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MUCUNA SEED AS A FEED INGREDIENT FOR SMALL RUMINANTS AND EFFECT OF ENSILING ON ITS NUTRITIVE VALUE

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SUMMARY

The seed of *Mucuna pruriens* var. *utilis* was nutritionally characterized as a source of protein to supplement poor quality roughage diets for small ruminants. The effect of ensiling *Mucuna* seed with varying proportions of maize grain was also evaluated. The grains were crushed and ensiled in plastic bags with the addition of molasses (10% v/v) and water (1 L to 10 kg). The feeds were analysed chemically at ensiling and 21 days later, and silage fermentation was assessed. The nutritive value of ensiled and unensiled 50:50 *Mucuna*-maize was compared with sheep dairy meal (crude protein 166 g kg DM^{-1}), fed iso-energetically at 1.2, 1.1 and 1.5 kg day^{-1}, respectively, as supplements to poor quality grass hay. Lactating goats were used in the feeding trial and also for determination of nitrogen retention. The 50:50 ratio was selected as it had a similar crude protein (CP) content to the commercial meal. Milk yields and composition were determined over a 5-week period during early lactation, and feed intake and doe and kid weights were monitored.

On a dry matter (DM) basis, whole *Mucuna* seed contained 310 g kg^{-1} crude protein, 198 g kg^{-1} neutral detergent fibre (NDF) and 37 g kg^{-1} L-Dopa; DM content was 71%. All *Mucuna*-maize mixtures ensiled well, with an average pH of 5.3, though the 50:50 mixture had a stronger typical silage smell. Ensiling improved palatability but decreased CP content; although ensiling increased feed intake and decreased doe weight loss, it did not result in more milk. The sheep dairy meal was preferred; does on this diet produced more milk and lost less weight than does given unensiled *Mucuna*-maize. Milk yields were 957, 614 and 624 mL day^{-1} for does fed the dairy meal and unensiled and ensiled *Mucuna*-maize diets, respectively. Kid growth was similar across treatment diets. *Mucuna*-maize supplements resulted in slightly lower milk lactose, but otherwise had no effect on milk composition. Duration of feeding had no significant effect on milk yield or milk composition. Positive nitrogen (N) balance results and low faecal and higher urinary N losses indicated satisfactory use of N in all diets. Nitrogen retention (including that in milk) was 12.0, 7.0 and 9.1 g day^{-1} with the dairy meal, and unensiled and ensiled *Mucuna*-maize diets, respectively.

Silage fermentation decreased L-Dopa content by 10-47%. This decrease was enhanced as the proportion of maize increased, with L-Dopa decreased to 9 g kg DM^{-1} in the 30:70 *Mucuna*-maize mixture. Ensiling *Mucuna* would not seem to have substantial overall benefits for ruminants, but might be useful for decreasing L-Dopa toxicity when feeding *Mucuna* to non-ruminant livestock such as pigs.

Although unensiled 50:50 *Mucuna*-maize was less palatable and had a lower nutritive value than the ensiled mixture or sheep dairy meal, the results indicated that *Mucuna* seed is a useful feed ingredient for small ruminants on poor quality roughage diets. Consumption might be improved by the addition of a small quantity of molasses.

Key words: *Mucuna*, feed, silage, goats, lactation, L-Dopa.

INTRODUCTION

Insufficient protein for ruminant animals during the dry season is a serious perennial problem in Zimbabwe and elsewhere in tropical and subtropical regions. It is one of the greatest constraints to ruminant animal production (Heady, 1994) and leads to sub-optimal animal production (Ngongoni and Manyuchi, 1993).

The adverse effects of undernutrition can be alleviated by judicious feeding of ruminants with nitrogen-rich supplements. Sources of such supplements include animal proteins, e.g., blood meal and fishmeal, and plant proteins, e.g., cottonseed meal and soyabean meal. Unfortunately these conventional commercial protein supplements are either unavailable or too expensive and they are, therefore, beyond the reach of most smallholder farmers. Due to their limited availability, the nutritive evaluation of alternative protein sources is a necessary area of research. A promising example is the seed of *Mucuna* (*Mucuna pruriens* var. *utilis*).

Mucuna is an annual legume that grows readily in tropical and sub-tropical regions which are frost-free (Duke, 1981). It has potential as a feed and can be used as a protein supplement to improve the nutritional value of poor quality roughage (Daka *et al*., 1996; Maasdorp *et al*., 2002). *Mucuna* is being promoted amongst mixed crop-livestock smallholder farmers in Zimbabwe, particularly those undertaking dairying and beef production, but there is insufficient knowledge about its nutritive value and utilization. Mature *Mucuna* seeds are rich in crude protein, with 314 g kg^{-1} reported, together with 52 g kg^{-1} crude fibre, 67 g kg^{-1} crude fat, 41 g kg^{-1} ash and 526 g kg^{-1} carbohydrates, and potassium, phosphorus and calcium in higher concentrations than in most commonly consumed legume grains (Siddhuraju *et al*., 1996).

While legumes form good protein supplements to poor quality roughages, they are constrained by their high content of anti-nutritional factors, arising principally from secondary metabolism in plants. Anti-nutritional factors affect ruminant animal production by lowering feed intake and by producing derivatives which reduce rumen microbial activity and depress growth (D'Mello and Devendra, 1995). *Mucuna* contains anti-nutritional factors, the most important being L-Dopa (3,4-dihydroxyphenylalanine). The side effects of L-Dopa in humans have been associated with dizziness, staggering, increased heart rate, vomiting, and psychiatric disturbances, which is consistent with it being on the synthetic pathway of the neurotransmitter dopamine (Szabo and Tebbett, 2002, citing Dollery, 1999; Metman and Mouradian, 1999; Standaert and Young, 1996). In pigs, L-Dopa in feeds results in reduced intake and depressed weight gains (Sesma, 1999, as cited in CIEPCA, 2001). In ruminants, however, the seed of *Mucuna* has been used without apparent ill effects (Buckles, 1995), though Topps and Oliver (1993) report that the pods have an unduly laxative effect if fed at more than 2 kg per day to cattle.

The objectives of this research were to conduct a nutritional characterization of *Mucuna* seed, to evaluate the impact of ensiling on the nutritional quality of *Mucuna*, and to assess the response of lactating goats to *Mucuna* supplementation of a poor quality roughage diet. This involved chemical analysis of the feeds, a feeding trial, and an assessment of nitrogen retention. Lactating animals were used in this study as they are useful in assessing the nutritive value of feeds because lactation imposes a greater strain on nutrient supply than any other physiological status. They also give a meaningful biological response, which convinces farmers and extension staff.[1]

MATERIALS AND METHODS

Ensilage

Black plastic bags of 60 x 90 cm were used as silos. Silage was made from crushed *Mucuna* seed and maize seed (particles passing through a 3-mm sieve), mixed to a total weight of 10 kg per plastic bag, containing either 30, 50, 70 or 100% *Mucuna*. To these mixtures was added water (1 L to 10 kg) and molasses (10% v/v) to moisten the crushed grains and increase the content of fermentable carbohydrates. Samples were taken before sealing the bags and then 21 days later.

Chemical composition of seed and silage

Samples were analyzed for dry matter (DM), crude protein (CP) and ash (AOAC, 1990). Neutral detergent fibre (NDF) and modified acid detergent fibre (MADF) were determined by the methods of Goering and Van Soest (1970). L-Dopa levels were determined using the method of St. Laurent (2002). Silage pH was measured on an aqueous extract of silage (20g sample soaked for 1 h in 125 mL distilled water).

Lactation trial

Twelve lactating indigenous Mashona does, weighing 23-45 kg, were selected from an initial larger group that had been synchronized in oestrous using prostaglandin $f_{2\alpha}$ injected twice, 11 days apart. The does were put into four groups (i.e., replications) according to preliminary milk yields, and within each group were randomly allocated to the treatment diets, which were as follows:

- **Treatment 1:** sheep dairy concentrate (11 MJ ME kg^{-1} and 16.6% CP)
- **Treatment 2:** mixed crushed maize and crushed *Mucuna* grain (ratio 50:50)
- **Treatment 3:** ensiled crushed maize and crushed *Mucuna* grain (ratio 50:50).

A 50:50 ratio of *Mucuna* and maize was used as this had a similar CP content to the commonly used dairy concentrate for sheep. The treatment diets were isoenergetic, and fed at the rate of 1.5, 1.1 and 1.2 kg

[1] An additional objective was to determine if, and to what extent, L-Dopa is transferred to milk from *Mucuna* feed. Milk samples are awaiting analysis at the time of writing this paper.

DM per day for treatments 1, 2 and 3, respectively, based on anticipated ME needs. The does were put in individual pens with their kids and had *ad libitum* access to milled Katambora Rhodes grass (*Chloris gayana*) hay (9.2 MJ ME kg^{-1} and 5% CP). Intake of the treatment diets was monitored.

The does had a pre-trial adaptation period of seven days. Prior to this they had all been given a common diet of commercial sheep dairy meal. Milk yield on this common diet was used as a covariate to adjust for initial differences.

Milk yield determination, sampling procedure and chemical analysis

The does were milked twice a week for five weeks during early lactation, using the oxytocin hand milking technique according to Ngongoni *et al*. (1989). The kids were separated from their dams at 6.00 hours in order for them to develop a strong suck. At 9.00 hours they were allowed to suckle for 10 minutes. The residual milk was stripped out after injecting 0.1 mL oxytocin, then bottle-fed to the kids. After milking, the does were allowed access to the treatment diets for four hours without the kids. A second oxytocin injection was then given and the does were hand milked again. The four-hour milk yield was recorded and this was adjusted to the 24-hour milk yield (Martin-Orue *et al*., 1996). Sub-samples of 250 mL were collected and refrigerated. The percentage of butterfat, lactose, protein and total solids were determined in duplicate. The kids were bottle-fed the remaining milk. Does and kids were weighed on each milking day for five weeks to assess rate of live weight change and growth rate, respectively.

The milk was analyzed using a computerized near infra red (NIR) Bentley analyzer (Bentley 2000, Meyer Services, Ontario, Canada).

Nitrogen balance trial

Nine does from the lactation trial, three from each treatment, were used to determine the nitrogen balance of the same dietary treatments. Immediately after the lactation trial, they were transferred to metabolism cages and allowed an adaptation period of five days. A five-day trial (collection) period followed. The metabolism cages allowed for separate total faecal and urine collection. The kids were brought into the cages to suckle three times a day. Amount of feed offered and refused were recorded daily to determine feed intake. Total faecal production was recorded and 100 g samples taken daily. Total urine production was collected in a vessel containing 100 mL of 10% sulphuric acid as a preservative. A 10% aliquot was sampled daily, placed in an airtight plastic bottle and stored at 4°C. Daily samples of an individual animal's feed refusals, faeces and urine were pooled over the 5-day collection period and sub-sampled for N determination using the Kjeldahl method. Nitrogen balance was calculated as the difference between N intake and total N excreted in the faeces and urine. Initial live weight of the does was used as a covariate.

Statistical analysis

Chemical composition and fermentation characteristics of the *Mucuna* seed and its ensiled mixtures were analyzed using a one-way analysis of variance (ANOVA) in a completely randomized design. ANOVA was used to examine the effect of treatment diet and days in milk on milk yield and milk composition, after adjusting for initial variation by using preliminary milk yield on a common diet as a covariate. ANOVA was also used to assess the effect of treatment diet on liveweight gain of kids, and feed intake and liveweight loss of does. Nitrogen balance and dry matter intake results were subjected to ANOVA, after adjusting for initial variation by covariance analysis. Multiple comparison of means were done using Tukey's studentized range test.

RESULTS

Chemical composition and fermentation characteristics

On a dry matter (DM) basis, the whole *Mucuna* seed was composed of 310 g kg^{-1} CP, 40 g kg^{-1} ash and 198 g kg^{-1} NDF, with a DM content of 71.0%.

The chemical composition of the fresh and ensiled mixtures of *Mucuna* and maize is shown in Table 1. Ensiling significantly ($P<0.05$) decreased CP content, with the loss being highest in the 50:50 and 70:30 *Mucuna*-maize mixtures. Dry matter, MADF and ash were not affected significantly by silage fermentation. On opening the silages, sensory evaluation was done. The 50:50 *Mucuna*-maize mixture had the typical smell of well fermented silage, whereas the 100% *Mucuna* silage smelled strongly of *Mucuna.* For the 30:70 and 70:30 mixtures, the typical silage smell was faint. The level of inclusion of *Mucuna* seed did not have a significant effect on the pH of the silages: the average pH was 5.32 ± 0.02.

The levels of L-Dopa in the fresh and ensiled mixtures are shown in Table 2. Although resources did not permit replication, the results consistently show a decrease in L-Dopa content following ensilage fermentation, with an apparent decline in conversion as the proportion of maize decreased.

Table 1. Chemical composition of crushed *Mucuna* seed-maize grain mixtures based on 30%, 50%, 70% and 100% *Mucuna* inclusion, before and after ensiling.

Component	Before Ensiling				After Ensiling			
	30%	50%	70%	100%	30%	50%	70%	100%
DM (%)	57.8[a]	58.97[a]	59.88[a]	53.88[a]	55.56[a]	52.92[a]	57.84[a]	52.59[a]
CP (g kg DM^{-1})	153.9[a]	198.3[b]	245.1[c]	307.4[d]	147.4[a]	164.4[a]	196.5[b]	277[c]
MADF (%)	5.17[a]	8.38[b]	8.7[b]	10.10[b]	5.24[a]	8.48[b]	9.03[b]	9.53[b]
ASH (%)	5.5[a]	5.93[a]	5.5[a]	4.94[a]	5.38[a]	5.3[a]	6.06[a]	4.81[a]

Treatment means with different superscripts in a row are significantly different (P<0.05)

Table 2. L-Dopa content in *Mucuna* seed and maize grain mixtures before and after ensiling.

Mucuna in the silage (%)	Before ensiling % DM	Before ensiling g[1]	After ensiling % DM	After ensiling g	Decrease (%)
30	1.58	91.3	0.86	47.8	47.6
50	2.18	75.8	1.69	47.3	37.6
70	2.55	152.7	1.95	112.8	26.1
100	3.68	198.3	3.38	177.8	10.3

[1] g per 10 kg unit of *Mucuna*-maize mixture

Lactation trial

As mentioned, only the 50% *Mucuna* mixture, both unensiled and ensiled, was included in the lactation trial, together with sheep dairy concentrate. Diet type had a significant effect (P<0.05) on milk yield and milk composition (Table 3), as well as on feed intake and liveweight change (Table 4). Does supplemented with sheep dairy concentrate produced the most milk. The concentrate was preferred to the *Mucuna*-maize diets. The does preferred ensiled *Mucuna*-maize to the unensiled mixture of the two, but milk yields were similar on the two diets. *Mucuna*-maize diets resulted in a decrease in milk lactose, but type of diet had no significant effect on content of protein, fat and total solids in the milk. The duration of feeding the different diets (days in milk) had no significant effect on milk yield or milk composition.

None of the three treatment diets was able to supply adequate nutrients to the does to avoid weight loss (Table 4). Does on the silage diet lost less weight than those fed the unensiled *Mucuna*-maize mixture. Differences in kid weight gain were not significant.

Nitrogen balance trial

The effects of dietary treatment on nitrogen (N) utilization are shown in Table 5. Intake of N was significantly greater (P<0.05) with the concentrate diet, whilst N intake with the unensiled and ensiled *Mucuna*-maize mixtures was similar. Nitrogen balance was positive for all the treatment diets. N retention (including that in milk) as a percentage of N intake was 45.4%, 36.1% and 43.0% for the concentrate, and unensiled and ensiled *Mucuna*-maize diets, respectively. It was noticed that the urine of animals fed the *Mucuna* diets was slightly darker.

Table 3. Milk yield and milk composition of does fed sheep dairy concentrate, and unensiled and ensiled crushed *Mucuna* seed mixed with crushed maize grain (50:50). Values presented are least square means and their standard errors.

	Concentrate	Treatment diet Unensiled *Mucuna*-maize	Ensiled *Mucuna*-maize	Diet effect
Milk yield (mL day^{-1})	956.6 ± 47.2	614.3 ± 55.5	624.0 ± 47.9	*
Milk protein (%)	4.70 ± 0.073	4.55 ± 0.090	4.44 ± 0.074	NS
Milk fat (%)	7.05 ± 0.40	7.10 ± 0.47	6.49 ± 0.41	NS
Lactose (%)	4.91 ± 0.028	4.71 ± 0.033	4.80 ± 0.028	*
Total solids (%)	17.56 ± 0.40	17.35 ± 0.47	16.64 ± 0.40	NS

NS: means not significantly different (P>0.05)
*: means significantly different (P<0.05)

Table 4. Feed intake and liveweight changes over five weeks of does and kids consuming sheep dairy concentrate, and unensiled and ensiled crushed *Mucuna* seed mixed with crushed maize grain (50:50). Values presented are least square means and their standard errors.

	Concentrate	Treatment diet Unensiled *Mucuna*-maize	Ensiled *Mucuna*-maize
Amount fed (g DM d^{-1})	1 500	1 100	1 200
Intake			
Supplement (g DM d^{-1})	1214 ± 30.2	718 ± 38.4	935 ± 30.2
CP (g d^{-1})	201.5	142.4	153.7
ME (MJ d^{-1})	13.35	10.77	12.86
Liveweight change (kg)			
Does	-1.72 ± 0.27	-2.00 ± 0.33	-1.50 ± 0.27
Kids	1.56 ± 0.19	1.40 ± 0.15	1.42 ± 0.15

Table 5. Balance of nitrogen in goats fed on Katambora Rhodes grass hay *(Chloris gayana)* supplemented with sheep dairy concentrate, and unensiled and ensiled crushed *Mucuna* seed mixed with crushed maize grain (50:50). Values presented are least square means and their standard errors.

Content of N (g d^{-1})	Concentrate	Diet supplement Unensiled *Mucuna*- maize	Ensiled *Mucuna*- maize
Total intake	26.31 ± 0.71	19.35 ± 0.71	21.07 ± 0.76
Excretion			
Faeces	5.30 ± 0.46	3.95 ± 0.45	4.21 ± 0.49
Urine	9.06 ± 0.70	8.41 ± 0.70	7.81 ± 0.74
Total	14.36 ± 0.57	12.36 ± 0.57	12.02 ± 0.61
Retention	11.95 ± 1.15	6.99 ± 1.14	9.05 ± 1.22

DISCUSSION

The CP, ash and NDF content of the local *M. pruriens* var. *utilis* seed was very similar to values reported elsewhere (Siddhuraju *et al*., 1996; Ravindran and Ravindran, 1988), and so, with regard to these components, the material used in this trial well represented this species.

All the *Mucuna*-maize mixtures ensiled well, with pH within the optimum range of 3.9-5.5 (Hunt *et al*., 1989). On the basis of its smell, 50% crushed *Mucuna* seed and 50% maize grain mixed with water and molasses (10% v/v) would appear to have ensiled better than the other *Mucuna*-maize ratios. Ensiling improved voluntary feed intake (VFI) (of the 50:50 mixture), but decreased nutritive value by decreasing CP content. This reduction in CP could have been caused by degradation of the protein fraction to non-protein nitrogen during the fermentation process (Whittenbury *et al*., 1967).

The higher voluntary feed intake of the sheep dairy concentrate indicates that it was more palatable than the *Mucuna*-maize. Hadjipanoyiotou (1994) also reported intake to be higher with concentrates than silages, which may be explained by the presence of fermentation products such as volatile fatty acids and ammonia that can depress the intake of silage (Beaumont *et al*., 1999). Ensiling increased intake of the *Mucuna*-maize diet over non-ensiled *Mucuna*-maize mixtures, probably by adding flavour to it and improving palatability.

This study proved that ensilage fermentation decreases L-Dopa content by 10-47%. There is evidence for the involvement of lactic acid bacteria in markedly decreasing L-Dopa content during the fermentation of *Mucuna* in the production of weaning food (Egounlety, this volume). Chhay and Rodrigues (2001) reported that ensiling reduces levels of anti-nutritional compounds in many feeds, like cyanogenic glucosides in cassava. There was an apparent diminishing of this reducing effect on L-Dopa with decreasing maize content. Fermentation is probably less intense with lower carbohydrate content, and this in turn may have less effect on L-Dopa. It would seem that fermentation with good levels of water soluble carbohydrates is required to have the best effect on L-Dopa.

Milk yield is affected by, among other factors, the amount of protein and energy in the diet (Gonzalez *et al*., 1982; Sutton *et al*., 1996). In this experiment, the highest intake of feed, and therefore of protein and energy, was with the sheep dairy concentrate, which was accompanied by greater milk production.

Diet type had an effect on milk lactose, but not on protein, fat and total solids. Except for a slightly lower level of lactose, the composition of milk from does fed *Mucuna*-maize supplements was similar to milk produced when feeding sheep dairy concentrate. All three supplements results in milk with satisfactory levels of protein. Consumption of high amounts of concentrates results in more acute peaks of rumen acidity, thus leading to cellulolysis and an increase in the proportion of propionic acid in the rumen fluid. This can result in more lactose because of its glucogenic effect (Moore, 1999).

Does on all three treatments lost weight, indicating that none of the treatment diets was able to supply sufficient nutrients. In early lactation, nutrient requirements typically surpass the capacity of animals for feed intake and body reserves of protein, lipids and minerals are mobilized to meet the deficits (Cowan *et al*., 1981; Jarrige, 1989). In commercial sheep production, it is normal for ewes to decrease in liveweight during this period. The magnitude of the liveweight loss is influenced by the concentration of protein in the diet (Robinson *et al*., 1974). In the case of the concentrate diet, the higher intake of dietary protein and ME did not prevent liveweight loss, as it had a stimulatory effect on milk yield. Mobilization of body protein is limited (ARC, 1984), whilst considerable quantities of body fat reserves can be mobilized to supply energy during this period (Cowan *et al*., 1981). As a result, the quality and quantity of protein reaching the small intestine in early lactation might have a stimulatory effect on milk yield through increased body fat mobilization.

The lack of significant differences in weight gain of the kids, even with the superior milk production by does receiving the concentrate diet, could be taken to indicate that either L-Dopa was not present in the milk, or it was present in sub-toxic quantities. Further evidence of a decrease in L-Dopa might be concluded by the similar lack of effect on milk yield of does on *Mucuna* diets, even after six weeks. Some L-Dopa was absorbed by the does, however, as evidenced by the slight darkening of their urine, assumed to be due to melanin excretion.

The positive N balance and low faecal and high urinary N losses with all the treatment diets may suggest satisfactory capture and utilization of the protein in the rumen and small intestines, but less so in the body tissues. Goats given concentrate had higher faecal N. As also hypothesized by Reed (1995), this probably reflects more hindgut fermentation resulting from the highest N and DM intake on this diet, implying a higher rate of passage. N retention was higher with the does given concentrate and ensiled *Mucuna*-maize, probably indicating a better ratio of rumen degradable protein to rumen fermentable metabolizable energy (RDP:RFME) in these diets. The increased N retention of the *Mucuna*-maize mixture due to ensiling could also be linked to increased microbial protein production from non-protein N in silage (AFRC, 1993).

Ensiling increased consumption of the 50:50 *Mucuna*-maize mixture and increased intake of energy. N retention as a percentage of N intake was improved by ensilage. Also, L-Dopa content decreased. However, these apparent improvements with respect to nutritive value did not result in a significant increase in milk yield, probably due to ensilage fermentation decreasing CP content, thus not increasing N intake significantly. Ensilage could be useful, however, in reducing L-Dopa content of *Mucuna* seed to be fed to non-ruminants.

CONCLUSION

Mucuna seed had a high content of CP (310 g kg DM^{-1}) and low NDF (198 g kg DM^{-1}). An unensiled 50:50 mixture of crushed *Mucuna* seed and maize grain was less palatable than sheep dairy concentrate (16.6% CP) and resulted in lower milk production. However, the results indicate that *Mucuna* seed would be a useful supplement feed ingredient for small ruminants on poor quality roughage diets. Possibly the addition of a small quantity of molasses would improve consumption. There were no signs of L-Dopa toxicity, suggesting that L-Dopa was detoxified to some extent in ruminants.

Although crushed *Mucuna* seed ensiled satisfactorily with crushed maize grain, and ensilage improved intake and N retention, and decreased liveweight loss of lactating does, it decreased CP content and did not improve milk yield. Hence the effort and expense of ensiling *Mucuna* seed might not be of particular benefit for ruminants. However, ensilage fermentation decreased L-Dopa content and could be a means of decreasing toxicity for non-ruminant livestock, such as pigs.

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