Production responses of tropical crossbred cattle to supplementary feeding and to different milking and restricted suckling regimes

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Abstract

The relationships between cow nutrition, restricted suckling and milking patterns and their effect on milk yield, milk composition and calf growth were examined under tropical conditions in south east Mexico. Eleven \textit{Bos indicus} $\times$ \textit{Bos taurus} cows, 14 days postpartum, with calves weighing on average 37 kg were used in a change-over experimental design. All cows were fed \textit{Cynodon nlemfuensis} hay ad libitum, and either 4.0 kg \textit{Leucaena leucocephala}, 2.0 kg sorghum grain and 0.25 kg sugar-cane molasses on a fresh weight basis (L1), or twice this amount of the same supplement (L2). The calves were offered the same hay ad libitum in addition to suckling milk. The milking/restricted suckling treatments were: twice-daily milking with suckling after morning milking (2 $\times$ AM), and once-daily milking in the morning with afternoon suckling (1 $\times$ PM). The two regimes were examined at L1 and L2 feeding levels. A suckling time of 30 min was allowed at each suckling occasion. For 2 $\times$ AML1, 2 $\times$ AML2, 1 $\times$ PML1 and 1 $\times$ PML2, respectively saleable milk yields (SMYs) (kg/day) were 5.43, 5.99, 3.47, 4.09 (S.E.M. 0.174); calf suckled milk (CSM) (kg/day) 1.36, 1.46, 3.14, 3.43 (S.E.M. 0.160); and total milk yield (kg/day) 6.79, 7.46, 6.62, 7.53 (S.E.M. 0.226). For SMYs, fat contents (g/kg) were 30.0, 29.4, 29.0, 28.7 (S.E.M. 1.11), respectively, and for CSM 59.6, 63.4, 38.8, 42.4 (S.E.M. 2.46). Protein contents (g/kg) for SMYs were 27.5, 29.1, 29.3, 30.4 (S.E.M. 0.67) and for CSM 27.9, 28.4, 29.1, 30.3 (S.E.M. 0.81). Total food intakes of cows were 10.84, 12.12, 10.99, 12.16 (S.E.M. 0.331) kg DM/day. Calf growth rates were, respectively, 0.17, 0.20, 0.41, 0.52 (S.E.M. 0.029) kg/day, and hay DM intake 0.58, 0.49, 0.41, 0.34 (S.E.M. 0.040) kg/day. It was concluded that level of supplementation and restricted suckling and milking regimes could both be used to manipulate TMY, SMY and calf performance.

Keywords: Cattle; Feed supplements; Tropical feeds; Milk production; Suckling

1. Introduction

Dual purpose (DP) cattle systems contribute a significant proportion of the total milk and meat produced in the tropics, and are characterised by...
cows being both milked and allowed to suckle their calves (Wadsworth, 1995). The cows are either of *Bos indicus* or *Bos indicus × Bos taurus* breeds, and when milked by hand or by machine, require the presence of the calf for milk ejection to occur (Preston and Vaccaro, 1989). A variety of milking and partial suckling regimes are practised according to the market demand for milk and meat. These regimes can influence milk yield (Leon and Vaccaro, 1984), milk quality (Boden and Leaver, 1994), and calf growth (Day et al., 1987).

In a previous study, Sandoval-Castro et al. (1999) examined the milk production and calf growth responses to four different milking and suckling patterns under both temperate and tropical conditions. They showed that twice daily milking combined with once daily suckling produced the highest saleable milk production, and that once daily milking in the morning combined with once daily suckling in the afternoon gave the highest calf growth rate.

The availability and quality of locally-produced feeds in tropical DP systems are extremely variable and consequently very influential on the level of milk and meat output achieved. Improved nutrition of the cow is likely to benefit both saleable milk production and the amount of milk sucked by the calf. The interactions of milking and restricted suckling regimes with nutrition under tropical conditions are however, poorly understood. The objective of this study was to evaluate the effect on cow and calf performance, of two milking and restricted suckling regimes which were known to produce different saleable milk and calf growth responses, at two feed supplementation levels for the cow using locally produced feeds.

2. Material and methods

2.1. Location

The experiment was carried out at the Faculty of Veterinary Medicine and Animal Sciences, University of Yucatan, Merida, Mexico between July and December 1995. The climate is classified as hot sub-humid (AWo), with a mean annual temperature of 26°C, and annual rainfall of 983 mm which is predominantly in the months June to October.

2.2. Animals

Eleven *Bos indicus × Bos taurus* (Brown Swiss × Zebu) cows were used with a mean parity of 3.6 (range 1–7), initial saleable milk yield (SMY) 6.9 (4.3–10.5) kg/day, liveweight (LW) 435 (350–540) kg and on average 14 (10–17) days postpartum. The calves were bred by a Zebu (Brahman) bull and had a mean initial LW of 36.6 (29.8–44.8) kg.

2.3. Feeds and feeding

Cows were housed individually in pens and offered star grass hay (*Cynodon nlemfuensis*) (SG) ad libitum after morning milking, following the removal of refused hay from the previous day. A sorghum grain ration was offered in two halves after the a.m. and p.m. milking. *Leucaena* (*Leucaena leucocephala*) leaves and branches (stem < 5 mm diameter) were chopped and served in one feed at 10.00 h. The *leucaena* was mixed with a small quantity of sugar-cane molasses to ensure total consumption. It was cut every day and served fresh except for Sunday, when the fodder from the previous day’s supply was fed.

The calves, which were housed in groups of two or three according to treatment, were allowed to suckle every day for one or two periods of 30 min according to the experimental design. SG hay was provided ad libitum. At suckling times, the calves were put into the pen occupied by their dam. During the third week of each period, calves were kept neck-tied when not suckling in order to record individual hay intakes. Calves were reallocated to new pens at the start of each period. Water was freely available to cows and calves.

2.4. Treatment

Previous experiments (Sandoval-Castro et al., 1999) examined four different milking/partial suckling regimes. They showed that twice daily milking with suckling after morning milking (2 × AM) yielded a higher saleable milk yield and lower calf growth than once daily milking a.m., with suckling p.m. (1 × PM). These two regimes which produced these widely different responses in saleable milk and calf...
suckled milk, were selected and studied at two supplementation levels as follows:

2 × AML1 – Twice daily milking (a.m. and p.m.) with calf suckling after a.m. milking. Cows supplemented with 4.0 kg leucaena, 2.0 kg sorghum and 0.25 kg molasses (fresh weight basis).

2 × AML2 – Twice daily milking (a.m. and p.m.) with calf suckling after a.m. milking. Cows supplemented with 8.0 kg leucaena, 4.0 kg sorghum and 0.50 kg molasses.

1 × PML1 – Once daily milking (a.m.) with calf suckling in the afternoon. Cows supplemented with 4.0 kg leucaena, 2.0 kg sorghum and 0.25 kg molasses.

1 × PML2 – Once daily milking (a.m.) with calf suckling in the afternoon. Cows supplemented with 8.0 kg leucaena, 4.0 kg sorghum and 0.50 kg molasses.

The morning milking took place at 05.30 h and afternoon milking at 14.30 h. The a.m. suckling (2 × AM) took place immediately after a.m. milking, and the p.m. suckling (1 × PM) whilst the cows on the 2 × AM regime were being milked. At milking time the calves were held “at foot” and allowed to suckle for about 10–20 s prior to machine milking to stimulate milk ejection.

2.5. Experimental design

A Latin rectangle design (Mead et al., 1993) was used, with cows (11) as columns and periods (4) as rows. Each period was of 3 weeks duration and was divided into a 2-week adaptation, and a 1-week (final week) measurement period.

2.6. Measurements

Individual milk yield was recorded daily throughout the experiment, but only data from the final week of each experimental period were used for statistical analyses. The machine extracted milk was regarded as saleable milk (SMY), and the total milk yield (TMY) was taken as the sum of the SMY + milk suckled by the calf (CSM). Samples of extracted milk were taken from the production of each cow at each milking, during 3 days in the final week of each experimental period to measure the composition of SMY.

Liveweight (LW) was monitored by weighing animals twice weekly during the experiment. Body condition score (CS) was recorded at the time of weighing (scale 0 = emaciated, 5 = extremely fat). These measurements were taken immediately after milking and suckling, and before receiving any additional feed. Feed intake was measured over 5 days during the third week of each period, and representative samples of feed were taken for laboratory analyses.

The calves were weighed twice weekly, on the same day as the cows, to assess LW change (procedure as for cows). The CSM was measured during 3 days of the final week of each period by the weigh–suckle–weigh method (Neidhardt et al., 1979). The calves were weighed on a scale to the nearest 0.5 kg. A record of all defaecations and urinations from the animals was taken, and 0.25 kg (the estimated average weight) was added to CSM to account for any such losses. In addition the time spent suckling was recorded to estimate both total suckling time and milk consumption rate.

Mean composition of CSM was determined for pooled samples taken from the four quarters of each cow immediately before and after suckling on three days in the final week of each period. To facilitate sampling after suckling, intra muscular oxytocin (10 i.u.) was given to ensure that a sample of adequate size was produced. Individual calf hay intake was measured during the final week of each period.

2.7. Feed degradability

The potential nutrient supply from the sorghum, leucaena and star grass hay used in the experimental diet was characterised using the dacron bag degradability technique. Two Bos indicus × Bos taurus bulls fitted with ruminal cannulae were used, and housed in individual pens. The animals received a diet consisting of fresh Taiwan grass (Pennisetum purpureum var. Taiwan) and a commercial concentrate (180 g CP/kg fresh weight) in a proportion of approximately 75:25 estimated to supply 1.0–1.5-times maintenance requirements.

All feed samples to be tested were oven dried, ground in a 3 mm mill and kept in air-tight containers. Approximately 3 g leucaena, 3 g star grass hay and 5 g of sorghum were placed in dacron bags.
(25 cm length × 8 cm wide, 43 μm pore size) previously washed, dried and weighed. Incubation times in the rumen were; 0, 2, 4, 8, 12, and 24 h for sorghum, 0, 4, 8, 12, 24, 48 and 72 h for leucaena and 0, 6, 12, 24, 48, 72 and 96 h for star grass hay. Two bags per incubation time per animal were placed in the rumen immediately before the morning feed and removed according to the incubation schedule.

After withdrawal all bags were dipped in cold water to stop further activity, and then frozen until all bags were collected. The bags were subsequently defrosted and washed thoroughly. They were then dried and weighed and the sample loss measured by difference. The residues were analysed individually or pooled (if the remaining sample was less than 1 g) for N. Soluble DM and N losses (fraction “A”) were measured by placing a bag in lukewarm water for 15 min. The data collected were fitted according to the equation $p = a + b(1 - \exp^{-c})$ (McDonald, 1981), where “$a$”, “$b$” and “$c$” are constants of the equation.

2.8. Feed and milk analyses

Star grass hay, leucaena and sorghum were analysed for oven dry matter (ODM), total nitrogen (N) to calculate crude protein (CP), ether extract (EE) and total ash by the methods of AOAC (1980). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed by the methods of Goering and Van Soest (1970). Toluene DM, N and total ash analyses (AOAC, 1980) were carried out on the samples of molasses.

For leucaena and star grass hay, ME content was estimated as:

$$\text{ME} = \text{DE} \times 0.81$$

(MAFF, 1975) where;

$$\text{DE (Mcal/kg)} = 0.042 \times \text{DMD} - 0.016$$

(Minson, 1981)

$$\text{DMD} = 143 - 5.4a + 6.6b - 190c$$

(Khazaal et al., 1995) where $A =$ washout losses, $B = a + b - A$.

Sorghum ME was estimated as:

$$\text{ME (MJ/kg)} = 0.012\text{CP} + 0.031\text{EE} + 0.005\text{CF} + 0.014\text{NFE}$$

(MAFF, 1975) where;

$$\text{CF} = 0.77 \times \text{ADF} - 0.49$$

(Jones, 1994).

Fat, protein and lactose analyses were carried out on all milk samples (AOAC, 1980).

2.9. Statistical analyses

Analyses of variance (ANOVA) were performed on the data using the General Linear Model procedure of the Minitab (1991) software package. Linear regression was used to assess LW change. The differences between milking/suckling regimes and between feeding levels were analysed with pre-planned contrasts.

3. Results

There were no significant milking/suckling regime × level of feeding interactions for any of the comparisons.

3.1. Saleable milk yield (SMY)

The yield of saleable milk (Table 1) was significantly affected by both milking/suckling regime ($P < 0.001$), and by level of supplementation ($P < 0.01$). The SMY of the 2×AM regime was significantly greater (1.51 times) than 1×PM, and the high level of supplementation was significantly greater (1.13 times) than the low level. The fat and lactose contents of SMY were not significantly affected by regime or supplement level. Milk protein content was significantly higher ($P < 0.05$) for the 1×PM milking/suckling regime and for the high level of supplementation.

Fat, protein and lactose yields of SMY were significantly greater for the 2×AM regime than for
Table 1
Mean saleable milk yield (SMY), milk composition and yield of constituents of cows

<table>
<thead>
<tr>
<th></th>
<th>2×AML1</th>
<th>2×AML2</th>
<th>1×PML1</th>
<th>1×PML2</th>
<th>sed*</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMY (kg/day)</td>
<td>5.43</td>
<td>5.99</td>
<td>3.47</td>
<td>4.09</td>
<td>0.173</td>
<td>***</td>
</tr>
<tr>
<td>Fat (g/kg)</td>
<td>30.0</td>
<td>29.4</td>
<td>29.0</td>
<td>28.7</td>
<td>1.07</td>
<td>NS</td>
</tr>
<tr>
<td>Protein (g/kg)</td>
<td>27.5</td>
<td>29.1</td>
<td>29.3</td>
<td>30.4</td>
<td>0.67</td>
<td>*</td>
</tr>
<tr>
<td>Lactose (g/kg)</td>
<td>51.3</td>
<td>48.8</td>
<td>51.9</td>
<td>50.5</td>
<td>1.63</td>
<td>NS</td>
</tr>
<tr>
<td>Fat yield (kg/day)</td>
<td>0.16</td>
<td>0.18</td>
<td>0.10</td>
<td>0.12</td>
<td>0.008</td>
<td>***</td>
</tr>
<tr>
<td>Protein yield (kg/day)</td>
<td>0.15</td>
<td>0.17</td>
<td>0.10</td>
<td>0.12</td>
<td>0.006</td>
<td>***</td>
</tr>
<tr>
<td>Lactose yield (kg/day)</td>
<td>0.29</td>
<td>0.29</td>
<td>0.18</td>
<td>0.20</td>
<td>0.014</td>
<td>***</td>
</tr>
</tbody>
</table>

*a* In this and subsequent tables *sed* relates to the main effects of the treatments.

1×PM (*P*<0.001). Fat yield (*P*<0.05) and protein yield (*P*<0.01) were significantly increased by supplementation level.

3.2. Calf suckled milk (CSM)

The milk intake of calves (Table 2) was significantly greater (*P*<0.001) for 1×PM compared with 2×AM, but there was no significant effect of supplementation level. The time spent suckling was not significantly different between treatments, but the rate of intake was almost three-times as high for 1×PM compared with 2×AM calves (*P*<0.001).

The milk composition before and after suckling, and the estimated mean composition of CSM is shown in Table 3. The fat content of the milk both before and after suckling was significantly greater (*P*<0.001) for the 2×AM system than the 1×PM, and as a consequence the estimated fat content of the suckled milk was also greater. The milk protein...

Table 2
Mean amount of milk consumed (CSM) by the calves (kg/day), time spent suckling (min) and rate of milk intake (kg/min)

<table>
<thead>
<tr>
<th></th>
<th>2×AML1</th>
<th>2×AML2</th>
<th>1×PML1</th>
<th>1×PML2</th>
<th>sed</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>1.36</td>
<td>1.46</td>
<td>3.14</td>
<td>3.43</td>
<td>0.160</td>
<td>*** NS</td>
</tr>
<tr>
<td>Time</td>
<td>24.3</td>
<td>24.4</td>
<td>22.5</td>
<td>21.9</td>
<td>1.07</td>
<td>NS NS</td>
</tr>
<tr>
<td>Rate</td>
<td>0.057</td>
<td>0.060</td>
<td>0.148</td>
<td>0.165</td>
<td>0.0096</td>
<td>*** NS</td>
</tr>
</tbody>
</table>

Table 3
Mean milk composition (g/kg) sampled before and after suckling, and estimated composition of calf suckled milk (CSM)

<table>
<thead>
<tr>
<th></th>
<th>2×AML1</th>
<th>2×AML2</th>
<th>1×PML1</th>
<th>1×PML2</th>
<th>sed</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat before</td>
<td>49.2</td>
<td>52.3</td>
<td>21.2</td>
<td>20.5</td>
<td>3.61</td>
<td>*** NS</td>
</tr>
<tr>
<td>Fat after</td>
<td>70.0</td>
<td>74.5</td>
<td>56.5</td>
<td>64.3</td>
<td>3.41</td>
<td>** NS</td>
</tr>
<tr>
<td>Estimated CSM fat</td>
<td>59.6</td>
<td>63.4</td>
<td>38.8</td>
<td>42.4</td>
<td>2.46</td>
<td>*** NS</td>
</tr>
<tr>
<td>Protein before</td>
<td>26.9</td>
<td>27.8</td>
<td>29.3</td>
<td>30.6</td>
<td>1.00</td>
<td>* NS</td>
</tr>
<tr>
<td>Protein after</td>
<td>28.8</td>
<td>29.0</td>
<td>28.9</td>
<td>29.9</td>
<td>0.85</td>
<td>NS NS</td>
</tr>
<tr>
<td>Estimated CSM protein</td>
<td>27.9</td>
<td>28.4</td>
<td>29.1</td>
<td>30.3</td>
<td>0.81</td>
<td>NS NS</td>
</tr>
<tr>
<td>Lactose before</td>
<td>50.3</td>
<td>48.9</td>
<td>47.8</td>
<td>48.4</td>
<td>2.14</td>
<td>NS NS</td>
</tr>
<tr>
<td>Lactose after</td>
<td>49.0</td>
<td>47.0</td>
<td>46.1</td>
<td>45.0</td>
<td>1.56</td>
<td>NS NS</td>
</tr>
<tr>
<td>Estimated CSM lactose</td>
<td>49.6</td>
<td>47.9</td>
<td>47.1</td>
<td>46.7</td>
<td>1.62</td>
<td>NS NS</td>
</tr>
</tbody>
</table>
content before suckling was significantly higher for the 1×PM regime ($P<0.05$) but there was no significant effect of milking/suckling regime on mean CSM protein content. Supplementation level had no significant effect on any CSM milk composition measurements.

3.3. Total milk yield (TMY)

TMY was significantly increased by the higher supplement level ($P<0.01$), but the weighted milk composition was not significantly affected (Table 4). Fat and protein yields were significantly increased by the higher level of supplement ($P<0.01$). The milking/suckling regime had no significant effect on total milk yield or fat, protein and lactose yields. The 1×PM regime had a significantly higher milk protein content ($P<0.05$) than 2×AM.

3.4. Liveweight and liveweight change

The liveweight gain of calves was significantly greater ($P<0.001$) for those calves suckling cows on the 1×PM regime than those on the 2×AM regime (Table 5). The high level of supplement fed to cows (L2) resulted in a higher liveweight gain of both the cows, and the calves ($P<0.05$). Condition score of the cows was not significantly affected by supplementation or milking/suckling regime.

3.5. Feeds and feed intake

The chemical composition of the feeds is presented in Table 6. The ME of the SG hay and leucaena was estimated using the degradability values shown in Table 7. The SG hay was high in NDF and ADF and consequently low in estimated ME, and was also low in CP. The leucaena was moderate in fibre, and estimated dry matter digestibilities of these forages using the equation of Khazaal et al. (1995) was applied to the degradability results in Table 7, were 457 g/kg DM for SG hay and 548 g/kg DM for leucaena. The sorghum grain had fitted values for $a$ and $b$ which totalled over 100% degradability of DM and N, and so 100% was assumed.

The higher level of supplement (L2) significantly ($P<0.001$) decreased SG hay intake of cows (Table 6). The ME of the SG hay and leucaena was estimated using the degradability values shown in Table 7.
Table 6
Chemical composition of the feeds (g/kg DM, except where stated)

<table>
<thead>
<tr>
<th>Component</th>
<th>Molasses</th>
<th>Leucaena</th>
<th>Hay</th>
<th>Sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODM (g DM/kg)</td>
<td>758*</td>
<td>269</td>
<td>900</td>
<td>878</td>
</tr>
<tr>
<td>CP</td>
<td>40</td>
<td>269</td>
<td>62</td>
<td>92</td>
</tr>
<tr>
<td>ASH</td>
<td>104</td>
<td>68</td>
<td>73</td>
<td>16</td>
</tr>
<tr>
<td>EE</td>
<td>–</td>
<td>29</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>NDF</td>
<td>–</td>
<td>513</td>
<td>828</td>
<td>156</td>
</tr>
<tr>
<td>ADF</td>
<td>–</td>
<td>345</td>
<td>434</td>
<td>57</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>12.7b</td>
<td>9.0c</td>
<td>6.5c</td>
<td>13.5b</td>
</tr>
</tbody>
</table>

* Toluene DM.
† MAFF (1975).
‡ From degradability value (Table 7) and Minson (1981), Khazaal et al. (1995) and Jones (1994).

Table 7
Degradability values for in situ rumen DM and N disappearance of feeds*  

<table>
<thead>
<tr>
<th>Feed</th>
<th>A</th>
<th>a</th>
<th>b</th>
<th>a+b</th>
<th>c</th>
<th>T</th>
<th>R.S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum grain</td>
<td>34.9</td>
<td>43.7</td>
<td>94.6</td>
<td>100</td>
<td>0.0168</td>
<td>0.0</td>
<td>0.78</td>
</tr>
<tr>
<td>Leucaena</td>
<td>28.5</td>
<td>33.7</td>
<td>34.8</td>
<td>68.5</td>
<td>0.0680</td>
<td>0.0</td>
<td>1.60</td>
</tr>
<tr>
<td>Star grass hay</td>
<td>20.9</td>
<td>13.6</td>
<td>38.7</td>
<td>52.3</td>
<td>0.0341</td>
<td>6.1</td>
<td>1.29</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum grain</td>
<td>22.1</td>
<td>34.1</td>
<td>81.9</td>
<td>100</td>
<td>0.0243</td>
<td>0.0</td>
<td>0.68</td>
</tr>
<tr>
<td>Leucaena</td>
<td>39.1</td>
<td>29.4</td>
<td>55.6</td>
<td>85.0</td>
<td>0.1015</td>
<td>1.9</td>
<td>2.82</td>
</tr>
<tr>
<td>Star grass hay</td>
<td>42.8</td>
<td>25.2</td>
<td>38.7</td>
<td>63.9</td>
<td>0.1044</td>
<td>5.8</td>
<td>1.80</td>
</tr>
</tbody>
</table>

* a and b = Fitted values in the equation \( y = a + b(1 - \exp^{-t}) \), A = washout losses, T = lag time.

8). The mean substitution rate was 0.59. However, the total DM intake of L2 was significantly \((P<0.01)\) greater than for L1 by 1.22 kg/day. Intake of SG hay by the calves was significantly \((P<0.001)\) greater for 2×AM than 1×PM, but there was no effect of cow supplementation level.

4. Discussion

The experiment investigated two levels of supplementation, two milking and partial suckling regimes, and their effect on cow and calf performance. The supplementary levels were offered in addition to a

Table 8
Mean feed DM intake of cows and calves (kg/day)

<table>
<thead>
<tr>
<th></th>
<th>2×AML1</th>
<th>2×AML2</th>
<th>1×PML1</th>
<th>1×PML2</th>
<th>sed</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cows</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay DM</td>
<td>7.81</td>
<td>6.19</td>
<td>7.98</td>
<td>6.15</td>
<td>0.345</td>
<td>NS</td>
</tr>
<tr>
<td>Leucaena DM</td>
<td>1.08</td>
<td>2.02</td>
<td>1.06</td>
<td>2.11</td>
<td>0.069</td>
<td></td>
</tr>
<tr>
<td>Sorghum DM</td>
<td>1.76</td>
<td>3.52</td>
<td>1.76</td>
<td>3.52</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>Molasses DM</td>
<td>0.19</td>
<td>0.38</td>
<td>0.19</td>
<td>0.38</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Total DM</td>
<td>10.84</td>
<td>12.12</td>
<td>10.99</td>
<td>12.16</td>
<td>0.330</td>
<td>NS</td>
</tr>
</tbody>
</table>

** Calves** |        |        |        |        |       |              |
| Hay DM   | 0.58   | 0.49   | 0.41   | 0.34   | 0.039 | ** NS        |

**2× vs. 1×, L1 vs. L2**
basal diet of SG hay offered ad libitum. The two milking regimes had previously been shown to favour either cow (2 × AM) or calf (1 × PM) performance (Sandoval-Castro et al., 1999).

4.1. Response to supplements

Total DM intakes of cows were lower than in the experiment of Sandoval-Castro et al. (1999). For L1 and L2 levels, respectively, they were 2.48 and 2.74 kg DM/100 kg liveweight. The substitution rate of 0.59 of supplement for SG hay when comparing L2 with L1, reduced the potential effect of supplementation on total DM intake (Table 8). The additional supplement from L1 to L2 feeding level of 2.95 kg DM/day resulted in an increase of only 1.22 kg DM day in total. The relatively high substitution is surprising in view of the low estimated DM digestibility of the SG hay of 457 g/kg DM.

The total diets were low in both ME and MP contents. The estimated values for 2 × AML1, 2 × AML2, 1 × PML1 and 1 × PML2, respectively were for ME, 8.0, 9.1, 8.0 and 9.2 MJ/kg DM and for CP, 87, 104, 86 and 106 g/kg DM. It might have been expected that the three supplements averaging 11.7 MJ ME/kg DM and 151 g CP/kg DM would have been beneficial to rumen conditions. Leucaena constituted 36% of the supplement and has been claimed to improve the rumen environment by providing additional N for the rumen microbes, thus increasing the rate of clearance of the rumen (Bamualim et al., 1984). It has been also suggested that leucaena may increase the amount of amino acids available at intestinal level, which in turn stimulates DM intake and milk yield (Flores et al., 1979). The leucaena degradability values were within the range found in the literature (Fekadu et al., 1994). Nevertheless, the relatively high NDF and ADF content of the leucaena may have been the cause of the relatively high substitution rates.

The increase in total DM intake of 1.22 kg DM/day produced an increase in total ME intake of 24 MJ/day. However, the response in total milk yield (TMY) of 0.72 kg/day represents a response of only 0.25 kg milk/kg supplement DM. This is greater than the response of 0.20 for cottonseed and 0.07 kg milk/kg DM found for molasses by Osuji et al. (1995), but less than responses of 0.80 and 0.46 kg milk/kg DM found by Musinga et al. (1992, 1995).

There were no significant effects of supplement level on TMY milk composition although both fat and protein contents were higher for L2 than L1 across both milking/suckling regimes. Consequently both fat and protein yields were significantly increased by L2, which is consistent with the effects of an increase in energy supply.

A nutritional balance of the cows (Table 9) indicated that the ME intake of treatments was 4 to 13 MJ/day greater on average than the estimated ME requirements. The difference could be due to an underestimation of ME requirements or overestimation of ME intakes. There are problems in estimating requirements for liveweight change due to difficulties of measuring cow liveweight change over short periods which are confounded by short-term changes in body water content and gut fill. Nevertheless a significant increase in liveweight change from L1 to L2 was shown (Table 5), indicating that a proportion of the extra ME intake had been partitioned to body weight. It is also possible that ME intakes were overestimated due to overestimation of the ME values of the feeds. Protein supply did not appear to be limiting performance in spite of the low CP content of the diets (87 and 105 g CP/kg DM for L1 and L2, respectively).

The increase in supplementation level from L1 to

| Table 9 | Metabolisable energy (ME) and metabolisable protein (MP) balance of cows |
|-----------------|------------------|------------------|------------------|------------------|
|                | 2 × AML1 | 2 × AML2 | 1 × PML1 | 1 × PML2 |
| ME requirement (MJ/day) | 83       | 100     | 79      | 98      |
| ME intake (MJ/day)    | 87       | 111     | 88      | 111     |
| Difference (MJ/day)   | +4       | +11     | +9      | +13     |
| MP requirement (g/day) | 470   | 590     | 460     | 590     |
| MP intake (g/day)     | 560      | 780     | 560     | 780     |
| Difference (g/day)    | +90      | +190    | +100    | +200    |
L2 significantly increased SMY, and saleable milk fat and protein yield. Milk composition of CSM was not significantly affected by feeding level, although both fat and protein contents tended to be higher at L2 level. Tegegne et al. (1994) and Little et al. (1994) showed that when cows were supplemented, the calves suckled more residual milk which is higher in fat content.

The amount of milk consumed by the calves was within the normal range for tropical conditions (Ugarte and Preston, 1972; Ugarte, 1976). CSM increased from L1 to L2 but the difference was not significant. The lack of significance may have been due to the method used to estimate CSM, which may not have been sensitive enough to determine significant differences, possibly due to the infrequency of the estimations (3 days in the final week of each period). The weigh–suckle–weigh method has been shown to be an accurate means of estimating CSM, providing losses due to urinations and defaecations are taken into account. Neidhardt et al. (1979) estimated these losses to account for 0.21 kg milk/day. In this experiment with once daily suckling, urination and defaecation occurred on about half of suckling occasions and CSM was adjusted accordingly. This accounted for an average of 0.13 kg CSM/day. The liveweight gains of calves showed a significant response to level of supplementation which indicates that effects on milk intake almost certainly had occurred.

### 4.2. Response to milking/suckling regime

There was no significant effect of milking/suckling regime on cow DM intake. This was probably due to the nutrient demand of cows on both regimes being similar, as indicated by similar TMY and liveweight changes.

The TMY at any particular feeding level, will be influenced by the degree of mammary gland emptying and the consequent residual milk remaining. The less residual milk removed, the higher will be the concentration of the feedback inhibitor of lactation (FIL) in the alveoli, which adversely affects the milk secretion rate (Wilde and Peaker, 1990). In both milking/suckling regimes, residual milk was removed once daily by the calf. This would have occurred at suckling following the morning milking for 2×AM, and at suckling in the afternoon for 1×PM. For both the afternoon milking of 2×AM, and the morning milking of 1×PM there would probably have been incomplete milking by the milking machine (Sandoval-Castro et al., 1999).

The proportion of the TMY removed as SMY or CSM was significantly affected by milking/suckling regime. SMY was significantly reduced, but CSM significantly increased by the 1×PM regime compared with 2×AM. This response is due to the calves on 2×AM having only the residual milk from the morning milking to suckle, whereas the calves on 1×PM had the morning residual milk plus the milk secreted between a.m. and p.m. milkings to suckle.

The fat content of saleable milk was lower (82% of TMY) than for total milk yield. This compares with 72% reported by Sandoval-Castro et al. (1999), and confirms that the removal of residual milk by the suckling calf reduces the fat content of saleable milk (Boden and Leaver, 1994). The fat content of milk was higher post-suckling than pre-suckling as reported previously (Sandoval-Castro et al., 1999). The lower fat content pre-suckling of the 1×PM regime compared with 2×AM was probably due to this being cisternal milk. For 2×AM post-milking, the pre-suckling milk would have been alveolar milk, which is higher in fat content than cisternal milk (Ugarte, 1977). The post-suckling milk on both regimes would have been residual alveolar milk, high in fat content. Milk protein content of the SMY was significantly greater for 1×PM compared with 2×AM, and there was a tendency for protein content to be greater in the CSM. There does not appear to be a clear explanation for this difference. The yield of fat, protein and lactose was significantly greater for the 2×AM saleable milk due to greater weight of milk removed on this regime. These results are consistent with the findings of Sandoval-Castro et al. (1999) for crossbred cows milked with the calf present.

### 5. Conclusions

The response in total DM intake and total milk yield to a supplement of leucaena, sorghum grain and sugar-cane molasses was low (0.41 kg DM and 0.25 kg/day per kg supplement DM, respectively). It
is not clear why the responses were so low as the extra supplement should have enhanced rumen microbial conditions and nutrient supply. There is a clear need for research into tropical feed supplementation both at rumen level, and at feeding strategy level.

The comparison of milking/suckling regimes confirmed that different regimes can be used to manipulate the yield and composition of saleable milk production and calf growth. Milk fat content of saleable milk was reduced by 18% on average due to the effect of suckling. There were no significant interactions between supplementary feeding and milking/suckling regime. The results demonstrate how feeding, milking and suckling regimes provide a means for smallholder farmers through management, to change outputs in order to meet variable market demands for milk and meat.

Acknowledgements

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