisation of cereal crop residues (CCRs) is limited because they contain a large proportion of lignocellulosic compounds and little nitrogen. Substantial increases in the nutritive value of CCRs can be obtained by treating them with strong alkalis and ammonia, but these chemicals are expensive and not readily available in rural Africa.

Supplementing poor quality roughages, including CCRs, with legumes has been shown to increase digestibility (Devendra, 1982) or intake (Mosi and Butterworth, 1985) or both (Minson and Milford, 1967; Lane, 1982; Moran et al,1983).

This study examined the effects of supplementing diets based on common Ethiopian crop residues (teff, wheat and oat straws and maize stover) with different proportions of hay made from a common local clover, *Trifolium tembense.*

Materials and methods

Maize stover (MS), oat straw (OS), teff *(Eragrostis tef)* straw (TS) and wheat straw (WS) were obtained from the local market. Trifolium *(Trifolium tembense)* hay was made at the ILCA headquarters farm. Twenty adult male castrate sheep of the Ethiopian highland type were used in the experiments. The animals were kept in individual metabolism cages, which allowed all faeces and urine to be collected. The urine was collected in sulphuric acid.

Five experiments were carried out. In four, one CCR was fed alone or with one of three proportions of TH (15, 30 or 45%) to five sheep. In the fifth, TH was fed alone to 10 sheep. Although the rates of inclusion of TH were approximately 15, 30 and 45% of the total diet during the adjustment period, the final proportion of TH in the diet consumed (as opposed to that offered) differed from these percentages because the animals ate the CCR ad libitum. TH was provided as a separate meal that was consumed completely before the animals were offered the CCR.

Adjustment and intake periods of 10 and 7 days, respectively, were followed by a collection period of 7 days, a rest period of 4 days and a further collection period of 7 days, except in the case of WS, for which there was only one collection period. Feed offered and the unconsumed portion of the feed were weighed each day, and daily samples of feed offered, feed residues and faeces were analysed. Volume and nitrogen content of the urine were determined.

Results and discussion

The chemical composition of the TH and the CCRs is given in Table 1. TH contained more CP and less neutral detergent fibre (NDF) and acid detergent fibre (ADF) than the CCRs.

Table 1. *Chemical composition of* Trifolium tembense *hay and cereal crop residues*.

Component	Content (% DM)				
	Trifolium	Maize stover	Oat straw	Teff straw	Wheat straw
Organic matter	89.5	88.2	91.9	90.8	89.5
Crude protein	20.1	5.1	6.2	3.6	2.3
NDF[1]	44.4	75.5	71.2	77.5	76.1
ADF[2]	36.6	51.3	46.6	44.3	51.7
Lignin	4.8	4.8	6.6	5.1	6.4
Silica	–	5.2	3.6	3.4	6.9
Phosphorus	0.30	0.17	0.15	0.25	0.22
Gross energy (MJ/g)	19.0	16.7	17.9	17.6	18.8

[1]Neutral detergent fibre.
[2]Acid detergent fibre.

The voluntary intake of DM and apparent digestibility coefficients of the various chemical components in mixtures of the CCRs and TH are given in Tables 2, 3, 4 and 5, and of TH fed alone in Table 6.

Table 2. *Voluntary intake, digestibility and nitrogen retention of sheep on diets containing different proportions of trifolium hay and maize stover*.

Component	*Trifolium* (%)				SE (±)
	0	25	35	50	
Intake of DM (g/kgW/day					
Maize stover	20[a]	14[bc]	15[b]	12[c]	0.9
Trifolium hay	0	5	8	12	0.7
Total	20[a]	19[a]	23[b]	24[b]	1.1
Digestibility (%)					
Dry matter	54[a]	61[b]	63[b]	64[b]	1.5
Organic matter	56[a]	63[b]	65[b]	66[b]	1.6
Crude protein	6[a]	47[b]	57[c]	57[c]	3.4
Neutral detergent fibre	59[a]	65[b]	66[b]	66[b]	1.9
Acid detergent fibre	64	67	68	67	1.7
Energy	54[a]	62[b]	63[b]	64[b]	1.8
Phosphorus	12[a]	28[b]	35[b]	28[b]	5.2
Nitrogen retention (g/day)	0.l[a]	2.4[b]	4.4[c]	3.5[c]	0.4
DDMI(g/kg/day)	10.8	11.6	14.5	15.4	

Values with different superscripts on the same line differ at P<0.05.

Table 3. *Voluntary intake digestibility and nitrogen retention of sheep on diets containing different proportions of trifolium hay and oat straw*.

Component	*Trifolium* (%)				SE (±)
	0	14	23.9	35.7	
Intake of DM (g/kgW/day)					
Oat straw	27	23	23^{b}	19.1^{c}	0.9
Trifolium hay	0	4	7	11	0.2
Total	27^{a}	27^{a}	30^{b}	30^{b}	0.9
Digestibility (%)					
Dry matter	52^{a}	56^{b}	60^{c}	60^{c}	0.8
Organic matter	55^{a}	59^{b}	63^{c}	62^{c}	0.8
Crude protein	39^{a}	48^{b}	55^{c}	56^{c}	2.1
Neutral detergent fibre	55^{a}	58^{b}	61^{c}	58^{c}	1.1
Acid detergent fibre	53^{a}	55^{a}	58^{b}	57^{ab}	1.3
Energy	52^{a}	56^{b}	59^{c}	58^{c}	0.8
Phosphorus	–54^{a}	–41^{b}	–16^{c}	–8^{d}	5.2
Nitrogen retention (g/day)	2.8^{a}	3.0^{a}	5.5^{b}	6.0^{b}	0.4
DDMI (g/kg/day)	14.0	15.1	18.0	18.0	

Values with different superscripts on the same line differ at $P<0.05$.

Table 4. *Voluntary intake digestibility and nitrogen retention of sheep on diets containing different proportions of trifolium hay and teff straw*.

Component	*Trifolium* (%)				SE (±)
	0	19	35	50	
Intake of DM (g/kgW/day)					
Teff straw	23^{a}	22^{a}	20^{b}	16^{c}	0.5
Trifolium hay	0	5	10	16	0.2
Total	23^{a}	28^{b}	30^{c}	32^{d}	0.5
Digestibility (%)					
Dry matter	45^{a}	48^{a}	52^{ab}	56^{b}	1.1
Organic matter	48^{a}	51^{a}	54^{ab}	58^{b}	1.19
Crude protein	–20^{a}	4^{b}	14^{c}	25^{d}	3.66
Neutral detergent fibre	53	54	56	58	1.87
Acid detergent fibre	56	55	56	59	1.2
Hemicellulose	50^{a}	56^{ab}	59^{b}	61^{b}	2.6

Cellulose	54[a]	57.2[ab]	60[bc]	65[c]	1.86
Energy	44[a]	48.8[ab]	53[b]	56[b]	1.8
Phosphorus	–51[a]	–18[b]	–9[c]	–2[d]	5.18
Nitrogen retention (g/day)	1.5[a]	0[a]	0.5[ab]	1.7[b]	0.3
DDMI (g/kg/day)	10.4	13.4	15.6	17.9	

Values with different superscripts on the same line differ at P<0.05.

Table 5. *Voluntary intake, digestibility and nitrogen retention of sheep on diets containing different proportions of trifolium hay and wheat straw*.

Component	*Trifolium* (%)				SE (±)
	0	19	34	44	
Intake of DM (g/kgW/day)					
Wheat straw	21[a]	20[a]	17[b]	16[b]	0.9
Trifolium hay	0	5	9	12	0.5
Total	21.2[a]	24[ab]	25[b]	28[b]	1.0
Digestibility (%)					
Dry matter	40[a]	42[a]	46[ab]	48[b]	2.2
Organic matter	47	48	51	53	2.1
Crude protein	–14[a]	24[b]	37[c]	43[d]	3.6
Neutral detergent fibre	47	47	50	50	2.2
Acid detergent fibre	52	49	52	53	2.4
Hemicellulose	42	43	44	42	3.5
Cellulose	58	57	60	60	2.0
Energy	42[a]	47[ab]	50[b]	51[b]	2.2
Phosphorus	65	64	61	60	2.5
Nitrogen retention (g/day)	–0.5[a]	0.4[b]	2.42[c]	3.6[d]	0.3
DDMI (g/kg/day)	8.5	10.1	11.5	13.4	

Values with different superscripts on the same line differ at P<0.05.

Table 6. *Voluntary intake and digestibility by sheep of* Trifolium tembense *hay when fed alone*.

Component	*Trifolium* hay
Intake of DM (g/kgW/day)	39.3±3.2
Digestibility (%)	
Dry matter	67 ± 2.5
Organic matter	66 ± 3.3
Crude protein	62 ± 3.5
Neutral detergent fibre	60 ± 3.5
Acid detergent fibre	61 ± 4.0
Energy	66 ± 3.8
Phosphorus	16 ± 7.5

The chemical composion of the CCRs used in this series of experiments was similar to that described by Jackson (1977) and Hogan and Leche (1983), in that they contained a large proportion of lignocellulosic cell-wall constituents and had low CP contents. From this, one would expect both voluntary intake and digestibility of the feed to be low and that substantial increases in both would be required to support reasonable levels of production from these feeds.

The estimated intakes of metabolisable energy (ME = digestible energy x 0.81) for the crop residues fed alone were 2.9, 4.1, 3.0 and 2.8 MJ/day for MS, OS, TS and WS, respectively, compared with a maintenance requirement of 3.4 MJ/day for a 20 kg male castrate sheep (ARC, 1980). Thus, ME intake was sufficient for maintenance in the case of OS only. Successive increments of TH in the diet increased average ME intake to 3.8, 4.6 and 4.8 MJ/day across the four CCRs. These levels of ME intake would be sufficient to support modest levels of production.

The DM intakes and apparent DM digestibilities of the four CCRs when fed alone were compared by analysis of variance. The DM intake of OS was significantly higher than that of the other three CCRs. This was consistent with the observation that OS contained less NDF than the other CCRs and with the hypothesis that the proportion of plant cell wall material in the feed is the primary determinant of feed intake (Mertens, 1973). The apparent digestibilities of MS and OS were significantly higher than that of TS, and that of TS was significantly higher than that of WS. Both lignin and silica content may have a negative relationship with digestibility (see, for example, van Soest, 1982), but in this series of trials there was no apparent relationship, except that WS had the highest lignin and silica contents and the lowest digestibility. There were, however, significant differences in metabolic loss among the CCRs. Values for the ‘true digestibility’ of DM (the sum of neutral detergent solubles and digestible NDF) were calculated for the various combinations, and metabolic loss was taken as the difference between true and apparent digestibility.

The negative values for the apparent absorption of P are in general agreement with the equation developed by Butterworth (1966) for tropical forages, which indicated that P absorption increases logarithmically with dietary P concentration, as was the case in this series of experiments. However, no explanation can be given for the high values observed in the case of WS.

In order to determine whether the CCRs had any associative effects on digestibility, which would give rise to values higher than would be expected from simple substitution, the digestibility coefficients of TH and the CCRs when fed alone were used to calculate theoretical values for digestibility coefficients for combinations of the various CCRs and TH. While these calculations are somewhat hypothetical and may be subject to cumulative error, there was, however, a strong indication that consistent, small, positive associative effects occurred when MS and OS were supplemented with TH, amounting to 8 and 6% of calculated DM digestibility, respectively.

The addition of TH to each CCR caused a significant increase in nitrogen retention, which was sufficient to support production with MS, OS and WS. The low levels of both crude protein digestibility and nitrogen retention with TS alone or when supplemented with TH were in agreement with results reported by Mosi and Butterworth (1985).

Jayasuriya (1984) stated that treating roughages with sodium hydroxide can increase their digestibility by 10 to 20 percentage points and increase intake by 30 to 50%. Supplementing CCRs with legume hay at the higher levels used in this study gave similar increases over the unsupplemented CCRs. At the same time, nitrogen retention was increased to a level that would support modest levels of production.

Supplementing diets with legume hay is a more appropriate and cost-effective way of increasing animal production from CCRs in Africa than is the use of strong alkalis. Growing forage legumes on land that would otherwise be fallowed has the additional benefit of increasing the yield of subsequent crops through the nitrogen fixed by the legume. The use of the legume in supplementing the CCR diet also does not carry the risks to the environment that treatment with sodium hydroxide carries, in that it does not result in large quantities of sodium being excreted by the animals.

Animal production systems based on the use of legume hay and CCRs are being developed by ILCA for use in the Ethiopian highlands.

References

ARC (Agricultural Research Council). 1980.*The nutrient requirements of ruminant livestock.* CAB, Farmham Royal, UK. 351 pp.

Butterworth M H. 1966. The utilisation of phosphorus in some Venezuelan forages. *Turrialba* 16:253–256.

Devendra C. 1982. Perspectives in the utilisation of untreated rice straw by ruminants in Asia. In: Doyle P T (ed.). *The utilisation of fibrous agricultural residues as animal feeds.* School of Agriculture and Forestry, University of Melbourne, Australia. 191 pp.

Hogan J P and Leche T F. 1983. Types of fibrous residues and their characteristics. In: Pearce G R (ed.). *The utilisation of fibrous agricultural residues.* Australian Development Assistance Bureau. 281 pp.

Jackson M G. 1977. Rice straw as livestock feed. *World Anim. Rev.* 23:34–40.

Jayasuriya M C N. 1984. Potential for the better utilisation of crop residues and agro-industrial by-products in animal feeding in the Indian sub-continent. In: Preston T R, Kossila V, Goodwin J and Reed S. (eds). *Guidelines for research on the better utilisation of crop residues and agro-industrial by-products in animal feeding in developing countries.* Proceedings of the FAO/ILCA expert consultation, 5–9 March 1984, Addis Ababa, Ethiopia. 177 pp.

Kossila V. 1984. Global review of the potential use of crop residues as animal feed. In: Preston T R, Kossila V, Goodwin J and Reed S (eds). *Guidelines for research on the better utilisation of crop residues and agro-industrial by-products in animal feeding in developing countries.* Proceedings of the FAO/ILCA expert consultation, 5–9 March 1984, Addis Ababa, Ethiopia. 177 pp.

Lane I R. 1982. Effects of forage legume supplements on intake and apparent digestibility of grass. In: Doyle P T (ed.). *The utilisation of fibrous agricultural residues as animal feeds.* School of Agriculture and Forestry, University of Melbourne, Australia. 191 pp.

Mertens D R. 1973. Application of theoretical mathematical models to cell wall digestion and forage intake in ruminants. Ph.D. thesis, Cornell University, USA. 218 pp.

Minson D J and Milford R. 1967. The voluntary intake and digestibility of diets containing different proportions of legume and mature Pangola grass *(Digitaria decumbens). Aust. J. Exp. Agric. Anim. Husb.* 7:546–551.

Moran J B, Satoto K B and Dawson J E. 1983. The utilisation of rice straw fed to Zebu cattle and swamp buffalo as influenced by alkali treatment and *Leucaena* supplementation. *Aust. J. Agric. Res.*34:73–84.

Mosi A K and Butterworth M H. 1985. The voluntary intake and digestibility of diets containing different proportions of teff *(Eragrostis tef)* straw and *Trifolium tembense* hay when fed to sheep. *Trop. Anim. Prod.* (in press).

van Soest P J. 1982. *Nutritional ecology of the ruminant.* O and B Books, Corvallis, Oregon, USA. 374 pp.