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Evaluation of Processing Methods for Increased Utilisation of Velvet Beans (*Mucuna pruriens*) as an Alternative Protein Supplement in Diets for Lactating Crossbred Dairy Cows Maintained on Smallholder Farms in Zambia

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ABSTRACT

This study aimed at evaluating the processing methods of velvet beans (Mucuna pruriens) as a protein supplement in concentrates for cross-bred dairy cows on smallholder farms in Zambia. The beans were harvested by pulling entire plants after drying in the field and divided into three portions; (i) whole crop consisting of vines, pods and grains; (ii) unshelled pods only; and (iii) grain only. Each portion was ground to pass through a 2mm screen before using it to make concentrate for the feeding trial. Prior to the preparation of rations, samples from each portion were collected for the determination of nutrient composition. Each ration was fed to a group of cross-breed milking cows maintained on a farm to monitor performance. Chemical composition analysis showed that shelled grains had more nutrients than the pods and vines. Milking cows readily accepted all the prepared rations and maintained constant milk production throughout the study period. None of the animals on the trial exhibited any sign of ill-health. This showed that velvet beans could be fed to milking cows by incorporating ground pods with other ingredients without adversely affecting animal health or milk production.

Keywords: Dry Season Supplementation, Indigenous Grain Legumes, On-Farm Concentrates, Rural Smallholder Dairying.

INTRODUCTION

In Zambia, like many other parts of the tropics, the production of animals in the dry season is constrained by poor nutrition, especially that of ruminants that depend on natural pastures and fibrous crop residues (Simbaya, 2020). During the dry season, the nutrient content of these feedstuffs is usually low and, as such, have limited capacity to meet animal nutritional requirements for increased productivity (Chibinga et al.. 2012, Kanyinji et al., 2017; Tekle and Gebru, 2018). Feeding livestock is still a major challenge to the sustainable productivity of pastoral communities in dryland areas (Chibinga et al., 2010).

Poor nutrition in the dry season is usually manifested through poor milk yields, low carcass weights, inferior reproduction rates and high disease incidences. One option for improving the nutritional status of animals on smallholder farms may be through the supplementation of animals with high-quality protein and energy concentrates that are commercially available. However, the use of such products is not feasible in rural areas as these materials are either unavailable or too expensive for smallholder farmers (Njarui et al., 2003). Furthermore, on-farm production of high energy and protein concentrates is hindered by the high cost of farming inputs that are required for the successful production of conventional feed crops like soybeans, sunflower, cotton and others (Simbaya et al., 2010).

One feasible approach to improving the nutrition of animals on smallholder farms is through increased use of local grain legumes and cereals that have a high content of essential nutrients and hence, the potential to meet animal nutritional requirements (Olorunnisomo, 2013 and Tshibangu et al., 2015). The advantage of using tropical grain legumes is that they are adapted to local growing conditions and do not usually need the use of purchased inputs such as chemical fertilisers, hybrid seeds, pesticides and inoculants for a successful production. Unfortunately, despite their high yield potential, tropical grain legumes are still underutilised as they are produced in smaller amounts to only meet local human consumption as traditional foods and to improve soil fertility through nitrogen fixation and the addition of organic matter that remains in the field after crop harvest (Pugalenthi et al., 2005; Carew and Gernat, 2006).

Due to the limited supply and rising costs of imported protein supplements in recent years, there have been concerted efforts to improve the nutrition of animals by using locally produced grain legumes like velvet beans (Oyaniran et al., 2018). Velvet beans (*Mucuna pruriens*) is a tropical grain legume that is characterised by a high content of proteins and carbohydrates that are comparable with that of soybeans (Pugalenthi et al., 2005). The crop is well adapted to local conditions and does not require purchased inputs for successful cultivation. Unfortunately, the crop is currently only cultivated on small-scale farms, mostly as a cover crop to improve soil fertility. The use of velvet beans as a feed crop by non-ruminants is limited by the high content of deleterious compounds, including polyphenols, lectinins, L-dopa, tannins and other protease inhibitors that limit feed intake and nutrient digestibility (Ayala-Burgos et al., 2003). When consumed in excess, some of the anti-nutritive factors are also known to cause organ malfunctions resulting in hepatotoxic and neurotoxic effects (Mugendi et al., 2010). In humans, the use of velvet beans is limited by long cooking hours and the deleterious effects of anti-nutritional factors described above (Mugendi et al., 2010). In ruminants, the effects of anti-nutritional factors are neutralised by the microflora of the rumen and the reticulum (Ajayi et al., 2010). However, despite this fact, only a small number of researchers have considered evaluating velvet beans as a protein supplement for ruminants. In Zambia, small-scale farmers have been encouraged to grow velvet beans as a feed crop for their dairy animals (Simbaya et al., 2010). However, the major concern for these farmers has been how to feed the crop to their animals, with all the concerns about the toxic effects of the crop.

The objective of this study was to evaluate processing methods for the increased use of velvet beans (*Mucuna pruriens*) as an alternative protein supplement in dairy concentrate rations for lactating cross-bred dairy cows maintained on traditional smallholder farms in Zambia.

MATERIALS AND METHODS

Study Areas

This study was conducted in two areas, namely the University of Zambia in Lusaka and Palabana in Chongwe District, located about 42km from the city of Lusaka. The study included on-station and on-farm animal feeding trials. On-station trials were conducted using cross-bred milking dairy cows from the University of Zambia maintained by the Schools of Agricultural Sciences and Veterinary Medicine, while on-farm trials were conducted on three separate smallholder farms in Palabana.

Processing of Velvet Beans

The velvet beans used in this study were cultivated at Palabana Dairy Training Institute (PDTI) farm and the University of Zambia (UNZA) School of Agricultural Sciences Field Station. After maturity and drying in the field, the velvet beans from both sites were harvested by uprooting the whole crop and dividing it into three equal portions for processing. The first portion consisted of whole plants, including the vines, remaining attached leaves and unshelled pods. The second portion was made up of pods that were separated from the vines but remained unshelled, while the third portion consisted of pods that were removed from the rest of the crop and later shelled by beating with a stick to obtain the grains. The vines were mostly without leaves as most of them had fallen off as the plants dried in the field. The three different portions were then ground to pass through a 2mm screen using hammer mills at PDTI and the UNZA Field Station. The selected processing methods for velvet beans were designed to be simple and as practical as possible for resource-poor small-scale farmers. Samples of the three processed preparations were collected for chemical composition analysis, while the rest was used for the preparation of experimental rations for animal feeding trials. Due to a limited number of experimental animals, the velvet beans preparations were not compared among treatments, but rather, each treatment was evaluated across weeks on how it affected the performance of animals during the eight-week study period.

Chemical Composition Analysis of Processed Velvet Beans

Before analysis, samples of processed velvet beans preparations were first ground to pass through a 1mm screen using a C and N Lab mill size 8” (Christy and Norris Limited, London, United Kingdom). The ground samples were then subjected to chemical compositional analysis to determine the content of nutrients and some anti-nutritional factors. Chemical composition analysis for various components was done in duplicate according to established procedures of the Association of Official

Analytical Chemists (AOAC, 1990). The dry matter (DM) content was determined by drying samples overnight at 105^{0}C in a Pol-Eko oven (Pszowska, Wodzialaw, Polska, SLN-32-ECO). Crude protein (CP) was analysed by determining nitrogen content using the Gerhardt KI 10/26 Macro Kjeldahl Digestion and KI 13/26 Distillation systems. The amount of nitrogen determined was multiplied by a factor of 6.25 to convert it to CP content. Ether Extract (EE) was determined by extracting samples with Petroleum Ether for 4 hours in a Gerhardt Soxhlet apparatus (address). Ash was determined by incinerating samples at 550^{o}C for 6 hours using the Nebertherm Muffle Furnace (Nebertherm Gmbh, Lilienthal, Bremen, Germany). Samples were also analysed for calcium and phosphorus content using methods No 7.101 and No 7.125, respectively, of the AOAC (1990). Gross energy was determined using the IKA C200 Bomb Calorimeter.

The dietary fibre components, including neutral detergent fibre (NDF) and acid detergent fibre (ADF), were analysed according to Goering and Van Soest (1970) with modifications of Mongeau and Brassardt (1979). In this analysis, samples were sequentially refluxed in NDF and ADF solutions, after which cellulose was hydrolysed with 72% Sulphuric acid to determine the residue as Klasson lignin (Theander and Westlund 1986). During refluxing, samples were sealed in NDF and ADF/CF crude fibre analysis bags (Gerhardt and F57 Ankom bags) according to recommendations by Lara et al., (1999). The crude fibre content was determined using the Weende procedure outlined in methods 7.066 to 7.070 of the AOAC (1990). Other components analysed included tannins as total polyphenols and condensed tannins using the procedures of Swain and Hillis (1959) and Makkar (2003).

Dairy Feeding Trials

Three experimental diets were prepared for on-station and on-farm feeding trials with cross-bred lactating dairy cows. The cows were of mixed cross-breeding combinations between Holstein Friesians and indigenous Zebu cattle. They also varied in terms of age, stages of parity and lactation phases. The composition of experimental diets used for the trial was as presented in Table 1. On-station trials were conducted at the School of Agricultural Sciences (Ground pods) and the School of Veterinary Medicine (Shelled grains). For on-station feeding trials, five milking cows were used for each treatment diet. This was not the case for on-farm trials, where the number of animals per treatment differed among different farms. The number of cows used was five (5) on Mtine's Farm, seven (7) on Haimbe's Farm and three (3) on Muyabe's Farm. Each farm was given a different treatment diet, and the response of animals to various diets was evaluated in terms of feed intake and milk yield over the eight-week experimental period. The number of animals at each site constituted replications for that particular treatment. The acceptability of diets was evaluated by monitoring the weekly average daily intake of concentrate diets by animals maintained on-station sites. The amount of concentrate offered to each cow depended on its daily milk production and was calculated as 0.44 kg feed per litre of milk produced. The animals were also observed for any changes in behaviour and ill-health indications that could be associated with consuming experimental diets.

Management of Experimental Animals

The animals were subjected to routine management practices and were allowed free access to natural grazing during the day. The animals were given experimental diets twice daily during milking in the morning and afternoon. No commercial dairy concentrate was provided to the animals throughout the study period. Since the cows were not accustomed to consuming velvet beans-based diets, those that could not finish their allocated portions during milking were allowed more time to finish their allocations outside the parlour.

Statistical Analysis

Statistical analysis was done to determine variations in the chemical composition of velvet beans fractions that were processed using different methods. Statistics analysis was also done to compare weekly variations in animal response to experimental diets using a single factor Analysis of Variance (ANOVA) to determine differences among treatment means. The analysis was done using MINITAB 16 Statistical Software Package. Significantly different means across weeks were separated using Tukey's test at $P \leq 0.05$ significance level.

RESULTS

Processing of Velvet Beans

For the preparation of dried velvet beans, it was demonstrated that the use of unshelled pods was more practical than having to beat the pods to get grains before grinding the beans to mix it with other ingredients. The use of a combination of vines and pods was not very feasible as it was too difficult to grind through a 2mm screen using small harmer mills that are common on smallholder farms. Mixing of fibrous materials from the vines with other concentrate ingredients also proved difficult. It was also noted that the use of vines together with attaching leaves for animal feeding would deprive crop fields of the soil-enriching organic matter, which is the original reason for cultivating velvet beans on smallholder farms.

The processing of velvet beans into shelled grain before milling was more of a challenge in that beating pods with a stick to remove husks was cumbersome and time-consuming. The unshelled pods were easier to prepare as they could easily be removed from the vines and taken to the hammer mill for grinding. While the preparation of the whole crop was straightforward, it was, however, difficult to grind it into a meal as the fibrous vines could not easily pass through the 2mm screen during grinding. The whole crop was nonetheless easy to grind with an industrial hammer mill that was based at PDTI. The other major difficulty of using the whole ground crop was in mixing its fibrous components with other ingredients to get a uniform concentrated mixture.

Chemical Composition Analysis

Results of the chemical composition analysis of the various velvet beans preparations are shown in Table 2. The dry matter content in the pods and grain was significantly ($P \leq 0.05$) lower than in the shelled grain and the pods and vines. The protein content was significantly ($P \leq 0.05$) higher in the shelled grains than in the pods and a combination of pods and vines. The ash content was similar in all the treatment preparations, with all recorded values being just above 4.0%. The content of Calcium and Phosphorus seemed to reflect ash content, with the values of calcium being lowest in the shelled grains (0.76%), followed by the pods (0.96%), with the highest values being in the combined pods and vines (1.12%). As for ash, the phosphorus content was similar in all the treatment preparations. The ether extract content was similar in the unshelled pods and the pods and vines but was higher ($P \leq 0.05$) in the shelled grains. However, the ether extract content did not seem to reflect gross energy content that was instead lowest in the shelled grains and highest in the combined pods and vines.

The CF content was significantly higher ($P \leq 0.05$) in the unshelled pods (18.99%) and the combination of pods and vines (21.08) than in the grains fraction, which had 8.81%. The content of ADF was similar to that of CF, with the unshelled pods and a combination of pods and vines having 19.03% and 22.94%, respectively; that were significantly higher ($P \leq 0.05$) than 9.80% that was recorded for the grains. However, this was not the case for the content of NDF, which was significantly higher ($P \leq 0.05$) in the grains and unshelled pods than in the combined pods and vines. The lignin content also reflected ADF and CF contents, with the grains having negligible amounts (0.67%) when compared with the other two fractions, which had statistically similar amounts of 4.42% and 4.86%, respectively. The content of total polyphenols in the processed velvet beans fractions did not follow any specific pattern as the values ranged from 3.60% in the unshelled pods to 3.95% in pods and vines, with the grains falling in between 3.70%. There were also minor variations in the content of condensed tannins among the various velvet beans fractions, although the grains contained significantly lesser ($P \leq 0.05$) amounts (1.17%) than unshelled pods (2.07%) and the combination of vines and pods that had 1.55%.

Animal Feeding Trials

The results on the intake of velvet beans-based rations by milking cows showed that the animals readily accepted the experimental diets (Table 3). During the first week, some animals developed slight diarrhoea, but after one week, the problem disappeared, and the animals readily ate all or nearly finished their allocated experimental diets throughout the study period. It was also clear that some of the animals could not finish their allocated concentrate amounts during the first few days. This was particularly true for animals at the School of Agricultural Sciences that, based on their relatively higher milk production levels, were given more of the prepared concentrate rations. However, overall, most of the animals either completed or nearly finished their allocated experimental amounts each day without any problem.

The results on milk production for animals supplemented with velvet beans-based diets showed a slight increase in average daily milk yields (Table 4). This slight increase in milk production demonstrated the capability of formulated concentrate rations to successfully replace purchased commercial dairy rations without having any ill-effects on milk production.

DISCUSSION

In terms of chemical composition, the current results were comparable with the findings of Ayala-Burgos et al., (2003), Mugendi et al., (2010) and Ashidi et al., (2019). Mugendi et al., (2010) demonstrated the potential of velvet beans as a protein supplement for feeding ruminants. The dry matter content in various velvet beans fractions tended to reflect drying conditions to which the crop is exposed. The higher protein content in grains when compared with that of unshelled pods and a combination of pods and vines was as expected due to the diluting effect of the high amount of fibre contained in them. This is demonstrated by the fact that pods have been reported to contain about 40% of the weight as fibrous husk (Ayala-Burgos et al., 2003). The current fat content in the grains was within expected levels of between 3% and 5%, as was reported by Carew and Gernat (2006), Carmen et al., (1999) and Bailey et al., (2014) but lower than 14%, which was reported by Bolagun (2012). These results were, however, outside the range of 6% to 10% reported by Ogunyi et al., (2003) and Renata (2015). The high fibre content in the pods and the combination of pods and vines was due to the high fibre-containing husks and vines. The ADF content in the grains was comparable with the 8.8% reported by Ayala-Burgos et al., (2010). There was, however, a variation to the content of NDF that was lower in the combined pods and vines fraction. This was contrary to expectations and could have been due to variations in the content of hemicellulose and cellulose in the different fractions. The similarity in the content of polyphenols among various velvet beans fractions may be an indication of a wide distribution of the phenolic compounds across plant parts, which was also reported by Tulean et al., (2008) and Vadivel (2012). Variations in nutrient content among legumes tend to reflect genetic makeup, environmental conditions and soil fertility differences where the crop is grown. These could be responsible for some of the variations between the current results and those reported elsewhere.

The feeding trials demonstrated that the animals accepted all the prepared rations after a few days of diet adaptation. All the treatments maintained stable milk production levels throughout the study period. This means that the velvet beans preparation methods to be adopted by farmers will depend on their capability to process the beans. The use of unshelled pods was recommended for ease of preparation and contributed to the supply of the much-needed fibre for milking animals. There was no real advantage in using a combination of pods and vines as most of the protein-containing leaves tend to fall off in the field as the crop dries up. The use of unshelled pods also tends to complement the initial purpose of growing velvet beans as a green manure crop as the leaves and vines remain in the field for soil fertility improvement (Eilitta et al.,, et al.,, 2003, Heuze et al.,, 2015, Jiri and Mafongoya, 2017); which was more a reflection of the changing weather patterns during September and October when it becomes too hot for cross-bred dairy animals.

CONCLUSION

Results from this study demonstrated that the prepared velvet beans-based rations had the capacity to replace commercial dairy concentrates for animals on smallholder farms. On-farm-produced velvet beans could be processed by simply separating the vines and pods and grinding the whole pods for mixing with other ingredients to make concentrate rations. Shelling velvet beans into grains before grinding for ruminant feeding may not be necessary due to added labour costs and subsequent loss of fibrous husks that are essential for ruminant feeding. The use of unshelled pods was recommended as they tend to facilitate leaving of vines and leaves in the field for improving soil fertility. It is also recommended that the feeding of velvet beans-based diets to milking animals be introduced gradually for the animals to get acclimatised to the meals. It should also be acknowledged that the value of using velvet beans in dairy rations should not only be seen in terms of the increase in milk yield per animal per day but more so, on the amount of money saved in purchasing and transporting concentrate feeds to the farm.

CONFLICT OF INTEREST

The authors certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

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Table 1: Composition Of Experimental Diets* (%) Used in the On-Farm and On-Station Feeding Trials with Cross-Breed Dairy Cows on Smallholder Farms

Ingredient (%)	Grain	Grains and pods	Pods and vines
No3. Meal	62	57	52
Velvet Beans	20	25	30
Cotton seed cake	14	14	14
Fish meal	2.0	2.0	2.0
Limestone	1.0	1.0	1.0
Di-calcium phosphate	0.5	0.5	0.5
Salt	0.4	0.4	0.4
Dairy Premix	0.1	0.1	0.1
Total	100	100	100
Dietary compositions(%) - Calculated analysis			
Dry matter	88.6	88.8	89.0
TDN	72.5	72.8	72.2
Crude protein	16.9	15.8	15.0
Crude fibre	2.34	5.85	9.79
Calcium	0.86	0.90	0.93
Phosphorus	0.69	0.75	0.68

*Treatments were based on processed grain (1), unshelled pods with grain (2) and vines with unshelled pods (3). TDN = Total Digestible Nutrients.

Table 2: Chemical Composition (%) of Velvet Beans Fractions Subjected to Different Processing Methods For Feeding Trials With Milking Cows

Component	*Grain fraction*	*Grain and pods*	*Pods and vines*	*SEM*
Dry matter	91.8^{a}	86.8^{b}	90.55^{a}	2.72
Crude protein	24.7^{a}	17.6^{b}	15.27^{c}	0.44
Ash	4.11	4.32	4.05	0.21
Ether extract	3.61^{a}	2.44^{b}	2.66^{b}	0.15
Calcium	0.76^{b}	0.96^{ab}	1.12^{a}	0.10
Phosphorus	0.42	0.72	0.37	0.16
Gross energy*	2763^{b}	3720^{a}	3980^{a}	185.5
Crude Fibre	8.81^{b}	18.99^{a}	21.1^{a}	1.04
NDF[1]	74.7^{a}	74.5^{a}	65.6^{b}	1.32
ADF[2]	9.80^{b}	19.0^{a}	22.9^{a}	1.73
Lignin	0.67^{b}	4.42^{a}	4.86^{a}	0.71
Poly phenols	3.70^{ab}	3.60^{b}	4.00^{a}	0.16
Tannins	1.17^{b}	2.07^{a}	1.55^{ab}	0.14

*Expressed in calories per gram. [1] = Neutral Detergent Fibre and [2]= Acid Detergent Fibre. SEM = Pooled standard error of the mean. Means with different superscript letters within the row were significantly different from each other at P ≤ 0.05%.				

Table 3: Average Weekly Acceptability of Velvet Beans-Based Diets by Experimental Dairy Animals used in the On-Station Feeding Trial at the Schools of Agric (n = 8) and Veterinary Medicine (n=6)

Study Period	Treatment 1(Agric. study)		Treatment 2 (Vet. Study)	
Week	**Offered***	**Consumed**	**Offered***	**Consumed**
One	5.2	5.13	2.0	1.88
Two	5.2	5.07	2.0	2.18
Three	5.5	5.28	2.0	2.04
Four	5.2	4.75	2.0	1.97
Five	5.2	4.76	2.0	1.82
Six	5.2	4.53	2.0	2.00
Seven	5.2	5.14	2.0	2.01
Eight	5.2	4.16	2.2	1.98

*The animals were offered an average of 2.2kg diet per litre of milk produced each day. There were no significant differences in the consumption of experimental diets across the feeding period.

Table 4. Weekly Milk Production in on-station and on-farm Maintained Multi-Parous Crossbred Dairy Cows Fed Selected Preparations of Velvet Beans Based Diets

	On–Station Studies		On-Farm Studies	
Week	***Vet. Study***	***Agric. Study***	***Haimbe Study***	***Mtine Study***
1	4.52^{abc}	11.5	17.6	8.06
2	4.56^{abc}	11.3	16.8	8.47
3	4.30^{abc}	11.9	17.1	8.28
4	3.97^{c}	7.20	16.6	7.98
5	4.06^{bc}	10.1	16.2	8.02
6	4.76^{a}	9.80	16.4	8.23
7	4.67^{ab}	9.91	16.6	8.16
8	4.82^{a}	8.49	16.5	8.13
SEM	0.95	4.72	4.75	2.85

Means with different superscript letters within a column were statistically different from each other (at P ≤0.05). SEM = pooled standard error of the mean. The numbers of animals were 8 and 12 for the Vet and Agric studies, respectively.