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Full Length Research Paper

Day-to-day variation in yield, composition and somatic cell count of saleable milk in hand-milked zebu dairy cattle

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The aim of the study was to determine the relative day-to-day variation in yield and composition of zebu cows. Ten multiparous zebu cows in day 41 ± 1.6 of lactation were used in the study. After a 14 day adaptation period, milk production was recorded daily for four consecutive weeks. Cows had access to natural pasture for 6.5 h per day and were also supplemented with hay, cottonseed cake and molasses. The cows were hand-milked and calves were used to stimulate milk ejection before and during milking. Average yield of saleable milk was 2.08 ± 0.23 l/day with a relative day-to-day variation of 18 -21%. The variation of saleable milk was 23 - 25% for fat, 12 - 14% for protein, 6% for lactose and 8% for somatic cell count. The variation in fat content was higher in strip milk (19 - 46%) than in saleable milk. The results indicated a larger variation in composition of milk from hand-milked *Bos indicus* Zebu than from machine-milked *Bos taurus* cows. The most likely reasons for the difference in variation are the suckling by the calf and that hand-milking entails larger variation in the degree of emptying machine-milking does.

Key words: Zebu, cow, milk, day-to-day variation, milk composition.

INTRODUCTION

Improving milk production remains a challenge for tropical and developing countries. Several studies have been done on zebu cattle with the ambition of increasing milk production by improved feeding and management (Coulibaly and Nialibouli, 1998; Bonfoh et al., 2005; Sidibé-Anago et al., 2006). An important management tool in dairy production is milk recording based on knowledge about the relative day-to-day variation in milk yield and composition.

The relative day-to-day variation in milk yield and milk composition for machine-milked dairy cows has been estimated to be about 6 - 8% for yield, 5 - 8% for fat content, 1.5 – 2% for protein content and just above 1% for lactose (Syrstad, 1977; Sjaunja, 1986). According to the same authors, the variation can be explained by the stage of lactation, parity, health, season and milking interval. The degree of udder emptying also has a strong effect on milk fat content since fat content increases during milking (Johansson et al., 1952). Protein content is less variable than fat content and lactose is the most constant constituent due to its osmotic regulatory effect (Svennersten-Sjaunja et al., 1997). The day-to-day variation in milk somatic cell count (SCC) has been estimated to be on average 9% for healthy cows and 7% for mastitic cows (Sjaunja, 1986).

Day-to-day variation is mainly described in dairy cows in machine-milking systems; there is a lack of information about other species and hand-milking systems. One example is zebu cows which are important in most West African countries and in many other arid parts of the world. Zebu cattle are hand-milked and calves are used for the stimulation of milk ejection. Restricted suckling by the calf during or after milking is a common practice in many tropical countries and a series of advantages with restrict-

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Table 1. Composition of diet fed in addition to natural pasture.

	DM[1)] (kg/day)	ME (MJ/day)	CP (g/day)
Grass hay	4.00	32.00	240.00
Cottonseed cake	1.50	15.45	487.50
Molasses	0.50	6.35	8.20
Total	7.00	53.80	735.70

1) DM = dry matter, ME= Metabolized Energy MJ = Mega Joule, CP = Crude Protein.

ed suckling has been reported (Combellas and Tesorero, 2003). One example is that suckling before milking or suckling and calf presence during milking, increased the yield of saleable milk and at the same time allowed a higher calf live weight gain. Lupoli et al. (2000) observed that suckling compared to machine milking gives a higher milking-related oxytocin release. Oxytocin is the hormone that is involved in milk let-down (Bruckmaier and Blum, 1998) and a higher oxytocin release allows a more efficient emptying of the udder which often stimulates a higher milk production.

In order to improve dairy production in developing countries, basic information about variation in milk production is necessary. The aim of the present experiment was to study the variation in milk yield, milk composition and SCC of local zebu dairy cattle in Burkina Faso, exposed to local milking management including calf stimulation of milk let-down, hand-milking and restricted suckling after milking.

MATERIALS AND METHODS

The experiment was conducted in Burkina Faso at the research centre "Institut de l´Environnement et de Recherches Agricoles" (IN.E.R.A) outside Bobo-Dioulasso. It lasted from February to May 2007, which was in the dry season of the climate in Burkina Faso. Ten multiparous local zebu cows (*Bos indicus*) were used. At the onset of the trial they were in day 41 ± 16 of lactation and weighed between 228 – 296 kg.

Experimental design

The experiment started with a 14 days adaptation period during which experimental diets (Table 1) and milking routines were introduced. After the adaptation period, a 30 days registration period followed. Each cow was inserted in the experiment according to calving date.

Diets

Cows had access to natural pasture for 6.5 h per day, 4 h in the morning and 2.5 h in the afternoon. In addition, each cow was fed hay (4 kg/day), cottonseed cake (1.5 kg/day) and molasses (0.5 kg/day) (Table 1) throughout the experiment. Diet formulation was based on calculated nutrient requirements for 250 kg BW and a daily milk yield of 7 kg, requiring a dietary intake of 875 g/day crude protein and 69.1 MJ/day metabolised energy (Chamberlain, 1989), in order to ensure that nutrient intake did not limit milk yield during the study. Chemical analyses of the feeds and calculations of nutrient content were made according to NRC (1978). The cows had limited access to salt and mineral stone, which was offered one day per month according to normal management in the barn. Water was offered four times a day, *ad libitum* from a large water tub shared by all cows.

Milking routines

The cows were hand-milked twice daily; at 7.30 am and 5.00 pm. Milking was performed by the same two persons throughout the experiment in accordance with normal milking management at the experimental farm. The milking routine began with cleaning the teats with water and then drying them with a towel. After teat cleaning, each cow's own calf was used for stimulation of milk ejection. The calves were allowed suckle all four teats during pre-stimulation. Time for calf stimulation of udder was measured with a stop-watch. After stimulation the milker tied the calf near his mother and started milking. If milk flow stopped before the udder was considered to be empty the calf was used for a short time again, to stimulate a new milk ejection. The cows were fed cottonseed cake during milking. After milking the calf was allowed to suckle the residual milk. After morning milking and suckling the cows were let out on pasture without calves and similarly the calves were separated from their mothers again after evening milking and suckling and were kept apart from the cows during the night.

Registrations and collection of milk samples

The milk yield from each individual cow was recorded on every milking occasion, six days per week during the experimental period. A 2000 ml test tube was used when comparing volume measurement with milk weight (Electronic Balance Sartorius Ip 6200, d = 0.1 g). The milk was then mixed before a 50 ml milk sample was taken to determine the composition of saleable milk. SCC was determined in morning milk samples taken from the bucket milk, representing the saleable milk from all four udder quarters. Furthermore, 10 ml strip milk sample was taken from each teat separately just after milk-ing in the morning; this was done before calves were allowed to suckle post-milking. Milk samples were stored at +4°C for one day before being analysed.

At each milking both the time of calf stimulation of the udder before and during milking and the time needed for milking were recorded using a stopwatch. The time that calves spent suckling after milking was not recorded. It was noted which of the two milkers that performed each milking.

Milk analyses

The concentration of fat, protein, lactose, dry matter and solids non fat (SNF) in the milk was determined with mid infra-red spectroscopy (FMA 2001, Miris AB, Uppsala, Sweden). SCC was determined in morning milk with a fluorescent method (DeLaval Cell Counter, DeLaval, Tumba, Sweden).

Data management and statistical analysis

The data on whole udder milk yield, milk composition and SCC as well as data on calf stimulation time were analyzed using the following model:

Table 2. The relative day-to day variation (CV) in milk yield, milk composition and milk somatic cell count (n=10), results are expressed as means and Standard error of mean. CV = Coefficient of Variation; Std Err = standard error of the mean.

	Morning milking			Evening milking		
	Means ± Std Err	**CV (%)**	**Sign effect of day**	**Means ± Std Err**	**CV (%)**	**Sign effect of day**
Milk yield (L)	1.30 ± 0.10	20.78	0.31	0.8 ± 0.08	18.42	0.03
Fat (%)	4.88 ± 0.25	23.23	0.00	5.52 ± 0.25	24.85	0.41
Protein (%)	3.46 ± 0.06	12.47	0.03	3.35 ± 0.07	14.33	0.00
Lactose	4.84 ± 0.03	6.65	0.22	4.73 ± 0.03	6.80	0.02

CV = Coefficient of Variation; Std Err = standard error of the mean.

$y_{ijt} = \mu + c_i + m_j + d_t + e_{it}$ where c_i, $i = 1...10$ $N(0, \sigma_c^2)$, is random effect of cow *i*, m_1, m_2 are the effects of milkers, d_t, $t = 1,..., 26$, are the effects of days. The normally distributed residual errors e_{it} are assumed to be independent among cows but dependent within cows according to an autoregressive structure, that is, with correlation $\rho(e_{it}, e_{iu}) = \rho^{|t-u|}$. The numerical value of the coefficient of variation (CV) was obtained by inserting estimated values into $CV = \sigma_e / (\mu + \overline{m}. + \overline{d}.)$ where $\overline{m}. = (m_1 + m_2)/2$ and $\overline{d}. = (d_1 + ... + d_{26})/26$ denote the average effects of milkers and days respectively. The analyses were performed on the whole data set and also on sub-sets of data from samples with SCC above or below 200,000 cells/ml. The threshold was set at this level based on Harmon (1994), who has suggested that the threshold level of 200,000 cells/ml could be used to separate healthy udders from mastitic udders.

Furthermore, descriptive statistics were performed for data on milk fat content in strip milk from separate udder quarters. These calculations gave data for the determination of CV for udder of each cow.

RESULTS AND DISCUSSION

The daily milk yield found in this study was 2.08 ± 0.23 L/cow, which is similar to that reported in zebu cows by Sidibé-Anago et al. (2006). The relative day-to-day variation in milk yield was 18 and 21% during evening and morning milking respectively, which is larger than the variation reported in machine-milked dairy cows (Gilbert et al., 1972; Gonzalo et al.,1994; Svennersten-Sjaunja et al., 1997). This is not surprising since the termination of the milking occasion and thereby the degree of emptying of the udder is more standardized in machine-milking than hand-milking. The restricted suckling applied in the management system in the current study probably also causes variation in yield between days. Milk yield decreased by 15% during the 30 days experimental period, shown as an effect of day ($P < 0.04$). The current study focused on the volume of saleable milk; the milk volume suckled by the calf was not included. Sidibé-Anago et al. (2006) aimed at determining the total milk volume and therefore included milk suckled by calf. It is likely that variation in the volume of milk suckled by the calf had a significant impact on the daily variation in saleable milk yield in the current study.

The fat content (Table 2) is in line with previous studies on zebu cows (Coulibaly and Nialibouli, 1998; Sidibé-Anago et al., 2006). However, relative day-to-day variation in fat content has not previously been investigated in Zebu cattle and the values found in the current study (23.50% in the morning and 24.90% in the evening) are far greater than what has been reported in *Bos taurus* dairy cows (Syrstad, 1977; Sjaunja, 1986). The large variation in fat content is probably an effect of calf suckling and variation in degree of udder evacuation, since milk fat content increases during udder emptying (Johansson et al., 1952).

The correlation between milk fat content and degree of udder emptying has not been established in the Zebu; however milk fat content in samples obtained after milking showed a large variation in the degree of udder emptying from cow to cow in the present study (Table 3). Fat content in strip milk ranged from 5.8 to 10.3% among individual cows. Furthermore, there was a large relative variation in milk fat content within the udder for each cow, between 19.5 and 45.7%, indicating differences in udder emptying between quarters. It is well known that fat content increases during milking (Johansson et al., 1952) and this is also shown in Tables 2 and 3 where the fat content in strip milk is higher than in saleable milk. The values obtained for fat content (Table 3) in post-milking strip samples were lower than those reported in *B. taurus* dairy cows (Svennersten et al., 1990). Knowledge of degree of udder emptying can be useful in studies in which milking techniques are evaluated or calf milk consumption is estimated. Further investigations are necessary in order to establish the efficiency of udder emptying in hand-milking systems.

The milk protein content measured in this study was similar to what has been reported previously in zebu cattle (Bonfoh et al., 2005; Sidibé-Anago et al., 2006; Millogo et al., 2008). The relative day-to-day variation in milk protein content was 14% in saleable milk (Table 2), which is higher than reported in other studies (Gilbert et al., 1972).

Table 3. The relative day-to-day variations for udder strip milk fat content for each cow.

Dairy cows	1	2	3	4	5	6	7	8	9	10
Fat (%) Std Err	6.68± 0.14	5.80± 0.20	9.27± 0.19	6.63± 0.32	10.28 ± 0.20	7.77± 0.19	6.02± 0.14	7.05± 0.15	7.10± 0.29	4.49± 0.16
CV (%)	20.61	35.34	19.51	45.77	19.66	24.15	22.70	22.47	40.70	34.73

The large difference in day-to-day variation in lactose; 6 - 8% in the current study compared to 1 – 2% in other studies (Sjaunja, 1986) was unexpected and could indicate a disturbance in milk synthesis or impaired integrity of the mammary epithelium. Leakage of lactose across the epithetlium could be shown by determining lactose content in blood or urine; however this was not included in the current study. It has been observed that lactose content decreases even for small increases in SCC (Berglund et al., 2007).

The relative day-to-day variation of SCC was 7.8% with SCC (Log_{10}) = 5.13 ± 0.13 as average. SCC differs in the different milk fractions. Milk yield, milk fat content and lactose content were higher in samples with SCC <200,000 cells/ml, compared to samples with SCC ≥ 200,000 cells/ml (Table 4). In contrast, milk protein content was lower. The samples with SCC < 200,000 cells/ml also showed smaller variations of fraction, the lowest concentration in the first alveolar fraction; SCC levels are also higher during removal of the alveolar milk towards the end of milking (Sarikaya and Bruckmaier, 2006).

Therefore, the degree of udder evacuation influences SCC. Markedly high SCC values indicate that the udder is affected by mastitis. Furthermore, in the case of incomplete emptying, milk remaining in the udder increases the risk of mammary infection since the residual milk is an exquisite substrate for microbial growth (Bruckmaier and Wellnitz, 2008). In the current study, high SCC was linked to lower milk yield (Table 4). It is a well known fact that increased SCC is correlated to decreased milk yield (Harmon, 1994). The results of the current study are also in line with Juozaitiene et al. (2006), who reported lower milk production in cows with high SCC. The two fold increase in SCC above 50,000 cells/ml resulted in a milk yield loss of 0.4 kg/day in primiparous cows and 0.6 kg/day in multiparous cow. In low yielding cows, such as the Zebu, 0.6 kg is a serious loss (Tables 2 and 4). In general, variation in milk yield is linked to variation in milk composition (Yilma et al., 2006). The relative day-to-day variation in protein content was larger (15%) when SCC increased. Dang and Anand (2007) and Berglund et al. (2007) reported lower lactose content in connection with higher SCC which was also observed in Table 4 in the current study.

The time spent on calf stimulation of the udder has been estimated to vary from 60 s to more than 2 min (Bruckmaier and Blum, 1998). In the present study, average calf stimulation time was found to be 90 s (Table 5). The stimulation time was very similar in the morning and evening, showing that the milking routine was well established. The lag time from start of tactile teat stimulation until onset of milk ejection depends on the degree of udder filling (Bruckmaier and Hilger, 2001). Milking took longer in the mornings, 8.05 ± 0.13 min, than in the evenings, 7.48 ± 0.13 min (Table 5); however, milking was more efficient in the morning, 0.16 l/min than in the evening, 0.10 l/min. There was no difference between mornings and evenings in time of stimulation by calf for evoking milk ejection, which is interesting since it is known that a longer stimulation time is needed for milk ejection when the udder fill is low (Bruckmaier et al., 1994). It is possible that the milkers had a routine to let the calves suckle for a certain time, regardless of the effect on milk ejection. If so, our data does not show the actual udder stimulation time needed for milk ejection.

Table 4. Milk yield and milk composition in cows with SCC < 200 000 cells/ml and SCC ≥ 200 000 cells/ml. Results expressed as LS Mean, Std Err and CV.

Variables	LS Mean	Std Err	CV (%)
SCC < 200000 cells/ml			
Yield (L)	1.30	0.16	21.96
Fat (%)	4.97	0.26	20.28
Protein (%)	3.41	0.10	9.54
Lactose (%)	4.92	0.04	3.13
DM (%)	14.20	0.32	8.12
SNF(%)	9.14	0.11	6.12
SCC (Log 10) (cells/mlx1000)	4.82	0.06	4.89
SCC ≥ 200000 cells/ml			
Yield (L)	1.24	0.16	16.98
Fat (%)	4.67	0.35	26.53
Protein (%)	3.48	0.09	15.48
Lactose (%)	4.68	0.07	9.89
DM (%)	13.90	0.39	10.06
SNF(%)	8.99	0.08	6.19
SCC (Log_{10})Cells/mlx1000)	5.66	0.09	5.28

Table 5. Milking Time (s) and time used by calf to stimulate (TCS) milk let down.

	Morning milking			Evening milking		
	Means ± Std Err	**CV (%)**	**effect of day**	**Means ± Std Err**	**CV (%)**	**Sign effect of day**
Milking time (s)	483.17 ± 7.87	4.95	0.00	449.23 ± 7.90	12.17	0.00
TCS (s)	88.85 ± 3.76	23.53	0.00	88.24 ± 4.15	23.70	0.26

CV = Coefficient of Variation; Std Err = standard error of the mean.

Conclusion

The main finding in the current study is that the relative day-to-day variation in milk yield and milk composition is larger in hand-milked and restrictedly suckled zebu than in machine-milked dairy cows. Fat content was found to vary more than protein and lactose. SCC was linked to milk yield and composition and influenced the relative daily variation of milk components. The recording of daily milk yield and knowledge of the relative day-to-day variation in milk yield and milk composition can be a tool for farmers to monitor their cows during lactation; however, more data on zebu lactation is needed in order to design a milk recording system for these animals.

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