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Effect of feeding different levels of foliage of *Moringa oleifera* to creole dairy cows on intake, digestibility, milk production and composition

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Abstract

An experiment was conducted in Nicaragua to determine the effect of feeding different levels of foliage from *Moringa oleifera* Lam (synonym: *Moringa pterygosperma* Gaertner) to dairy cows on intake, digestibility, milk production and milk composition. The treatments were: *Brachiaria brizantha* hay ad libitum, either unsupplemented or supplemented with 2 kg or 3 kg of Moringa on a dry matter (DM) basis. Six *Bos indicus* cows of the Creole Reyna breed, with a mean body weight of 394 ± 24 kg were used in a replicated 3×3 Latin square design. Supplementation with Moringa increased ($P < 0.05$) DM intake from 8.5 to 10.2 and 11.0 kg DM day^{-1} and milk production from 3.1 to 4.9 and 5.1 kg day^{-1} for *B. brizantha* hay only and supplementation with 2 kg and 3 kg DM of Moringa, respectively. Milk fat, total solids and crude protein and organoleptic characteristics, smell, taste and colour, were not significantly different between the diets. Apparent digestibility coefficients of DM, OM, CP, NDF and ADF increased ($P < 0.05$) in the diets supplemented with Moringa compared with *B. brizantha* hay alone. The results showed that the inclusion of Moringa as a protein supplement to low quality diets improved DM intake and digestibility of the diet and increased milk production but did not affect milk composition.

Keywords: *Moringa oleifera*; Dairy cows; Intake; Digestibility; Milk production; Milk composition

1. Introduction

Production of milk and beef are very important activities for small farmers in Nicaragua. Traditional systems are often economically marginal and land use practices are not sustainable in a long-term perspective, in particular when hillsides and forest margins are exploited (Mendieta et al., 2000). Ruminant feeding is mainly based on grazing, specifically of gramineas. Grass yield is in general not enough to satisfy the nutritional requirements of animals in the

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6 months of dry period each year. The dry season causes nutritional stress and consequently decreases animal productivity. Supplementation with concentrates during the dry season is generally not a profitable practice due to high feeding costs, because available ingredients for concentrate production are limited (Benavides, 1994).

A potential strategy for increasing the quality and availability of feeds for smallholder ruminant animals in the dry season may be through the use of fodder trees and shrub forages (Pezo, 1991). Most trees and shrubs are easily propagated and do not require high management inputs (fertilizer, pesticides, etc.) or advanced technology. One of these potential tree forages is Moringa (*Moringa oleifera* Lam (synonym: *Moringa pterygosperma* Gaertner), commonly referred to as the ”drumstick tree”, which grows throughout the tropics.

Moringa grows in all types of soil, from acid to alkaline (Duke, 1983), and at altitudes from sea level to 1800 m. It is drought tolerant and will grow even during the 6 months of the dry season. Dry matter (DM) yield is high, 15 tons/ha/year. In a study in Nicaragua, the fresh leaves were found to contain 23% crude protein (CP) in DM, 12.3 MJ ME/kg DM and had an in vitro DM digestibility of 79.7% (Becker, 1995) and Moringa can thus be a valuable supplement for animals. Moringa leaves, petioles and young stems have a slightly lower protein content than *Gliricidia sepium* (26%) and *Leucaena leucocephala* (25%). However, the CP of Moringa is of better quality for ruminants than the CP of leaves of Gliricidia or Leucaena because of its high content of bypass protein, 47% versus 30% and 41% respectively (Becker, 1995). Moringa is also rich in carotene, ascorbic acid, iron and in the two amino acids generally deficient in other feeds, i.e. methionine and cystine (Makkar and Becker, 1996).

In a trial with goats, the inclusion of 9%, 27% and 36% of Moringa leaves in the ration resulted in DM intakes (DMI) of 251, 335 and 311 g/day, respectively. However, incorporation of different levels of Moringa leaves did not affect the body weight (BW) gain, at 16.1, 15.0 and 13.6 g/day, respectively (Sarwatt et al., 2002). Goats supplemented with 20% and 50% of Moringa leaves had a DMI of 50.9 and 51 g/kg$W^{0.75}$ per day, which was similar to goats that were not supplemented. Supplemented goats had an average BW gain of 86 and 78 g/day while non-supplemented goats gained only 55 g/day (Aregheore, 2002). When bullocks were stall-fed with only star grass hay (*Cynodon dactylon*) or hay supplemented with Moringa leaves at 0.6% of BW in DM, Castellón and González (1996) found significant differences in weight gain, 0.045 versus 0.380 kg/day, respectively.

Rocha and Mendieta (1998) fed dairy cows with *Hyparrenia rufa* grass and sorghum straw supplemented with different levels of Moringa leaves, Moringa was readily accepted by the animals and did not seem to have any toxic effect or contain any factors limiting intake. Supplementation with Moringa leaves at a level of 0.3% of BW resulted in a milk yield of 5.7 kg cow day^{-1}, and this was 13% higher than for the control treatment, which was grazing only. Sarwatt et al. (2004) found that when cotton seed cake was substituted by Moringa leaf meal at levels of 10, 20 or 30% of DM, milk yield was significantly increased by 1.4, 0.9 and 0.8 kg cow day^{-1} respectively. There were no effects of substituting cotton seed cake with Moringa leaf meal on total solids, fat and CP content of the milk.

The objective of this study was to evaluate the effect of feeding different levels of *M. oleifera* to creole dairy cows on intake, digestibility, milk production and composition.

2. Materials and methods

2.1. Location

The experiment was conducted at the farm of the National University of Agriculture in Managua, Nicaragua, located at 12°08′15″ north and 86°09′36″ east. The mean annual temperature is 28 °C and the mean annual rainfall 1200 mm, with a marked dry season (November–May).

2.2. Land preparation and planting procedure of *M. oleifera*

Soil preparation was done by conventional tillage using a tractor and mechanical tools, cleaning the land from plant debris and disk ploughing followed by two disks harrowing and furrowing. The Moringa was established as a pure crop with a spacing of 5 cm between plants and 0.4 m between rows, with seeds and without irrigation or fertilisation. The seeds were planted at a depth of 1 cm in the soil and there were 2 seeds per drill. Hand weeding was done twice. During the experiment Moringa was harvested daily at 1.5 m plant height and 25 cm cutting height, at approximately 45 days of regrowth and stems thicker than 5 mm were removed to ensure uniform forage composition. Before the start of the experiment, a uniformity cut was carried out in the plots to assure availability of regrowth of 45 days of age.

2.3. Management and feeding of the cows

Six cows of the dual purpose Reyna Creole breed from the herd at UNA, with a body weight of 394 (24) kg and in their second or third lactation, were used in the experiment. The cows were selected for the experiment at the fourth week of lactation.

The animals were weighed at the beginning of the trial and were confined to individual, well ventilated stalls. Before the start of the trial all animals were injected with Vitamin A 625,000 UI, Vitamin D3 125,000 UI and Vitamin E 125 UI, and were treated with Ivomec against external and internal parasites and vaccinated against anthrax. The cows were exercised daily in a common area, while individual boxes were cleaned, and when walking to the milking.

Brachiaria brizantha grass, 60 days of age and not fertilized or irrigated, was utilized for hay production. The hay was made according to standard procedures using a tractor and mechanical tools. The grass was cut with a mechanical harvester and sun dried in the field during 4 h, baled, and stored in a warehouse. Moringa was harvested using a machete and chopped in pieces to approximately 2 cm length using an electric chopping machine daily in the morning for feeding the same afternoon and in the evening for feeding on the next day in the morning. All animals had access to water ad libitum and mineral salts according to requirements. The mineral salt consisted of 23.0% Ca, 18.1% P, 5.0% NaCl, 2% Mg and 2.1% trace elements and 49.8% inert material used as a carrier.

B. brizantha hay and sugar cane molasses were mixed thoroughly before being offered to the cows. *B. brizantha* hay and Moringa were offered individually in separate feed troughs twice per day, in the morning at 7:00 h and in the afternoon at 15:00 h. The total amount of *B. brizantha* offered, kg DM cow^{-1} day^{-1}, was the same for all three treatments. The DM content of Moringa foliage was determined twice per week by using a microwave oven according to the procedure described by Undersander et al. (1993).

The voluntary feed intake was determined daily during each experimental period, by the conventional difference method between offered and rejected. The refusals from the *B. brizantha* hay were assumed to contain the same percentage of sugar cane molasses as was offered. Feeds were weighed prior to feeding. Refusals were collected and weighed separately before offering new feed the next day. *B. brizantha* hay and Moringa, offered and rejected, were sampled daily and were stored frozen. DM was determined in each case at 65 °C for 48 h and the samples were stored for subsequent chemical analysis.

Milk yield was recorded once daily at 06.30 h in the morning. The cows were milked by hand with the calf present. Individual samples of milk were collected in the 7 days of each experimental period and were stored frozen. At the end of each experimental period, these samples were pooled to obtain one sample per cow per period.

For digestibility estimation all faeces from each animal during the last week at the end of each period were collected manually. The faeces from each animal were put in a large container, weighed and mixed thoroughly and 5% of the faeces were taken as a sample and frozen. When the collection was completed the faecal samples from each cow were thawed and then mixed together thoroughly to one homogeneous mixture for each animal. Approximately 300 g of the mixture from each animal were taken and spread as a small dung pat on a plate. The dung was dried at a maximum of 60 °C. After 12 to 24 h, the crust that was formed was broken and the dung pat turned. Drying was continued until the whole sample became completely dry. The dried dung sample was broken into pieces and ground to 1 mm size.

2.4. Chemical analysis

Feed offered and refused and faeces were analysed for DM, ash, CP, neutral detergent fibre (NDF) and acid detergent fibre (ADF). DM was determined by oven drying samples at 105 °C for 6 h.

Ash determination was done at 550 °C for 8 h, total nitrogen (N) by the semi-micro Kjeldahl procedure (Kass and Rodriguez, 1993) and CP calculated from N content (CP=N × 6.25) according to the official methods of AOAC (1990). NDF and ADF were determined by the procedure proposed by Goering and Van Soest (1970). Apparent digestibility coefficient for DM was calculated from dietary intake of constituent and amount recovered in faeces. Milk samples were analysed for fat by the Babcock method (Pereira, 1988), CP by the Kjeldahl method and total solids according to AOAC (1990). Sensory evaluation of milk samples was done by a panel of 15 people with experience in crude milk examination. A triangle difference test (Wittig de Penna Enma, 1995) was applied using a milk sample with normal organoleptic characteristics (colour, smell and taste) as a standard.

2.5. Experimental design and statistical analysis

The experimental design used was a change over 3 × 3 Latin Square, replicated twice. Each experimental period consisted of 3 weeks of adaptation to treatments and 2 weeks data collection. The last week of each period was used for collecting manure for estimation of digestibility. The treatments were: 1. *B. brizantha* hay + sugar cane molasses, 2. *B. brizantha* hay + 2 kg DM Moringa + sugar cane molasses and 3. *B. brizantha* hay + 3 kg DM Moringa + sugar cane molasses.

The data was analysed using the GLM procedure in the Minitab Statistical Software Version 12.0 (Minitab, 1998). Tukey's pairwise comparison procedure was used when the difference between treatments means was significant. The mathematical model used was $Y_{ijkl} = \mu + S_i + C_{j(i)} + P_k + T_l + \epsilon_{ijkl}$ where μ was the overall mean, S_i the random effect of square, $C_{j(i)}$ the random effect of cow within square, P_k the fixed effect of period, T_l the fixed effect of treatment and ϵ_{ijkl} the random residual error.

3. Results

3.1. Chemical composition

The chemical composition of the feeds used in the experiment is presented in Table 1. Moringa forage had a high CP and ash content but a low NDF content. *B. brizantha* hay had a low CP and a very high content of NDF.

Table 1
Chemical composition of feed components[a]

Constituents	Feeds		
	Brachiaria brizantha hay	*Moringa oleifera*	Sugar cane molasses
DM (g kg^{-1})	883.0 (14.4)	164.0 (17.0)	247.0 (20.7)
g kg^{-1} DM			
CP	48.2 (4.3)	178.0 (26.7)	40.5 (1.9)
NDF	767.3 (23.4)	506.0 (47.5)	3.48 (0.1)
ADF	532.0 (27.5)	376.3 (45.2)	0.15 (0.03)
Ash	72.5 (3.8)	107.6 (6.3)	129.5 (10.0)
Number of samples	18	12	18

DM (dry matter); CP (crude protein); NDF (neutral detergent fibre); ADF (acid detergent fibre).
[a] Means and standard deviations.

3.2. Intake and apparent digestibility

DM, OM, CP and fibre components (NDF and ADF) intakes for the different diets are shown in Table 2. Average daily intake of the diet with only *B. brizantha* hay was 8.5 kg DM. The total intakes of cows supplemented daily with 2 kg DM and 3 kg DM of Moringa were significantly ($P < 0.05$) higher than the intake of the unsupplemented cows. Total DM intake increased with supplementation in proportion to the amount of Moringa offered, although the intake was not significantly different between 2 kg or 3 kg DM of supplement. The differences in DM intake compared to *B. brizantha* hay were +1.7 and +2.5 kg DM for the diets supplemented with 2 kg and 3 kg DM of Moringa, respectively.

Apparent digestibility coefficients of the diets are shown in Table 2. The supplemented diets had significantly ($P < 0.05$) higher digestibility coefficients than the unsupplemented *B. brizantha* hay diet. The cows supplemented with 2 kg or 3 kg DM Moringa daily had similar apparent nutrient digestibility coefficients. An estimation using the intakes and digestibilities for the diets with 2 or 3 kg DM Moringa and assuming that the digestibilities were the same for the diet components showed that the digestibility of the *B. brizantha* hay was 52% and of the added Moringa foliage about 80%.

Table 2
Intake and apparent digestibility of Reyna cows fed different levels of *Moringa oleifera*

Items	Diets			S.E.
	B. brizantha hay	*B. brizantha* hay+2 kg DM *M. oleifera*	*B. brizantha* hay+3 kg DM *M. oleifera*	
Feed offered kg DM day^{-1}				
Brachiaria brizantha hay	12.4	12.4	12.4	0.05
Moringa oleifera	0.0	2.0	2.9	0.11
Sugar cane molasses	0.5	0.5	0.5	0.01
Total	12.9	14.9	15.8	0.09
Feed intake (kg DM day^{-1})				
Brachiaria brizantha hay	8.2^{a}	7.9^{a}	7.7^{a}	0.23
Moringa oleifera	0.0	2.0	2.9	
Sugar cane molasses	0.3^{a}	0.3^{a}	0.3^{a}	0.01
Feed intake kg day^{-1}				
DM	8.5^{b}	10.2^{a}	11.0^{a}	0.21
OM	7.9^{b}	9.4^{a}	10.0^{a}	0.20
CP	0.4^{c}	0.7^{b}	0.9^{a}	0.03
NDF	6.3^{b}	7.2^{a}	7.5^{a}	0.19
ADF	4.4^{b}	4.9^{ab}	5.2^{a}	0.15
Apparent digestibility coefficients (%)				
DM	44.2^{b}	57.3^{a}	60.0^{a}	0.94
OM	46.1^{b}	58.6^{a}	61.1^{a}	0.89
CP	36.8^{c}	53.6^{b}	60.9^{a}	2.10
NDF	43.6^{b}	55.2^{a}	56.4^{a}	1.50
ADF	40.3^{b}	49.9^{a}	52.3^{a}	1.57

[abc] Means in the same row with different superscript differ significantly ($P<0.05$).

3.3. Milk production and composition

Mean daily milk production was significantly ($P<0.05$) higher for cows offered Moringa supplement than for those offered *B. brizantha* hay only (Table 3). Increasing the amount of Moringa offered from 2 to 3 kg DM did not increase daily milk production but supplemented cows produced significantly more milk (1.80 and 1.97 kg, respectively) than cows offered *B. brizantha* hay alone.

Milk composition was not significantly different between the treatments (Table 3), although protein concentration increased and total solids and fat concentrations decreased slightly with increased levels of Moringa in the diets. The higher milk yield of cows supplemented with Moringa resulted in significantly higher yields of milk fat, milk protein and fat corrected milk yield. The organoleptic characteristics of the milk were not significantly different between the diets. Smell, taste and colour

Table 3
Milk production and milk composition of Reyna cows fed different levels of *Moringa oleifera*

Items*	Diets			S.E.
	B. brizantha hay	BBH+2 kg DM *M. oleifera*	BBH+3 kg DM *M. oleifera*	
Milk (kg cow day^{-1})	3.10^{b}	4.91^{a}	5.07^{a}	0.20
FCM (kg cow day^{-1})	3.14^{b}	4.86^{a}	4.95^{a}	0.16
MF (kg cow day^{-1})	0.13^{b}	0.20^{a}	0.20^{a}	0.01
MF (g kg^{-1})	41.8^{a}	39.8^{a}	38.7^{a}	0.10
TS (g kg^{-1})	132.1^{a}	131.2^{a}	130.6^{a}	0.10
MCP (g kg^{-1})	33.8^{a}	33.5^{a}	34.6^{a}	0.05
MCP (kg cow day^{-1})	0.11^{b}	0.17^{a}	0.18^{a}	0.01

[abc] Means in the same row with different superscript differ significantly ($P<0.05$).
* FCM: fat corrected milk 4% (FCM=(Milk yield × 0.4)+(Milk fat yield × 15)); MF (Milk fat); TS (Total solids); MCP (Milk crude protein).

of the milk were characterized as normal for all diets.

4. Discussion

The quality of the *B. brizantha* hay offered in the current experiment was typical of dry season forages with low CP concentration (48.2 g kg^{-1} DM), low DM, OM, CP, NDF and ADF apparent digestibility coefficients and high NDF concentration (767 g kg^{-1} DM). The mean CP concentration of Moringa was 178 g kg^{-1} DM, which is within the range of 156 to 264 reported by other workers (Malik et al., 1967; Gupta et al., 1989; Becker, 1995; Makkar and Becker, 1996, 1997). The mean NDF and ash concentration of Moringa were 506 g kg^{-1} and 108 g kg^{-1}, respectively. Theses values were within the range of 219 to 684 g kg^{-1} and 88.7 to 134 g kg^{-1} reported by others authors (Malik et al., 1967; Gupta et al., 1989; Becker, 1995; Makkar and Becker, 1996, 1997) for NDF and ash, respectively.

Leng (1990) defined low-quality forages as forages with CP less than 80 g kg^{-1} DM and the DM intake will be reduced due to nitrogen deficiencies and suggested supplementation of such forages with appropriate nutrients to achieve high levels of animal production. Protein supplementation has been found to increase total DM intake in diets with low quality roughage (Church and Santos, 1981; Guthrie and Wagner, 1988), resulting in a mere additive effect, sum of basal diets and supplements, as found in the present experiment. Feeding Moringa had an additive effect on *B. brizantha* hay intake and this and other studies demonstrate the potential of forage trees to improve the utilization of low quality fibrous feeds. Goodchild and McMeniman (1994) indicated that inclusion of 20–50% of plants rich in protein, in the diet results in a 10–45% increase in intake of fibrous forage.

The increase in nutrient intake, DM, OM and CP, when Moringa was fed, was probably a result of its high CP and low NDF concentrations. According to NRC (1989), the CP intake of the diets supplemented with 2 kg and 3 kg of Moringa met or exceeded recommended standards. However, the *B. brizantha* hay basal diet was clearly deficient in protein. In the unsupplemented cows some body protein reserves were probably mobilized to support synthesis of the milk components (Komaragiri and Erdman, 1997).

Diets supplemented with Moringa had higher values ($P<0.05$) for DM, OM, CP, NDF and ADF apparent digestibility coefficients compared to *B. brizantha* hay. This response could be due to the fact that feeding Moringa foliage improved N supply and corrected the N deficiency in the diet with *B. brizantha* hay only (Poppi and McLennan, 1995) or probably only exerted a limited effect on rumen fill because of the low NDF concentration (Umunna et al., 1995). Digestibility was also influenced by the intake of supplement because Moringa had a lower NDF concentration than *B. brizantha* hay. The estimations of digestibility of the different diet components in the supplemented diets also showed that the digestibility of *B. brizantha* hay was improved and the digestibility of the supplemented Moringa foliage was high, around 80%. Minson and Milford (1967) found that the positive response of legume supplements on nutrient digestibility is significant when the proportion in the diet is greater than 10%.

Milk production was higher in the supplemented cows than those offered *B. brizantha* hay alone (3.1 kg cow day^{-1}). Cows offered 2 kg DM or 3 kg DM of Moringa had a similar milk production, 4.9 and 5.1 kg cow day^{-1}, respectively. Rocha and Mendieta (1998) found that cows supplemented with Moringa at a level of 0.3% of BW had 13% higher milk production than cows fed a basal diet of *H. rufa* grass and *Sorghum vulgare* straw. According to Sarwatt et al. (2004) Moringa improved the milk yield due to a positive effect on the rumen environment, leading to increased rumen microbial output, and that the protein in Moringa also has good rumen bypass characteristics.

Milk yields averaged 5.0 kg cow day^{-1} in this experiment, demonstrating that relatively high levels of production in dual purpose systems can be achieved during the dry season with Moringa supplement. It should be mentioned that in traditional systems milk yields during the dry season are only 2 to 3 kg cow day^{-1}, and low levels of production are generally associated with poor animal nutrition (Hollmann and Estrada, 1997).

Milk total solids content was similar among the diets. Vélez et al. (2002) reported that the diet can cause variation in milk fat and of milk protein content, but the tendency is that the content of total solids remains constant.

Milk fat and milk protein contents were not significantly different between diets. This could be explained by increasing level of CP in the diet over normal standards which generally has inconsistent effects on milk fat content (Huhtanen, 1994). The diet can influence the yield of milk protein more than it can influence the milk protein content.

Cows supplemented with Moringa yielded more milk fat and milk CP ($P<0.05$) than the cows fed only *B. brizantha* hay. These increases in milk fat and protein yields were due to the increased milk yield, because the percentages of milk fat and milk protein were not affected by the Moringa supplementation (Table 3). Spörndly (1989) observed no relationship between milk protein content and percentage of dietary CP ($r=0.06$), but found that milk protein yield and CP were correlated ($r=0.37$). Numerous studies (DePeters and Cant, 1992) demonstrated increases of 4% to 10% in milk protein yields over controls when cattle were fed 180 g CP kg^{-1} to diet.

According to Judkins and Keener (1960) milk produced under normal conditions has a slightly sweet taste and aromatic smell. The sweet taste comes from lactose and the aromatic smell mainly from fat. Both taste and smell are affected by the environment and the feeding. The effects on taste, smell and colour appear when the cow consumes forages with strong taste or pigments and intense smell. Taste and smell are absorbed at level of the lung or gastro-intestinal tract and pass to the milk across the circulatory systems (Vélez et al., 2002).

The results of milk sensory analysis (taste, smell and colour) in cows supplemented with Moringa showed that feeding Moringa did not affect milk organoleptic characteristics and there was no difference between treatments. Since the cows were milked 14 h after feeding Moringa any effects on taste, smell or colour could probably not be expected.

5. Conclusions

M. oleifera fed at 2 kg or 3 kg DM day^{-1} can significantly improve dry matter intake, nutrient digestibility and milk yields of dairy cattle fed a basal diet of *B. brizantha* hay in the dry tropics without affecting milk composition (fat, crude protein and total solids) or organoleptic characteristics of milk (smell, taste and colour), and has thus a great potential to contribute protein rich forage, particularly in dual purpose production systems during the dry season.

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