Trop Anim Health Prod (2015) 47:1095–1100
DOI 10.1007/s11250-015-0832-5

REGULAR ARTICLES

Effect of feeding strategies on weaning weight and milk production of Holstein × Zebu calves in dual purpose milk production systems

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Received: 13 November 2014 / Accepted: 15 April 2015 / Published online: 26 April 2015

Abstract The objective of this study was to evaluate the effect of five feeding strategies on calf weaning weight, and cow milk production and composition in Brazilian Holstein × Zebu cows. A total of 60 cows and their calves were allocated to each of five treatments. Cows in treatments 1, 2 and 3 were milked for 270 days and cows in treatments 4 and 5 were milked for 180 days. Calves in treatment 1 (CON) were not supplemented with concentrate whereas calves from treatment 2 (CLPN) received 1 kg of concentrate daily from 90 to 270 days of age and calves from treatment 3 received 1 kg of concentrated from 180 to 270 days of age. Calves in treatment 4 (CCPS) were supplemented with 1 kg of concentrate from 90 to 180 days of age and calves in treatment 5 (CLPS) were supplemented with 1 kg of concentrate from 90 to 270 days of age. Calves from the CLPS treatment had greater milk and protein intakes ($P<0.05$) and greater growth rate than calves from the other treatments. Our results indicate that the traditional system of feeding calves with no concentrate results in a weight gain of 600 g/day. The CLPS treatment produced calves with the highest live weight and growth rate. The nutritional strategy with restricted supply of milk for the calves with concomitantly short-term concentrate supplementation does not improve performance of calves but did increase feed costs.

Keywords Concentrate supplement · Crossbred cattle · Nutrient intake · Performance · Short-term lactation

Introduction

Crossbreeding Holstein bulls with Zebu cows has been used to improve milk production in tropical areas and commonly from dairy systems that explore dairy-meat dual purpose. However, although feeding management of calves in high-technology dairy production systems has been widely investigated (Huber et al. 1984; Miller-Cushon et al. 2013), there is a lack of information regarding the feeding management dual purpose production systems.

Holstein × Zebu dairy cows have low milk production lactation persistency (Santos et al. 2014). Additionally, differently to what is commonly observed in intensive dairy cattle production systems where calves are commonly separated from dams within 1 to 3 days after birth, crossbred Zebu cows require the presence of their calves during milking to stimulate the milk flow from the mammary gland (Junqueira et al. 2005). Thus, supplementation of calves with concentrate seems to be an interesting strategy as calves will become less dependent on milk leading to an improvement of calves performance and milk production by the dams.

Five supplementation strategies were evaluated to determine the best feeding management to improve calves performance.

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Material and methods

Experimental design and animal management

The experiment was performed at the *Empresa de Pesquisa Agropecuária de MInas Gerais*, Felixlândia, Brazil. All animal procedures were approved by the Animal Care and Use Committee of the Department of Animal Science from *Universidade Federal de Viçosa*, Brazil.

Milk production was measured in F1 Holstein×Zebu cows grazing Brachiaria pasture. Cows were milked twice a day and naturally mated with beef Zebu bulls. The feeding of calves was composed of the milk consumed before (stimulus for milk flow) and after (residual milk) cows were milked. Sixty F_1 Holstein×Zebu multiparous cows of fifth and sixth lactation were allocated to one of the five experimental treatments. Each treatment had a total of 12 calves with 5 females and 7 males.

The experimental period started when calves reached 90 days of age. Cows were kept with their respective calf (3/4 Zebu 1/4 Holstein) in a dual purpose milk and meat production system. The strategy short period of cows in milking of 180 days (S) and a normal of 270 days (N) were evaluated. Milk production was individually measured every 15 days through an automatic milking system. The characterization of treatments is shown in Table 1.

Concentrates were formulated based on corn and soybean meal. A mineral mixture was offered ad libitum. The chemical composition of experimental concentrate and Brachiaria grass are presented in Table 2.

Data collection

To estimate the milk intake by calves, cows received 1 mL of oxytocin after milking and the remaining milk was quantified (Mendoza et al. 2010). Milk samples were collected in each experimental period before and after milking the cows to characterize the milk consumed by calves. The concentrations of fat, crude protein (CP), lactose (Lac), total solids (TS), and somatic cell count (SCC) in milk were determined as described by the International Dairy Federation (1996). Milk intake by calves before milking the cows was obtained by the difference of milk production after administration of oxytocin (without calf) and by milk production with stimulus of the calf during milking of the cows. The intake of residual milk by calves was obtained after the milking cows when 1 mL of oxytocin was administered and cows were immediately re-milked.

To estimate the pasture intake by the calves, a composed sample of pasture was obtained from samples collected at the first and last week of each 30-day period as described by McMeniman (1997). Faeces production of calves was estimated by using titanium dioxide as external indicator. A total of 10 g of titanium dioxide was administered once a day during 7 consecutively days. Faeces samples were collected directly

Table 2 Chemical composition of Brachiaria grass and experimental concentrate

	Period of 30 days						Concentrate
	1	2	3	4	5	6	
DM (%)	26.0	26.0	25.0	26.0	26.0	28.0	87.9
OM[a]	95.3	94.0	94.8	93.0	93.4	93.5	94.3
CP[a]	6.0	8.5	9.6	9.4	11.0	10.2	23.0
NDFap[a]	62.3	50.3	48.5	55.9	57.2	55.6	17.0
EE[a]	2.0	2.3	1.6	0.7	0.8	1.10	1.5
NFC[a]	25.0	32.9	35.1	27.0	24.4	26.6	52.7
NDFi[a]	21.0	16.0	14.0	14.0	17.0	17.0	2.5

[a] Percent on DM

Table 1 Characterization of experimental treatments

Items	Experimental treatments				
	CON[a]	CLPN[b]	CCPN[c]	CCPS[d]	CLPS[e]
Number of cows	12	12	12	12	12
Number of calves	12	12	12	12	12
Period length (days)	270	270	270	180	180
Calves kept with their mothers (age)	–	–	–	180 a 270	180 a 270
Concentrate supplementation (kg/day)	0	1	1	1	1
Period of supplementation (days)	–	90–270	180–270	90–180	90–270

[a] *CON* control treatment

[b] *CLPN* supplementation with concentrate for a long period

[c] *CCPN* supplementation with concentrate for a short period

[d] *CCPS* supplementation with concentrate for a short period and cows milked for 180 days

[e] *CLPS* supplementation with concentrate for a long period and cows milked for 180 days

from the rectum throughout the last 3 days of titanium oxide administration at different periods: day 1 at 6, 12 and 16 h; day 2 at 8, 14 and 18 h; and day 3 at 7, 13 and 17 h. Faeces samples were dried in a forced air oven. Concentration of titanium dioxide was determined as described by Myers et al. (2004). Faecal excretion was calculated by dividing the amount of titanium oxide offered by its faecal concentration.

Quantification of indigestible neutral detergent fibre (NDFi) in faeces, concentrate and forage samples were performed by using Ankom F57 filter bags (Ankom Tech Corp, Fairport, NY). Samples in filter bags were incubated for 264 h in the rumen of fistulated calves (Casali et al. 2008). After incubation, the remaining material was rinsed under tap water prior to NDF analysis. The residue of NDF analysis of the incubated samples was considered NDFi. Roughage intake was calculated by dividing the total excretion of NDFi minus the intake of NDFi from concentrate by the concentration of NDFi in the forage.

Analysis of dry matter (DM) (method 930.15), ashes (method 942.05), ether extract (EE) (method 2003.05), and CP (method 990.09) was performed as described by AOAC (2000). Analysis of neutral detergent fibre corrected for ashes and protein (NDFap) was performed as described by Mertens (2002) by using alpha-amylase without sodium sulphite. Neutral detergent-insoluble nitrogen was evaluated by Kjeldahl method (Licitra et al. 1996). Non-fibre carbohydrates (NFC) were calculated according to the equation described by Detman and Valadares Filho (2010): NFC=100−(%CP+% NDF+% EE+% ashes).

Statistical analysis

All statistical analyses were carried out using SAS (Statistical Analysis System, version 9.3; SAS Institute Inc., Cary, NC, USA). Data from the calves were analysed using a mixed linear model that included the fixed effects of treatment and sex of calf and the random effect of calf to account for repeated measures. Similarly, data from cows were analysed with a mixed linear model that included the fixed effects of treatment and sex of calf and the random effect of cow to account for repeated measures on the same animal. A compound symmetry structure was used to model the structure of the matrix of residuals. The degrees of freedom were estimated according to the Kenward-Roger criteria and means were compared using the Fisher's least significant difference test. Differences between means were declared significant at $P<0.05$. Traits that were measured only once in the cows or calves were analysed with a linear model that included the fixed effects of treatment and sex of calf. Somatic cell count was analysed as somatic cell score (SCS) calculated as $SCS=Log_2(SCC)$.

Results

Nutrients intake and animal performance

Similarly, the intake milk levels of fat, CP and Lac, TMS and SCS were similar ($P>0.05$) among calves from experimental treatments, before and after milking cows (Table 3). Calves from CCPS and CLPS strategies had a greater daily milk intake than calves from CON, CLPN and CCPN ($P<0.05$; Table 4). Calves from CON and CCPN groups had the lowest intake of DM, NFC, TDN (kg day), and DE (Mcal day) ($P<0.05$). Calves from CLPN had a greater average daily intake of forage and NDFap (kg day) ($P<0.05$) than calves from CCPN and CCPS treatments, and similar values ($P>0.05$) compared to calves from CLPS treatment. The use of CCPS nutritional strategy decreased ($P<0.05$) the protein intake compared to CLPS (Table 4). The calves from CLPS nutritional strategy resulted in highest ($P>0.05$) protein intake (Table 4). The intake of forage (g/kg of body weight) of calves did not differ ($P>0.05$) among CON and CCPN treatments. The calves from the CON treatment had a greater average daily intake of forage in g/kg of body weight ($P<0.05$) than calves from the CLPN, CCPS and CLPS treatments.

The cows from the CCPS and CLPS strategies had the lowest ($P<0.05$) total milk production per lactation but the highest ($P<0.05$) daily milk production (Table 5) because these cows were milked for a shorter period than cows from the other treatments.

The CCPN treatment produced calves of similar weaning weight as calves from CON group, but decreased ($P<0.05$) average daily gain, and weaning weight compared to calves from CLPN, CCPS and CLPS (Table 5).

The growth rate and weaning weight of calves did not differ ($P>0.05$) among calves from CLPN and CCPS treatments. The calves from CLPS treatment resulted in the highest ($P>0.05$) live weight gain and weaning weight (Table 5).

Discussion

Nutrients intake by calves and performance

An increase of forage intake is observed when calves have a restricted access to milk (Ansotegui et al. 1991). This was observed in this study when concentrate was not supplemented (CON) leading to a greater increase of forage intake by the calves.

The composition of the milk intake by calves before and after milking (fat and crude protein) affects the calves' growth rate and weaning weight. In the CON group, milk contributed with 158-g CP and 353-g fat to the total daily intake of calves, which represent 31 and 150 % (or 50 % more than the required) of the nutritional requirements for protein and fat

Table 3 Milk composition and intake by the calves before and after milking the cows

	Experimental treatments						
	CON[a]	CLPN[b]	CCPN[c]	CCPS[d]	CLPS[e]	SEM	*P* value
Milk composition (%)							
Fat before milking	4.35	3.98	4.16	4.06	4.12	0.16	0.055
Fat after milking	9.70	9.82	9.72	10.4	10.3	0.16	0.876
CP before milking	3.36	3.27	3.36	3.28	3.37	0.07	0.857
CP after milking	2.95	2.87	2.91	3.01	2.91	0.11	0.912
Lac before milking	4.62	4.62	4.64	4.60	4.60	0.03	0.880
Lac after milking	4.27	4.27	4.28	4.01	3.97	0.06	0.232
TMS before milking	13.1	13.0	13.0	12.6	12.7	0.61	0.078
TMS after milking	17.6	17.6	17.8	18.3	18.1	0.80	0.549
SCS before milking	6.03	5.28	5.70	5.40	6.18	0.50	0.610
SCS after milking	8.50	7.87	8.20	8.10	8.41	0.60	0.132

SEM standard error of the mean

[a] *CON* control treatment

[b] *CLPN* long period of concentrate offer

[c] *CCPN* short period of concentrate offer

[d] *CCPS* short period of concentrate offer and cows milked for 180 days

[e] *CLPS* long period of concentrate offer and cows milked for 180 days

based on requirement values calculated by Fonseca et al. (2012). Therefore, for Zebu crossbred calves that are able to achieve weaning weight 240–270 lb, it is necessary to supplement them, via the use of concentrate from the third month of life or else use the strategy with a shorter milking period of cows, and to offer more milk to calves before weaning.

The high-fat content in milk after milking of cows has been previously reported (Margerison et al. 2002). A possible

Table 4 Total milk production of the cows and nutrient intake by calves according to the nutritional strategies

	Experimental treatments						
	CON[a]	CLPN[b]	CCPN[c]	CCPS[d]	CLPS[e]	SEM	*P* value
Intake (kg/day)							
Total milk	5.02b	5.19b	5.02b	7.72a	8.19a	0.24	<0.001
Forage	1.79b	1.88a	1.69b	1.74b	1.80ab	0.28	<0.001
TDM	2.56c	3.22ab	2.56c	3.08b	3.42a	0.24	<0.001
CP	0.37d	0.53b	0.43c	0.49b	0.60a	0.20	<0.001
NDFap	0.91b	1.08a	0.92b	0.97b	1.00ab	0.28	<0.001
NFC	1.19b	1.63a	1.36b	1.63a	1.78a	0.40	<0.001
TDN	1.90a	2.37b	2.06a	2.34b	2.58b	0.32	<0.001
DE Mcal/day	8.08b	12.00a	10.34b	11.56a	12.41a	0.28	0.0143
Intake g/kg of body weight							
Forage	13.3a	11.2bc	12.4ab	11.5bc	10.8c	0.34	0.003
NDFap	6.78b	7.84a	7.36ab	7.06b	7.30ab	0.19	0.010
TDM	17.8b	20.5a	19.0ab	18.2b	19.1ab	0.50	0.004

SEM standard error of the mean, *Forage* DM of Brachiaria grass, *TDM* DM of milk plus DM of Brachiaria grass and concentrate

[a] CON control treatment

[b] CLPN long period of concentrate offer

[c] CCPN short period of concentrate offer

[d] CCPS short period of concentrate offer and cows milked for 180 days

[e] CLPS long period of concentrate offer and cows milked for 180 days

Table 5 Milk production of cows, weight gain and weaning weight of calves according to nutritional strategies

	Experimental treatments						
	CON[a]	CLPN[b]	CCPN[c]	CCPS[d]	CLPS[e]	SEM	*P* value
Cows							
Total milk production kg	3296a	3231a	3431a	2591b	2539b	0.21	<0.001
Milk production daily (kg)	12.2b	12.0b	12.7b	14.4a	14.1a	0.11	<0.001
Calves							
Weight gain (kg/day)	0.65c	0.81b	0.69c	0.91b	1.12a	0.06	<0.001
Weaning weight (kg)	200c	242b	210c	258b	270a	0.06	<0.001

SEM standard error of the mean

[a] CON control treatment

[b] CLPN long period of concentrate offer

[c] CCPN short period of concentrate offer

[d] CCPS short period of concentrate offer and cows milked for 180 days

[e] CLPS long period of concentrate offer and cows milked for 180 days

explanation is based on the increase of fat content during the removal of the socket fraction or due to the fact that fat droplets during milking may move slower than the aqueous phase of milk (Ontsouka et al. 2003).

The relationship between the milk production and protein content is curvilinear and depends on the stage of lactation and feeding level (Coulon and Remond 1991). The presence of somatic cells in milk is one of the main protecting mechanisms of the mammary gland against infections (Harmon 2001), but current evidence does not support this concept because cows have high levels of somatic cells at the end of the lactation without any infection (Jeffrey and Reneau 1986). Although somatic cell have no effect on the rate of growth of the calf, it was observed that the milk suckled after milking results indirectly in better quality milk to be commercialized due to the extraction of somatic cells by the calf.

As beef is one of the final products of the dual-purpose production system, the nutritional adequacy of the diets for crossbred dairy calves is necessary because the high weaning weight may lead to a production of high-quality carcasses (Menezes et al. 2014). In the present study, this was possible when calves had a high intake of milk associated with concentrate supplementation resulting in weaning weight ranging from 200 to 270 kg. The weaning weight observed in this trial shows the potential of these calves to be used for beef production being comparable to the average Brazilian calf weaning live weight of 153 kg (Souza et al. 2000).

Studies carried out in tropical areas show low average daily gain of calves (Bhatti et al. 2012; Das et al. 2000). However, the lactation curve of Zebu cows allows the adoption of different management strategies (Santos et al. 2014), since their reduced milking period allows the milk produced in late lactation to be consumed by the calves resulting in higher weaning weights.

Milking cows for only 180 days limits milk production and increases calf growth.

The benefits can be added on the farm management with increased of daily milk production and better economic and productive aspect of calves destined for market, favouring the two income sources for a dual-purpose system. The short lactation is also able to improve the use of labour during the 3 months that cows are not milked, because the workers may be used for other activities, and probably results in a lower cost of energy from the milking parlour and other equipment for milk harvesting.

Considering that the price of milk and meat are established according to fluctuations in the market supply, a reduction of milking period results in a decreased milk production and an increase of 26 % in live weight of calves at weaning. Milk production up to 180 days represented 78 % of total milk production in 270 days, while the remaining 22 % was used for growth of calves in the CCPS and CLPS nutritional strategies. The use of this system would be possible for cows having low production or rapid decline in milk production during late lactation to result in optimal partition of milk between calf and human consumption (De'Besi and Thieme 2013).

Conclusions

This study demonstrated that in dual-purpose cattle systems of Brazil, the weaning weight of crossbred calves can significantly be increased by concentrate supplementation of calves while also allowing calves to consume the milk directly from their mothers from day 180 to day 270 of the lactation of the cow. A further economic analysis is required to evaluate if this strategy results in higher farm profitability than the traditional production system as the potential milk sold in the market was significantly reduced because cows were machine milked only for 180 days.

Acknowledgment This research project was supported by the Fapemig, INCT de Ciência Animal and EPAMIG, Brazil.

Conflict of interest The authors have declared that no conflict of interest exists.

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