The effect of 2 liquid feeds and 2 sources of protein in starter on performance and blood metabolites in Holstein neonatal calves

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ABSTRACT

The aim of present study was to investigate the effect of 2 liquid feeds and 2 protein sources in starter on the performance and blood metabolite responses of Holstein neonatal calves from birth to 6 wk of age. Calves (20 males and 20 females) based on sex were randomly assigned to 4 treatments in a $2 \times 2 \times 2$ factorial arrangement, including soybean meal (SBM) and meat and bone meal (MB) with either fermented colostrum (or fresh milk. Although sex and liquid feed had no significant effect on feed intake, calves consumed more feed intake on the diet containing SBM (15 ± 0.2 kg) than MB (13 ± 0.2 kg) during the experimental period; also, weight gain was affected by both liquid feed and starter. Liquid feed and starter had significant effects on calf body size, including pin width, hip width, withers height, hip height, and stomach size, but no significant effects were observed on calf body size between the sexes. Plasma glucose concentration was not affected by sex, liquid feed, or starter. Plasma urea nitrogen concentration decreased in the first 3 wk and then started to increase during the last 3 wk, but it was only affected by starter and calves receiving SBM (10.18 mg/dL) had a higher concentration of plasma urea nitrogen than calves receiving MB (9.6 mg/dL) at the end of the experiment. Plasma growth hormone and insulin-like growth factor I concentrations decreased in all treatment groups from d 0 to the end of the study. No significant effects were observed on plasma growth hormone and insulin-like growth factor I concentrations between the 2 sexes, but they were significantly affected by both liquid feed and starter. Results of the present study provide useful information to apply to Holstein neonatal calves during the first 6 wk of life when liquid feed and 2 sources of protein in starter are considered.

Key words: calf, performance, blood metabolites, body size

INTRODUCTION

Calf health, growth, and productivity rely heavily on nutrition and management practices. Colostrum is the first milk produced after a normal dry period and mammary involution, or the first milk secreted by a heifer, and it is an essential part of a newborn calf's survival. Colostrum produced by dairy cows during the first 3 to 4 d postpartum is much more than can be utilized by the calf. In large dairy herds, surplus colostrum can be utilized by feeding it to all calves in the herd. However, surplus colostrum can remain if calving is not dispersed uniformly throughout the year. Colostrum can be stored by freezing without nutrient loss during storage (Foley and Otterby, 1978) or can be stored by fermentation. However, several problems, such as undesirable fermentation, excessive acidity, reduced acceptability by calves, or increased nutrient losses, were reported when colostrum was stored at warm ambient temperatures (Muller et al., 1976; Rindsig and Bodoh, 1977). Chemical additives have been used to control fermentation, especially at warm ambient temperatures.

Several researchers reported that weight gains for calves fed colostrum treated with propionic acid (Otterby and Linn, 1981), acetic acid (Polzin et al., 1976), lactic acid (Foley and Otterby, 1978), and formaldehyde (Jenny et al., 1977) were similar to weight gains calves fed fresh milk (FM) or naturally fermented colostrum (FC). In addition, newborn calves require both of liquid and dry feed to improve their performance and digestive tract. Barley, corn, and soybean meal (SBM) are typical ingredients in ruminant diets (Sahlu et al., 1984). Calves fed SBM-based diets performed about as well as or better than those fed other sources of protein (Muller et al., 1976; Chiba, 2001). It would be interesting, however, to know if alternative regional protein sources, such as meat meal, could replace soybean meal without any adverse effects on performance or body composition. On the other hand, the possible use of the animal waste products is of major importance, both in terms of maintenance of the environment and of economic meat production (Miller and De Boer, 1988). The feeding value of meat meal as a protein supplement for ruminants has been studied in relation to milk yield

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(Mäntysaari et al., 1989), calf growth (Leibholz, 1967; Leibholz and Moss, 1967; Khorasani et al., 1989), and in feed lot performance of steers and lambs (Stock and Klopfenstein, 1979; Loerch and Berger, 1981). However, none of these studies involved the effects of supplying meat meal on growth factors and body size of growing calves. The objective of this study was to determine the effect of 2 liquid feeds and 2 protein sources in starter on the performance and blood metabolites in Holstein neonatal calves.

MATERIALS AND METHODS

Experimental Design, Treatments, and Calves

Before starting the experiment, the chemical composition of FM and FC acidified with formic acid was measured using a MilkoScan analyzer (Foss Electric A/S, Hillerød, Denmark) at the ruminant nutrition laboratory of Ferdowsi University of Mashhad (Mashhad, Iran). The chemical compositions of liquid feeds are shown in Table 1.

Forty neonatal Holstein calves (20 males and 20 females) with 43.3 ± 0.1 and 42.3 ± 0.1 kg of BW (male and female, respectively) were used in a 42-d experimental period (the experiment took from March to April, because the calves were born at different times). According to the environmental temperature, calves were monitored indoors up to 6 wk of age at the calf Housing Facilities of Ferdowsi Research station (Ferdowsi University of Mashhad). At the beginning of the experiment, calves were separated from their dams immediately after birth and then were placed in individual pens. They were hand-fed their dam's fresh colostrum twice daily (1.5 to 2 kg per meal) for the first 2 d of life. On the third day, calves were switched to their treatments, including the respective liquid diets and starters. Calves based on sex were assigned randomly to 1 of 4 treatments, including SBM and meat and bone meal (**MB**) with either FC or FM.

The experiment was conducted according to a factorial $2 \times 2 \times 2$ design (2 sexes, 2 liquid feeds, and 2 sources of protein in their starters). The 8 treatments were male/female fed (1) FM and SBM, (2) FM and MB, (3) FC and SBM, and (4) FC and MB. The trials

continued for 6 wk. Colostrum collected for the first 8 milkings postpartum from dams of calves assigned to the experiments was acidified with formic acid and stored separately in covered plastic containers of 60 or 120 L. For acidification of colostrum, pure formic acid (98–100%, Riedel-de Haën) was used. Briefly, formic acid was diluted 1:10 (1 part formic acid to 10 parts water) and then 25 mL of diluted formic acid was added per kilogram of liquid diets (1 part FC with formic acid was mixed with 2 parts water so that both FC and FM would have equal TS, fat, protein, and lactose contents). Thus, approximately 2.27 mL of pure formic acid was added per kilogram of liquid diet (approximately 0.23%, vol/wt). Calves received liquid diets twice daily (2 kg per meal) and water and starters were available for ad libitum intake until the end of the trial at 6 wk of age.

Body Size Measurements, Blood Sampling, and Analyses

Calves were measured for growth to determine performance throughout the trial. At birth and every 3 wk, the following measurements were taken: BW, feed intake, pin width, hip width, body length, stomach size, withers height, and hip height, by using a wooden height stick with horizontal crossbar and level, calibrated in 0.635-cm increments (actual calibrations were in English units). Body length (measured from point of shoulder to caudal projection of pin bone). Weights were determined with a digital scale. Starter intake was measured daily by weighing refusals. The amount of starter fed was increased by 50 g if daily orts were less than 25 g. Calves were limited to no more than 2.5 kg/d, but no calves reached this limit. Fresh, clean water was available ad libitum beginning 1 to 2 d after birth.

Blood samples were collected by jugular venipuncture into evacuated tubes containing 0.1 mL of 15% EDTA (Vacutainer; Becton Dickinson, Rutherford, NJ), placed on ice, and transported to the laboratory. Plasma was harvested by centrifugation at $5,000 \times g$ for 15 min at 4°C and stored at –20°C until analyzed for glucose, urea, growth hormone (**GH**), and IGF-1 (Technicon Corp., Tarrytown, NY). Plasma glucose concentrations were measured by the glucose oxidase method using a commercial kit (No. 115; Sigma Diagnostics, St. Louis, MO). Plasma urea nitrogen (**PUN**) concentration was determined using urease and the indophenol reaction (Chaney and Marbach, 1962). Urea standards were prepared by dissolving 0.2142 g of urea in 100 mL of deionized water to form a stock solution and then further diluting the stock with deionized water to prepare a set of standards.

Table 1. Chemical composition of liquid feeds

Composition (% of DM)	Fermented colostrum acidified with formic acid	Fresh milk
TS	19.20	12.00
Protein	8.00	3.40
Fat	6.10	3.50
Lactose	3.60	4.80
Minerals	1.10	0.80

Plasma IGF-1 concentration was measured by a commercial 125I-RIA Kit (Nichols Institute Diagnostics, San Juan Capistrano, CA). The IGF-1 was separated from binding proteins through acid-ethanol (12.5% 2 *N* HCl and 87.5% ethanol) precipitation. Each sample was analyzed in duplicate ($2 \times 100 \mu\text{L}$). All steps of the RIA were performed according to the manufacturer's instructions. A test on samples with 2 different IGF-1 contents (undiluted and diluted, respectively) indicated parallelism. The intraassay and interassay coefficients of variation were 4.4 and 9.9%, respectively.

Plasma concentrations of GH were determined by the double antibody RIA technique, as described by Barnes et al. (1985). Purified bovine GH was used for standards and iodination, with rabbit anti-ovine GH antibody (first antibody) and sheep anti36 rabbit IgG (second antibody). Duplicates of each sample or standard were diluted (200 μL of sample plus 300 μL of buffer) before beginning the assay. Assay buffer (pH 7.5) contained 0.5% BSA in 0.05 *M* PBS. The first antibody (100 μL) was added and to each tube and samples were incubated for 24 h at room temperature. Then, GH tracer (^{125}I -labeled GH, 100 μL) was added to each tube and incubated at room temperature for 24 h. Subsequently, 100 μL of the second antibody was added to each tube and incubated for 72 h at 4°C. Tubes were decanted and a gamma counter measured the radioactive binding. Interassay and intraassay coefficients of variation averaged less than 20%, which is acceptable variation (Akers, 2002).

Statistical Analysis

Two liquid feeds (FM and FC) and 2 protein sources in starter (SBM and MB) were compared in a $2 \times 2 \times 2$ factorial design during the 42-d period of the experiment. Data were subjected to ANOVA with a general linear model (GLM) using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC; Littell et al., 1996). The means of parameters were analyzed with the Tukey test. Significance was declared at $P < 0.05$, unless otherwise indicated. Least squares means were separated using the PDIF option of SAS.

RESULTS

The chemical compositions of starters are presented in Table 2. In addition, results of the analysis of the SBM and MB are summarized in Table 3. These protein sources were chosen based on availability and their complementary contributions to amino acids absorbed when growing calves are fed a corn-based diet. The advantage of combining animal by-products such as MB is to achieve a complementary effect of the different

Table 2. Feed ingredients and chemical composition of the calf starters

Item	Starter 1	Starter 2
Ingredient (% of DM)		
Corn grain	51.50	52.50
Barley grain	14.50	14.50
Soybean meal	20.00	0
Meat and bone meal	0	19.00
Beet pulp	6.00	6.00
Wheat bran	4.80	4.80
Calcium carbonate	1.60	1.60
Vitamin premix	1.60	1.60
DM (%)	92.50	91.50
Chemical composition (% of DM)		
CP	18.30	18.10
Ca	0.80	2.70
P	0.40	1.20
ME (Mcal/kg of DM)	3.02	3.21

amino acid compositions and varying degradability of protein sources in the rumen.

Although consumption of DM during wk 1 to 6 was greater ($P < 0.05$) for calves fed SBM diet (15 ± 0.2 kg) than MB (13 ± 0.2 kg), sex and liquid feed had no significant effect on feed intake. In addition, during the whole experimental period, BW gain were higher ($P < 0.05$) for calves fed the SBM diet than those fed the MB diet (Table 4), but liquid feed had only effect at the last 3 wk of the experiment. The obtained data showed that liquid feed and sources of protein in starter had a significant effect ($P < 0.05$) on pin width, hip width, withers height, hip height, and stomach size, but no significant difference was observed between the sexes during the experimental period (Table 5).

The plasma glucose concentration was not affected by sex, liquid feed, or starter (Table 6). Although the PUN concentration decreased from d 0 to wk 3 in all treatments and then started to increase for the rest of the experiment, it was not affected by sex or liquid feed during the experimental period, whereas the sources of protein in the starter had a significant effect on PUN concentration ($P < 0.05$).

No statistically significant differences were detected between treatments in the concentration of GH at birth ($P = 0.12$). The concentration of GH in plasma tended

Table 3. Chemical composition of soybean meal and meat and bone meal

Composition (% of DM)	Soybean meal	Meat and bone meal
DM (%)	89.00	94.00
CP	44.00	54.20
Fat	1.60	10.40
Ash	6.60	30.40
RUP	93.00	60.00
Ca	0.40	10.60
P	0.70	4.73
TDN	80.00	62.40

Table 4. Effect of sex, liquid feed, and starter on weight gain, starter intake, and ADG of Holstein calves

Item	Treatment ¹									
	Male					Female				
	FM		FC			FM			FC	
	SBM	MB	SBM	MB	SBM	SBM	MB	SBM	SBM	MB
BW (kg)	44.00	43.00	44.40	41.80	42.40	42.60	43.40	41.00	43.40	
wk 3	52.20	47.30	48.40	47.10	47.80	47.40	47.10	47.70	47.10	
wk 6	56.40	52.80	54.40	51.00	53.90	52.10	51.30	51.40	51.30	
Total BW gain	12.40	9.20	10.00	9.20	10.50	9.50	7.90	10.40	7.90	
ADG (kg/d)	0.30	0.22	0.24	0.22	0.25	0.23	0.18	0.25	0.18	
Total DMI (kg)	16.92	13.68	14.72	13.26	15.98	14.06	12.48	13.5	12.48	
wk 2	1.16	0.84	0.92	0.86	1.12	0.92	0.90	0.72	0.90	
wk 3	2.26	1.44	1.64	1.70	2.24	2.00	1.84	1.84	1.84	
wk 4	3.50	2.62	3.10	2.72	3.50	2.92	2.46	2.86	2.46	
wk 5	4.52	3.84	3.92	3.60	4.04	3.54	3.28	3.54	3.28	
wk 6	5.48	4.94	5.14	4.38	5.08	4.68	4.00	4.52	4.00	

¹FM = fresh milk; FC = fermented colostrum acidified with formic acid; SBM = soybean meal; MB = meat and bone meal.

to decrease in all treatment groups from d 0 to the end of the study. No significant difference was observed in the plasma GH concentrations between the 2 sexes. Concentrations of GH were significantly higher ($P < 0.05$) in calves fed FM than those fed FC in wk 6. Moreover, plasma GH concentration was significantly affected by starter ($P < 0.05$). Calves fed SBM had a greater concentration of GH than calves fed MB.

The plasma IGF-1 concentration decreased from d 0 to the end of the study in the treatment groups. No significant effect was observed between male and female calves, but liquid feed and starter had significant effect on plasma IGF-1 concentration during the experimental period ($P < 0.05$).

DISCUSSION

In the present study, liquid diets had a significant effect ($P < 0.05$) on weight gain only during the last 3 wk of the experiment, so that calves that received FM gained more than those fed FC acidified with formic acid (10.4 vs. 9.77 kg, respectively). As our data shows in Table 1, the amount of TS in FC was 19.2%, which decreased to 10.1% when it was diluted with water in a ratio of 1:2 compared with FM with 12.1% TS, so that reduced growth on FC compared with FM diets in most cases can be explained by reduced TS intake on diluted FC diets (Rindsig and Bodoh, 1976). Generally, equal volumes of liquid materials have been fed rather than diets equivalent in protein and energy.

In addition, data from the current study showed that DMI and BW gain tended ($P < 0.05$) to be higher when calves were fed SBM containing less RDP, which probably provided more nitrogen to the small intestine for digestion and absorption, resulting in better DMI (Maiga et al., 1994). On the other hand, the undegradable protein content in SBM and MB could be as effective as the protein level in increasing the voluntary intake (Manso et al., 1998), so that the increase in DMI and BW gain was probably due to the amino acid balance arising from increased RUP content on the SBM compared with the MB diet (93 vs. 60%, respectively). The balance of essential amino acids enhanced feed intake and BW gain, consequently (Bunnakit and Khampa, 2011). This result is similar to the results of Olivares Reyna et al. (1992), who found greater weight gain in young dairy calves when the starter diet contained sources with high RUP concentrations. Palatability problems with animal by-product meals have been previously reported (Leibholz and Kang, 1973) and this effect was also evident in the present experiment with concentrates containing 190 g/kg of MB. Associative effects of feeds and experimental conditions could also influence performance measurements of calves.

Table 5. Effect of sex, liquid feed, and starter on body size (pin width, hip width, body length, stomach size, withers height, and hip height) of Holstein calves

Item (cm)	Treatment ¹								SEM	<i>P</i> -value		
	Male				Female							
	FM		FC		FM		FC					
	SBM	MB	SBM	MB	SBM	MB	SBM	MB				
Initial pin width	7.20	7.10	7.40	7.10	7.30	7.00	7.00	7.10				
wk 3	8.10	8.10	8.10	8.00	7.90	8.10	7.70	7.80	0.13	0.18	0.15	0.44
wk 6	9.30	8.80	9.00	8.90	8.90	9.00	8.40	8.50	0.19	0.48	0.02	0.86
Initial hip width	18.0	17.60	18.30	17.80	17.80	17.70	18.10	17.90				
wk 3	19.10	19.20	19.20	18.70	19.00	18.70	19.40	18.70	0.17	0.85	0.87	0.01
wk 6	21.30	20.60	20.60	19.70	21.00	20.70	21.10	20.10	0.29	0.75	0.19	0.004
Initial body length	71.00	68.60	71.60	69.20	70.80	68.60	69.40	69.40				
wk 3	72.80	71.20	71.40	70.80	71.30	70.70	71.10	71.60	0.35	0.78	0.80	0.01
wk 6	77.60	74.60	74.70	72.80	75.80	72.60	74.80	74.60	0.69	0.50	0.27	0.005
Initial stomach size	84.00	83.40	86.80	84.40	84.00	83.20	80.60	83.80				
wk 3	90.30	88.40	89.20	87.90	90.20	89.50	88.60	89.00	0.64	0.42	0.04	0.05
wk 6	97.60	93.60	95.40	91.80	95.60	94.70	93.00	93.80	1.04	0.69	0.01	0.014
Initial withers height	78.40	77.40	78.60	76.80	78.10	77.40	77.20	77.40				
wk 3	80.80	79.10	80.10	79.00	79.80	78.10	79.00	79.30	0.34	0.07	0.20	0.002
wk 6	82.80	81.30	81.50	80.50	82.20	81.10	80.80	81.10	0.39	0.58	0.005	0.004
Initial hip height	82.10	81.40	82.60	80.80	81.80	81.20	81.30	81.60				
wk 3	84.10	83.90	84.10	83.70	84.90	83.90	83.20	83.10	0.25	0.35	0.07	0.007
wk 6	87.40	85.70	86.00	85.40	86.80	86.10	86.20	85.90	0.30	0.61	0.008	0.001

¹FM = fresh milk; FC = fermented colostrum acidified with formic acid; SBM = soybean meal; MB = meat and bone meal.

Table 6. Effect of sex, liquid feed, and starter on blood metabolite concentrations [glucose, plasma urea nitrogen (PUN), growth hormone (GH), and IGF-1] of Holstein calves

Item	Treatment ¹										P-value			
	Male					Female								
	FM		FC		SBM	FM		FC		SEM		Sex	Liquid	Starter
	SBM	MB	SBM	MB		SBM	MB	SBM	MB					
Glucose d 0 (mg/dL)	83.63	81.60	82.24	86.65	86.50	82.55	90.24	80.89						
wk 3	81.18	74.92	75.94	79.58	71.39	78.91	79.43	72.91		1.76	0.74	0.26	0.14	
wk 6	69.42	66.09	63.77	63.77	65.83	65.01	68.08	61.10		1.51	0.77	0.16	0.14	
PUN d 0 (mg/dL)	11.21	11.58	11.49	11.83	10.62	10.75	11.76	10.91						
wk 3	8.56	8.38	8.54	8.78	8.68	8.10	8.72	8.64		0.14	0.90	0.27	0.50	
wk 6	10.54	9.62	9.56	9.76	10.80	9.16	9.84	9.95		0.13	0.80	0.15	0.004	
GH d 0 (ng/mL)	49.50	48.50	44.00	48.00	48.50	47.00	48.50	49.00		0.39	0.11	0.66	0.12	
wk 6	31.50	27.50	29.50	25.50	28.50	29.50	27.50	24.50		0.61	0.28	0.005	0.02	
IGF-1 d 0 (ng/mL)	115.30	122.30	112.10	126.70	128.20	114.40	118.50	114.10		4.01	0.37	0.70	0.88	
wk 6	95.40	85.48	86.85	86.54	94.45	86.70	80.29	79.70		1.43	0.14	0.008	0.05	

¹FM = fresh milk; FC = fermented colostrum acidified with formic acid; SBM = soybean meal; MB = meat and bone meal.

Published values for ADG vary widely and range from 199 to 790 g/d, with most values in the range of 400 to 500 g/d. Fiems et al. (1986) reported poorer digestibility and efficiency of weight gain and slower ADG in calves when they received cottonseed meal compared with SBM as a source of protein in the starter. Replacing soybean meal with corn gluten feed resulted in higher feed intake and ADG in the calves. As a group, these studies indicate that SBM is as good as or better than most protein sources for calf starters.

In the present study, liquid feed and starter had a significant effect on calf structural growth measurements ($P < 0.05$), but no significant difference was observed between the sexes. Values for body length of dairy calves were not found in the literature, although Wilson et al. (1997) reported an average of 72.8 ± 0.11 cm in 3-wk-old Holstein male veal calves. Results obtained in the current experiment indicated that protein sources of starter and liquid feed had significant effects on stomach size. Stomach size is correlated with DMI, so calves fed SBM and FM had higher DMI and stomach size in the entire experimental period. In addition, results obtained from the current experiment for withers height in Holstein calves (81.3 ± 0.95 cm) at the end of 42 d of age are similar to those reported in some studies (80.1 ± 0.30 cm; Heinrichs and Hargrove, 1987), but greater than in other reports (74 to 78 cm; Kertz et al., 1998; Lammers et al., 1998).

Data obtained in this study showed that even though plasma glucose concentrations were more decreased in calves fed FC than those fed FM, no significant difference was observed between them as they grew older. This change has been attributed to the physiological shift in the primary energy source from glucose to VFA when the rumen in young calves becomes functional (Hammon et al., 2002). In neonatal calves, due to the reflexive closure of the reticular groove and the lack of short-chain FA in the ruminal lumen, the primary source of energetic substrate is glucose derived from intestinal absorption (Khan et al., 2007). With the initiation of solid feed consumption, ruminal fermentation proceeds and VFA starts replacing glucose as an energy source (Baldwin et al., 2004).

In addition, high concentrations of PUN at birth could result from maternal influences, as PUN in the young calf is much lower than that of the mature cow (Kitchenham et al., 1975). Continued clearance of maternal urea nitrogen as well as clearance of the glut of protein provided in the initial feedings account for further declines in PUN concentrations. Concentrations of PUN then increase as calves begin to consume greater amounts of grain and development of ruminal fermentation occurs (Quigley and Bernard, 1992). As the digestive system matures, the low PUN concentrations

increase to adult concentrations (9.5 to 19.5 mg/dL; Kitchenham et al., 1975). Differences in CP content of liquid feeds may also contribute to differences between calves fed FM and calves fed FC. Greater total protein content in the diluted (2×) colostrum (6%) compared with the FM (3.5%) could cause an excess of dietary protein in the fermented colostrum-fed calves. These results were in agreement with those obtained by Foley and Otterby (1978). In the current study, at wk 3, calves fed FC had higher PUN concentrations than calves fed FM, so it is likely that the colostrum provided more total protein than the FM. In older animals, this excess protein would likely be metabolized into urea for excretion from the body, but the digestive system of the calf is not fully functional in the first 3 wk. By 3 wk of age, calves are more able to digest non-milk proteins (Heinrichs et al., 1994; Davis and Drackley, 1998). Therefore, differences in PUN concentrations are probably due to differences in total dietary protein. It is known that a large amount of ammonia, carbon dioxide, and methane are produced from feed proteins by the fermentation activity of the rumen microbes in ruminants. Ammonia is absorbed through the rumen wall into the portal blood stream and synthesized into urea by the liver. Urea is recycled to the rumen via saliva and across the rumen wall. Urea is an important source of nitrogen for the synthesis of microbial proteins; in turn, the microbes provide a supply of amino acids for the host animal after digestion and absorption in the small intestine (Abdel Rahman, 1966; Obara et al., 1991). Therefore, it is thought that recycling of urea increases with development of the rumen. In the present study, the higher PUN concentrations ($P < 0.05$) in calves fed SBM may be due to greater deamination activity or lower ability of microbial protein synthesis or both (Agabawi et al., 1968). This finding suggests that urea irreversible loss and recycling rates gradually increase with age as well as with the development of the reticulorumen in calves (Hayashi et al., 2006). In addition, results of urea and ammonia nitrogen concentration in the blood confirm the parallelism between ammonia nitrogen in the rumen and blood urea (Lewis, 1957).

Several studies have been conducted to investigate the effect of nutrient intake on plasma hormone concentrations. Often, nutrient intakes are varied by fixing the feed intake and varying the diet composition, or the other way around. In the present study, the concentration of GH in plasma trended to decrease in all treatment groups from d 0 to the end of the experiment. Differences in GH between treatment groups in the current study may be related to nutritional factors. Coxam et al. (1989) reported that increased triglyceride concentrations depressed GH secretion. Differences in the fat content and composition between FC and the FM may

have elicited differential responses in GH secretion in the calves of the current study during the experimental period. Fermented colostrum contains 6.1% fat (Table 1), whereas FM contains about 3.5% fat. Considerably higher fat concentrations in FC compared with the FM probably influenced the energy balance of calves and possibly affected GH secretion. In addition, previous research has shown that nutritional status plays a major role in determining plasma GH concentrations (Kaufhold et al., 2000). As reviewed by Breier and Sauerwein (1995), plasma GH concentrations are enhanced in growing cattle during energy restriction, and Kühne et al. (2000) found higher plasma GH concentrations in calves fed only milk replacer. Contrary to a deficient nutrient supply, our results indicated reduced GH concentration when calves were fed MB with higher fat content than SBM (10.4 vs. 1.6% respectively). Thus, the high level of triglycerides in starter can inhibit GH secretion (Coxam et al., 1989). Results obtained from this study are supported by the explanation that because SBM offers a good balance of amino acids, free of many antinutritional factors, and is low in fiber and consistently digestible, it could increase the feed intake in calves and, consequently, GH secretion. Although no conclusive experimental evidence exists to associate GH with growth in ruminants, results of the present study suggest a correlation between the elevated GH concentration and the rapid growth rates in calves, at least in the initial phase of growth.

Plasma IGF-1 decreased from d 0 to the end of the study in treatment groups. Colostrum contains very high concentrations of IGF-1 compared with FM (Baumrucker and Blum, 1993), so it was expected that plasma IGF-1 concentration be higher in calves fed FC than calves fed FM, but in the present study, the results were contrary to expectation (83.35 vs. 89.25 ng/mL, respectively). Feeding colostrum containing IGF-1 caused an increase in intestinal growth in both calves and piglets in some studies (Baumrucker and Blum, 1993; Xu et al., 1994; Xu et al., 1996; Bühler et al., 1998). The current belief is that although IGF-1 is barely absorbed by the intestine of the newborn calf, it may enhance development of the neonatal digestive system and may affect or interact with other growth factors, such as feed intake, to influence the neonatal intestine (Vacher et al., 1995; Odle et al., 1996). Effects of age and nutrient intake on IGF-1 cannot be distinguished, because positive correlations exist among total DMI, weight gain, and plasma IGF-1 concentrations (Kerr et al., 1991). As weight gain increased, plasma IGF-1 concentrations also increased (Smith and Sheffield, 2002).

In the present study, calves fed the SBM diet had greater total DMI, weight gain, and plasma IGF-1

Table 7. Comparison of total DMI, BW, plasma growth hormone (GH), and plasma IGF-1 concentrations in Holstein calves at wk 6

Item (kg)	Treatment ¹										P-value	
	Male					Female						
	FM		FC			FM		FC				
	SBM	MB	SBM	MB	SBM	SBM	MB	SBM	MB	SBM		Sex
Plasma IGF-1 (ng/mL)	79.70	80.29	86.70	94.45	86.54	86.85	85.48	95.40	1.43	0.14	0.008	0.05
Plasma GH (ng/mL)	24.50	27.50	29.50	28.50	25.50	29.50	27.50	31.50	0.61	0.28	0.005	0.02
Total DMI (kg)	16.92	13.68	14.72	13.26	15.98	14.06	13.50	12.48	1.28	0.48	0.07	0.04
BW gain (kg)	12.40	9.20	10.00	9.20	10.50	9.50	10.40	7.90	1.24	0.18	0.035	0.032

¹FM = fresh milk; FC = fermented colostrum acidified with formic acid; SBM = soybean meal; MB = meat and bone meal.

concentrations than calves fed the MB diet during the experimental period (89.25 vs. 84.6 ng/mL for IGF-1, respectively). In addition, Petitclerc et al. (1999) determined that heifer calves allowed ad libitum intake had greater concentrations of IGF-1, and in our experiment the greater plasma IGF-1 concentrations in response to a higher feeding rate and to higher dietary CP concentration was as Bartlett (2001) reported. The mechanism of colostral IGF-1 action and the specific influence it may have on the neonate remain unclear (Table 7).

CONCLUSIONS

Calves fed the SBM had greater feed intake, weight gain, and ADG than calves fed MB. Increased feed intake in calves that consumed SBM and fresh milk resulted in greater calf body size. Calf blood metabolites were affected by both protein sources in the starter and liquid feeds. Plasma urea nitrogen concentration was higher in calves fed SBM than those fed MB. Growth hormone and IGF-1 decreased in all treatment groups and they were significantly affected by both liquid feed and starter.

REFERENCES

Abdel Rahman, S. 1966. Comparative study of the urease in the rumen wall and rumen content. *Nature* 209:618–619.

Agabawi, K. A., H. El Sayed Osman, and A. R. Abou Akkada. 1968. Feed efficiency, ruminal activity, and effects on some blood constituents on early weaned calves. *J. Dairy Sci.* 51:744–747.

Akers, R. M. 2002. Lactation and the Mammary Gland. Iowa State Press. Ames.

Baldwin, R. L., VI, K. R. McLeod, J. L. Klotz, and R. N. Heitmann. 2004. Rumen development, intestinal growth and hepatic metabolism in the pre- and post-weaning ruminant. *J. Dairy Sci.* 87(E. Suppl.):E55–E65.

Barnes, M. A., G. W. Kazmer, R. M. Akers, and R. E. Pearson. 1985. Influence of selection for milk yield on endogenous hormones and metabolites in Holstein heifers and cows. *J. Anim. Sci.* 60:271–284.

Bartlett, K. S. 2001. Interactions of Protein and Energy Supply from Milk Replacers on Growth and Body Composition of Dairy Calves. University of Illinois, Urbana.

Baumrucker, C. R., and J. R. Blum. 1993. Secretion of insulin-like growth factors in milk and their effect on the neonate. *Livest. Prod. Sci.* 35:49–72.

Breier, B. H., and H. Sauerwein. 1995. Regulation of growth in ruminants by the somatotrophic axis. Pages 451–474 in *Ruminant Physiology: Digestion, Metabolism, Growth and Reproduction*. W. von Engelhardt, S. Leonhard-Marek, G. Breves, and D. Giesecke, ed. F. Enke Verlag, Stuttgart, Germany.

Bühler, C., H. Hammon, G. L. Rossi, and J. W. Blum. 1998. Small intestinal morphology in eight-day-old calves fed colostrum for different durations or only milk replacer and treated with long-R³-insulin-like growth factor I and growth hormone. *J. Anim. Sci.* 76:758–765.

Bunnakit, K., and S. Khampa. 2011. Effect of rumen undegradable protein levels on performance of Thai Native × Brahman beef cattle. *Pakistan J. Nutr.* 10:1163–1167.

Chaney, A. L., and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. *Clin. Chem.* 8:130–132.

Chiba, L. I. 2001. Protein supplements. Pages 803–837 in *Swine Nutrition*. 2nd ed. A. J. Lewis and L. L. Southern, ed. CRC Press, Boca Raton, FL.

- Coxam, V., M.-J. Davicco, and J.-P. Barlet. 1989. Effect of triglycerides on growth hormone (GH)-releasing factor-mediated GH secretion in newborn calves. *Domest. Anim. Endocrinol.* 6:389–393.
- Davis, C. L., and J. K. Drackley. 1998. *The Development, Nutrition, and Management of the Young Calf*. 1st ed. Iowa State University Press, Ames.
- Fiems, L. O., C. V. Boucqué, B. G. Cottyn, and F. X. Buysse. 1986. Cottonseed meal and maize gluten feed versus soybean meal as protein supplements in calf starters. *Arch. Anim. Nutr.* 36:731–740.
- Foley, J. A., and D. E. Otterby. 1978. Availability, storage, treatment, composition, and feeding value of surplus colostrum: A review. *J. Dairy Sci.* 61:1033–1060.
- Hammon, H. M., G. Schiessler, A. Nussbaum, and J. W. Blum. 2002. Feed intake patterns, growth performance, and metabolic and endocrine traits in calves fed unlimited amounts of colostrum and milk by automata, starting in the neonatal period. *J. Dairy Sci.* 85:3352–3362.
- Hayashi, H., M. Kawai, I. Nonaka, F. Terada, K. Katoh, and Y. Obara. 2006. Developmental changes in the kinetics of glucose and urea in Holstein calves. *J. Dairy Sci.* 89:1654–1661.
- Heinrichs, A. J., and G. L. Hargrove. 1987. Standards of weight and height for Holstein heifers. *J. Dairy Sci.* 70:653–660.
- Heinrichs, A. J., S. J. Wells, H. S. Hurd, G. W. Hill, and D. A. Dargatz. 1994. The National Dairy Heifer Evaluation Project: A profile of heifer management practices in the United States. *J. Dairy Sci.* 77:1548–1555.
- Jenny, B. F., S. E. Mills, and G. D. O'Dell. 1977. Dilution rates of sour colostrum for dairy calves. *J. Dairy Sci.* 60:942–946.
- Kaufhold, J. N., H. M. Hammon, R. M. Bruckmaier, B. H. Breier, and J. W. Blum. 2000. Postprandial metabolism and endocrine status in veal calves fed at different frequencies. *J. Dairy Sci.* 83:2480–2490.
- Kerr, D. E., B. Laarveld, M. I. Fehr, and J. G. Manns. 1991. Profiles of serum IGF-1 concentrations in calves from birth to eighteen months of age and in cows throughout the lactation cycle. *Can. J. Anim. Sci.* 71:695–705.
- Kertz, A. F., B. A. Barton, and L. F. Reutzel. 1998. Relative efficiencies of wither height and body weight increases from birth until first calving in Holstein cattle. *J. Dairy Sci.* 81:1479–1482.
- Khan, M. A., H. J. Lee, W. S. Lee, H. S. Kim, K. S. Ki, T. Y. Hur, G. H. Suh, S. J. Kang, and Y. J. Choi. 2007. Structural growth, rumen development, metabolic and immune response of Holstein male calves fed milk through step-down and conventional methods. *J. Dairy Sci.* 90:3376–3387.
- Khorasani, G. R., W. C. Sauer, F. Maenhout, and J. J. Kennelly. 1989. Substitution of milk protein with soy flour or meat-solubles in calf milk replacers. *Can. J. Anim. Sci.* 69:373–382.
- Kitchenham, B. A., G. J. Rowlands, R. Manston, and S. M. Dew. 1975. The blood composition of dairy calves reared under conventional and rapid-growth systems. *Br. Vet. J.* 131:436–446.
- Kühne, S., H. M. Hammon, R. M. Bruckmaier, C. Morel, Y. Zbinden, and J. W. Blum. 2000. Growth performance, metabolic and endocrine traits, and absorptive capacity in neonatal calves fed either colostrum or milk replacer at two levels. *J. Anim. Sci.* 78:609–620.
- Lammers, B. P., A. J. Heinrichs, and A. Aydin. 1998. The effect of whey protein concentrate or dried skim milk in milk replacer on calf performance and blood metabolites. *J. Dairy Sci.* 81:1940–1945.
- Leibholz, J. 1967. The source of protein in calf diets. 1. A comparison of dried skim milk and meat meal. *Aust. J. Agric. Res.* 18:149–155.
- Leibholz, J., and H. S. Kang. 1973. The crude protein requirement of the early-weaned calf given urea, meat meal or soybean meal with and without sulphur supplementation. *Anim. Prod.* 17:257–265.
- Leibholz, J., and F. P. Moss. 1967. The source of protein in calf diets. II. Meat meal quality. *Aust. J. Agric. Res.* 18:157–168.
- Lewis, D. 1957. Blood-urea concentration in relation to protein utilization in the ruminant. *J. Agric. Sci.* 48:438–446.
- Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. *SAS System for Mixed Models*. SAS Institute, Cary, NC.
- Loerch, S. C., and L. L. Berger. 1981. Feedlot performance of steers and lambs fed blood meal, meat and bone meal, dehydrated alfalfa and soybean meal as supplemental protein sources. *J. Anim. Sci.* 53:1198–1203.
- Maiga, H. A., D. J. Schingoethe, F. C. Ludens, W. Tucker, and D. P. Casper. 1994. Response of calves to diets that varied in amounts of ruminally degradable carbohydrate and protein. *J. Dairy Sci.* 77:278–283.
- Manso, T., A. R. Mantecón, F. J. Giraldez, P. Lavín, and T. Castro. 1998. Animal performance and chemical body composition of lambs fed diets with different protein supplements. *Small Rumin. Res.* 29:185–191.
- Mäntysaari, P. E., C. J. Sniffen, T. V. Muscato, J. M. Lynch, and D. M. Barbano. 1989. Performance of cows in early lactation fed isonitrogenous diets containing soybean meal or animal by-product meals. *J. Dairy Sci.* 72:2958–2967.
- Miller, E. L., and F. De Boer. 1988. By-products of animal origin. *Livest. Prod. Sci.* 19:159–196.
- Muller, L. D., F. C. Ludens, and J. A. Rook. 1976. Performance of calves fed fermented colostrum or colostrum with additives during warm ambient temperature. *J. Dairy Sci.* 59:930–935.
- Obara, Y., D. W. Dellow, and J. V. Nolan. 1991. The influence of energy-rich supplements on nitrogen kinetics in the ruminants. Pages 515–539 in *Physiological Aspects of Digestion and Metabolism in Ruminants*. T. Tsuda, ed. Academic Press, San Diego, CA.
- Odle, J., R. T. Zijlstra, and S. M. Donovan. 1996. Intestinal effects of milk borne growth factors in neonates of agricultural importance. *J. Anim. Sci.* 74:2509–2522.
- Olivares Reyna, L., R. Herrera Saldana, R. Barcena Gama, and S. Gonzalez Munoz. 1992. The effect of different protein and starch sources in starter diets for young calves. *J. Dairy Sci.* 75(Suppl. 1):269. (Abstr.)
- Otterby, D. E., and J. G. Linn. 1981. Advances in nutrition and management of calves and heifers. *J. Dairy Sci.* 64:1365–1377.
- Petitclerc, D., P. Dumoulin, H. Ringue, J. Matte, and C. Girard. 1999. Plane of nutrition and folic acid supplementation between birth and four months of age on mammary development of dairy heifers. *Can. J. Anim. Sci.* 79:227–234.
- Polzin, H. W., D. E. Otterby, J. M. Murphy, and J. B. Williams. 1976. Crude casein and meat solubles in milk replacers. *J. Dairy Sci.* 59:1842–1844.
- Quigley, J. D., and J. K. Bernard. 1992. Effects of nutrient source and time of feeding on changes in blood metabolites in young calves. *J. Anim. Sci.* 70:1543–1549.
- Rindsig, R. B., and G. W. Bodoh. 1977. Growth of calves fed colostrum naturally fermented, or preserved with propionic acid or formaldehyde. *J. Dairy Sci.* 60:79–84.
- Sahlu, T. D., J. Schingoethe, and A. K. Clark. 1984. Lactational and chemical evaluation of soybean meals heat-treated by two methods. *J. Dairy Sci.* 67:1725–1738.
- Smith, J. L., and L. G. Sheffield. 2002. Production and regulation of leptin in bovine mammary epithelial cells. *Domest. Anim. Endocrinol.* 22:145–154.
- Stock, R., and T. Klopfenstein. 1979. Feeding value of blood meal and meat meal as protein supplements for ruminants. *J. Anim. Sci.* 49(Suppl. 1):121. (Abstr.)
- Vacher, P.-Y., G. Bestetti, and J. W. Blum. 1995. Insulin-like growth factor I absorption in the jejunum of neonatal calves. *Biol. Neonate* 68:354–367.
- Wilson, L. L., C. L. Egan, and T. L. Terosky. 1997. Body measurements and body weights of special-fed Holstein veal calves. *J. Dairy Sci.* 80:3077–3082.
- Xu, R. J., D. J. Mellor, M. J. Birtles, B. H. Breier, and P. D. Gluckman. 1994. Effects of oral IGF-I or IGF-II on digestive organ growth in newborn piglets. *Biol. Neonate* 66:280–287.
- Xu, R. J., D. J. Mellor, M. J. Birtles, G. W. Reynolds, H. V. Simpson, B. H. Breier, and P. D. Gluckman. 1996. Morphological changes in the oesophagus of newborn pigs: Effects of age, diet and oral insulin-like growth factor I (IGF-I) or IGF-II. *Reprod. Fertil. Dev.* 8:903–909.