Effect of a mixture of steam-flaked corn and soybeans on health, growth, and selected blood metabolism of Holstein calves

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ABSTRACT

The objective of the experiment was to evaluate the effects of steam-flaked corn grains and soybeans on calf health, growth, and selected blood parameters. Holstein bull calves ($n = 30$, approximately 7 ± 3 d of age) were purchased from local dairy farms and offered milk, starter diets, and hay, and were then assigned to the experiment at 21 ± 3 d of age. Calves were blocked into 3 treatments by birth date and body weight and randomly assigned to receive fresh milk and a commercial pelleted starter containing extruded corn and soybeans (ECS), steam-flaked corn and soybeans (SFCS), or ground corn and soybeans (GCS). The experiment was conducted with calves from 3 to 13 wk of age. Body weight, calf starter intake, milk intake, total dry matter intake, and body structural growth were not significantly influenced by corn and soybean processing during the study; however, feed efficiency was significantly improved by the SFCS treatment. Average daily gain generally decreased during the weaning week for all treatments, but did not differ significantly among treatments. Health incidences for calves fed the SFCS starter were lower than those fed the other 2 treatments. The blood hematocrit was higher for calves fed the SFCS starter than for those fed the GCS and ECS starters during wk 6 to 11. The concentration of plasma β -hydroxybutyrate was higher for the calves fed the GCS and SFCS treatments than for those fed the ECS treatment during wk 6 to 13, but lower during wk 4 and 5. Plasma glucose concentrations decreased remarkably with increasing calf age but were not affected by corn and soybean processing. Plasma non-esterified fatty acids were influenced by calf age, and higher NEFA concentration was observed in the SFCS treatment than in the other 2 treatments during wk 5 to 9. Calves consuming the SFCS starter had similar average daily gain, milk intake, starter intake, total dry matter intake, and body structure, but had improved

feed efficiency when compared with animals consuming the GCS and ECS starters. The SFCS starter decreased incidence of diarrhea during the postweaning period and required less veterinary treatment. These data suggest that the steam-flaking of corn and soybeans can influence the growth performance and the selected blood parameters of calves and that, in this study, the extrusion of corn and soybeans had no beneficial effect on the growth performance of calves.

Key words: heat processing, Holstein calf, growth performance, blood parameter

INTRODUCTION

In calves, solid feed, especially concentrate or high carbohydrate diets, stimulates rumen microbial proliferation and VFA production and subsequently initiates rumen development (Harrison et al., 1960). Therefore, alterations in solid feed intake and its digestibility through a certain mechanical processing method may influence the rate and extent of rumen development. It was reported that grain processing methods and degree of processing influenced DMI and digestibility (Owens et al., 1997). The highest intake was found in diets containing dry-rolled grains, followed by whole, steam-rolled, and steam-flaked grains, with finely ground grains resulting in the lowest feed intake (Owens et al., 1997). Crocker et al. (1998) reported that starch digestibility was the highest in steam-flaked grains, followed by finely ground, and then dry-rolled grains, and was the lowest in whole grains; however, this is not always the case (Reis and Combs, 2000). Feeding raw roasted or conglomerated sorghum grain to calves resulted in no effects on calf performance or rumen and blood metabolites (Abdelgadir and Morrill, 1995). However, Lesmeister and Heinrichs (2004) reported that rumen development, blood VFA concentrations, and ruminal propionate production were enhanced by incorporation of steam-flaked corn into the calf starter, but intake, feed efficiency, and growth were negatively influenced.

Most corn processing studies have been conducted using mature ruminants, and extrapolation of these results to immature ruminants may be limited because of

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known differences in digestion kinetics, microbial populations, and rumen capacity (Vazquez-Anon et al., 1993). Limited data are available concerning the processing of grains and protein feedstuffs influencing development of ruminal function in calves. Furthermore, much of the literature evaluating development of ruminal function has addressed characteristics associated with size or metabolic activity of the organ (Quigley et al., 1991). Therefore, this study was conducted to determine the effects of corn and soybean processing methods on feed intake, growth performance, and the changes of blood parameters in Holstein calves.

MATERIALS AND METHODS

Animals and Treatment Diets

Holstein bull calves ($n = 30$) were purchased from local dairy farms at approximately 7 d of age and transported to the Huachen Dairy Farm in an eastern suburb of Beijing, China. All calves were visibly healthy and had been offered fresh milk, calf starter, and hay since they were introduced to the farm. After 2 wk of adaptation, when calves were visibly free of diseases and were ambulatory, they were assigned to 3 groups at the age of 21 ± 3 d and fed fresh milk and calf starter pellets. Commercial calf starters (Table 1) were formulated to contain extruded corn and soybeans (**ECS**), steam-flaked corn and soybeans (**SFCS**), or ground corn and soybeans (**GCS**). Steam-flaked corn and soybeans were processed with a Roskamp Flaking Mill (model FX 1600–36, Roskamp Champion, Waterloo, IA) in Hebei Kaite Feed Mill Group (Hebei Xingtai, China). Processing conditions were set at 55 min of steam-conditioning and 0.8- to 1.2-mm flaking thickness. Extruded corn and soybeans were processed according to the procedure described by Friesen et al. (1993). All ingredients were used in 3 calf starters within the same lots.

Animal Housing and Management

The experiments were conducted under the approval of China Agricultural University Animal Science and Technology College Animal Care and Use Committee (Beijing). Calves were housed in naturally ventilated barns in individual pens (1.5×3.0 m) bedded with wood shavings. Nose-to-nose contact between calves was minimized by pen arrangement. Milk was provided in 3 equal feeding intervals per day at 10% of initial BW at 0600, 1300, and 2000 h and gradually decreased with the increased calf starter intake; the milk amount allowance was gradually reduced at a level of about 0.25 to 0.5 kg/calf every 3 d. Based on the calf feeding

tradition in China, calf starter and hay were both offered ad libitum and intake was recorded daily. Calves were weaned when starter consumption reached 0.7 kg/d for 2 consecutive days. Water was provided freely and changed daily.

Starter Sampling and Analyses

Three calf starter samples were collected from each commercial calf starter when new bags were opened throughout the study, ground through a 1-mm screen in a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA), and analyzed in triplicate for DM, Ca, P, ether extract (**EE**; AOAC, 1990), NDF, and ADF (Van Soest et al., 1991). Crude protein was analyzed using a nitrogen analyzer (model Rapid N III, Elementar, Analysen Systeme GmbH, Germany) based on the Dumas combustion method (AOAC, 1990). Starch was determined according to Xiong et al. (1991). Values for total digestible nutrients, NE_M , and NE_G were calculated based on the NRC (2001) model.

Calf Health Monitoring and Experimental Measurement

Calf health was monitored each day using the procedure of Larson et al. (1977). Body weight, withers height (**WH**), hip height (**HH**), hip width (**HW**), and heart girth (**HG**) were measured at 3, 4, 5, 6, 7, 9, 11, and 13 wk of age. Blood samples were collected on the same sampling day within 30 min postprandial to the a.m. feeding via jugular venipuncture into evacuated tubes containing EDTA. One of the blood sampling tubes was collected for measurement of hematocrit (**HEM**) by microhematocrit centrifuge. The other tubes were centrifuged for 10 min at $1,600 \times g$ for plasma separation. The plasma was frozen (-20°C) until analyzed for BHBA acid, glucose, and NEFA. Plasma BHBA was determined using the Stanbio BHBA LiquiColor kit (procedure no. 2440, Stanbio Laboratory, Boerna, TX). Plasma glucose was determined using a glucose kit (number 510, Sigma-Aldrich Chemical Co., St. Louis, MO).

Statistical Analysis

Initial BW, WH, HH, HW, and HG were analyzed as a completely randomized design by ANOVA (SAS Institute, Cary, NC). Parameters taken at weaning and at the end of the study were analyzed as described by Lesmeister and Heinrichs (2004) but without block effects.

Blood variables (HEM, BHBA, glucose, and NEFA), ADG, and DMI were analyzed by MIXED procedures

Table 1. Ingredients of calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans

Ingredient (% of starter DM)	Calf starter		
	GCS	SFCS	ECS
Whole corn	45.5	—	—
Steam-flaked corn	—	45.5	—
Extruded corn	—	—	45.5
DDGS ¹	16.0	16.0	16.0
Soybean hulls	3.0	3.0	3.0
Wheat bran	1.0	1.0	1.0
Apple pulp	1.5	1.5	1.5
Cottonseed meal	6.5	6.5	6.5
Raw full-fat soybeans	7.3	—	—
Steam-flaked full-fat soybeans	—	7.3	—
Extruded full-fat soybeans	—	—	7.3
Brewers dried grain	14.0	14.0	14.0
Fine limestone	1.5	1.5	1.5
Dicalcium phosphate	1.1	1.1	1.1
Salt	0.8	0.8	0.8
1% cobalt chloride	0.014	0.014	0.014
5% urease inhibitor	0.14	0.14	0.14
Flavor promoter	0.0028	0.0028	0.0028
Zinc sulfate	0.035	0.035	0.035
Ferric sulfate	0.014	0.014	0.014
Copper sulfate	0.0175	0.0175	0.0175
Manganese sulfate	0.042	0.042	0.042
5% potassium iodide	0.007	0.007	0.007
Sodium selenite	0.014	0.014	0.014
Rare earth	0.028	0.028	0.028
17% zinc proteinate	0.007	0.007	0.007
Bentonite	0.14	0.14	0.14
Zeolite powder	0.2387	0.2387	0.2387
Vitamin A ²	0.0028	0.0028	0.0028
50% vitamin E	0.014	0.014	0.014
Vitamin D ³	0.0007	0.0007	0.0007
Nicotinic acid	0.0035	0.0035	0.0035
Bentonite	0.049	0.049	0.049
Diamond V XP ⁴	0.48	0.48	0.48
Dynamate ⁵	0.1	0.1	0.1
Magnesium oxide	0.4	0.4	0.4
Luctarom sucklers ⁶	0.05	0.05	0.05

¹DDGS = dehydrated distillers grains with solubles.

²500,000 IU/kg.

³500,000 IU/kg.

⁴Diamond V XP (Diamond V Mills, Cedar Rapids, IA): *Saccharomyces cerevisiae* yeast and the media on which it was grown consisting of ground yellow corn, hominy feed, corn gluten feed, wheat middlings, rye middlings, diastatic malt and corn syrup, and cane molasses.

⁵Dynamate (Mosaic Co., Plymouth, MN): Potassium and magnesium sulfate; typical chemical composition is S 22.20%, K 18.40%, Mg 11.10%, Cl 1.25%, Fe 0.06%, Na 0.78%, Ca 0.22%, Mn 25.00 mg/kg, Zn 5.00 mg/kg, Mo <1.00 mg/kg, Cu 69.00 mg/kg, Co <1.00 mg/kg, and Se 5.00 mg/kg.

⁶Luctarom sucklers (Lucta S. A., Barcelona, Spain): Feed flavor enhancement. The ingredients were a mixture of natural aromatic products and their corresponding synthetic products.

of SAS (SAS Institute) using repeated measures with the model

$$Y_{ijk} = \mu + T_i + C_{(ij)} + P_k + (TP)_{ik} + e_{(ijk)},$$

where Y_{ijk} = dependent variable, μ = overall mean, T_i = treatment i , $C_{(ij)}$ = calf j within treatment i , P_k = time period k , $(TP)_{ik}$ = treatment $\times$ period interaction, and $e_{(ijk)}$ = residual. The term $C_{(ij)}$ was used as error to

test differences because of treatments. Significance was declared as $P < 0.05$ unless noted otherwise.

RESULTS AND DISCUSSION

Dietary Composition

Nutrient composition of calf starter is presented in Table 2. Though the ingredients over the whole experi-

Table 2. Nutrient composition of calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans¹

Item (% unless noted) ²	Calf Starter		
	GCS	SFCS	ECS
DM	89.26	90.20	91.14
TDN	78.46	79.74	78.30
NE _M (Mcal/kg)	1.98	2.01	1.98
NE _G (Mcal/kg)	1.34	1.38	1.34
CP	21.45	21.05	18.87
Starch	38.45	38.08	38.58
Crude fat	5.03	3.88	3.39
NDF	32.44	32.54	34.98
ADF	18.14	18.25	20.24
Ca	1.33	1.21	1.20
P	0.67	0.67	0.62
Crude ash	8.23	7.98	7.67

¹Means of 3 observations from 3 samples per treatment starter.

²Total digestible nutrients (TDN), NE_M, and NE_G were derived from NRC (2001).

ment were from the same purchase batches for 3 calf starters by design (Table 1), a lower CP and a higher NDF and ADF were observed in the ECS starter compared with the GCS starter. As an effective heating treatment method, extrusion can provide an extensive heat-denatured effect on the protein materials (Wang et al., 2004). A similar result was reported by Falder et al. (1992) in which the diet containing extruded soybeans had lower CP content than the diet containing raw soybeans (37.2% vs. 35.9%). The reduced CP content of protein feeds caused by extrusion did not occur in steam-flaked soybeans (Table 1). We also observed reduced EE content after heat processing occurring in SFCS and ECS starter diets. Although the exact mechanism for this reduction is unknown, heat damage to lipid compositions of corn grains and soybeans during steam-flaking and extrusion is probably a major reason. Other researchers (Chouinard et al., 1997) also observed that extrusion of raw soybeans decreased EE content from 17% to 16.3%. Slightly higher NDF and ADF contents in the ECS diet than in the GCS and SFCS diets were expected because of a concentrating effect from the decreased CP content of the former starter caused by extruding processing. No matter what changes occur during heat processing, nutrients provided by all 3 starter diets would meet the requirement of calves (NRC, 2001).

Calf Health

Calves were generally healthy throughout the trial. Least squares means for days scoured are presented in Table 3. Calves fed the ECS and GCS starters had increased scouring days and generally were not as healthy

compared with calves fed the SFCS starter. This observation is inconsistent with the report of Lesmeister and Heinrichs (2004) in which no significant treatment differences for calf health were observed. The reason may be related to a relatively lower starter intake for the SFCS treatment than for the ECS and GCS treatments in the present study.

Growth Performance

Least squares means for initial, weaning, and final BW, ADG, starter intake, total DMI, and feed efficiency of the whole period are summarized in Table 3. All of the calves weaned at about wk 8 according to their starter intake. Therefore, values for ADG, starter intake, and total DMI are separately presented during the preweaning, postweaning, and overall periods. Initial BW was similar among 3 treatments and averaged 51.77, 50.50, and 49.14 kg for GCS, SFCS, and ECS treatments, respectively, resulting in similar fresh milk intake among treatments. Final BW did not differ significantly among treatments ($P > 0.05$). During the preweaning period, no treatment differences were detected for ADG, starter intake, or total DMI, and weaning BW was similar for all treatments. During the postweaning period, starter intakes for the SFCS treatment were relatively lower than for the GCS and ECS treatments, though they were not significantly different ($P > 0.05$). Calves fed the SFCS diet had a better overall feed efficiency compared with those fed the GCS and ECS diets ($P = 0.05$) because of relatively lower starter intake with similar BW gain. This result is inconsistent with the observation of Lesmeister and Heinrichs (2004) in which calves were weaned at 28 d and the feed efficiency was negatively influenced by incorporation of steam-flaking corn in the starter during postweaning wk 5 and 6. Heat processing has been recognized to increase postruminal energy availability (Huntington, 1997; Crocker et al., 1998; Lesmeister and Heinrichs, 2004).

In addition, ADG was influenced by week of the treatment ($P < 0.05$; Figure 1). Daily gain was generally decreased during the weaning period (around wk 8; 574.49 g/d) compared with the preweaning (912.41 g/d) and postweaning (963.78 g/kg) weeks. Compared with ADG data from Lesmeister and Heinrichs (2004) using the texturized calf starter, preweaning ADG from this study was higher but postweaning ADG was similar. The difference in ADG between both studies may be attributed to the difference in physical form of calf starters (pelleted and texturized) and feed intake (higher in this study) between the 2 studies.

Body Structural Change

Least squares means for initial, final, and average daily change of HH, WH, HW, and HG are presented in Table 4. Heat processing of starter corn and soybeans had no significant ($P > 0.05$) effect on all of the structural growth traits (HH, WH, HW, and HG). This result is consistent with the previous report with processed sorghum in which calves offered steam-flaked sorghum starter had no differences in growth rate but tended to have higher grain intake (Schun et al., 1970; Abdelgadir and Morrill, 1995).

Blood Parameters

Blood HEM was significantly ($P < 0.01$) affected by starter treatment and by weeks of treatment (Figure 2), although the trends of change were different. The HEM for the SFCS treatment was the lowest at wk 3 and increased to the highest at wk 9, then decreased for all treatments. There was a higher ($P < 0.05$) blood HEM for the SFCS treatment than for the other 2 treatments from wk 6 to 13. This result was inconsistent with the observation of Lesmeister and Heinrichs

(2004) in which no treatment effects for HEM were measured over time. Adams et al. (1993) suggested that calves with lower hematological variables had higher mortality rates because of the difficulty in maintaining normal body temperature. Therefore, the higher HEM resulting from the SFCS treatment than from the other 2 starter treatments suggests that calves receiving the SFCS starter have better health conditions than those receiving the other 2 treatments.

The concentration of blood BHBA was significantly different ($P < 0.05$) among 3 starter treatments throughout the 10-wk trial except wk 3 and 6. A significant ($P < 0.05$) interaction between week and treatment indicated that magnitude of differences among 3 starter treatments varied with treatment time. As indicated in Figure 3, calves fed the SFCS starter had higher concentrations of blood BHBA than those fed the GCS and ECS starters, especially in the period of wk 3 to 6. The concentration of blood BHBA fluctuated within the average range values before weaning, increased markedly from wk 6 to 9, and finally kept constant after wk 9. During wk 6 to 9, calves fed the SFCS and GCS diets had higher BHBA concentrations, though DM feed intake was similar. This result is inconsistent

Table 3. Least squares means for BW, ADG, DMI, and days scoured of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans¹

Item	Calf starter			SEM	P-value
	GCS	SFCS	ECS		
BW (kg)					
Initial	51.77	50.50	49.14	2.247	NS
Weaning	76.76	76.27	75.03	2.782	NS
Final	114.10	108.59	110.16	4.115	NS
ADG (g/d)					
Prewaning	892.4	920.4	924.5	33.9	NS
Postweaning ²	889.1	769.4	843.5	52.5	NS
Overall periods	890.4	829.8	875.9	38.7	NS
DMI (g/d)					
Milk	860.2	850.7	823.1	30.71	NS
Starter					
Prewaning	117.2	111.9	156.1	23.3	NS
Postweaning	2,031.9	1,802.6	2,008.2	114.8	NS
Overall periods	1,266.0	1,126.3	1,267.4	73.4	NS
Hay					
Overall periods	189.9	168.9	190.1	11.0	NS
Total DMI					
Prewaning	1,034.8	1,015.2	1,036.8	43.6	NS
Postweaning	2,370.7	2,111.2	2,343.1	129.5	NS
Overall periods	1,836.4	1,672.8	1,820.6	88.1	NS
Feed efficiency ³	0.529 ^b	0.562 ^a	0.538 ^b	0.023	0.05
Days scoured ⁴	3.7 ^a	2.0 ^b	3.5 ^a	1.46	0.01

^{a,b}Means within a row without a common superscript letter differ ($P < 0.05$).

¹All of the data for each index were sampled from 10 calves.

²The decrease of ADG was probably caused by the transition from milk.

³Expressed as a ratio of kilograms of gain to kilograms of total DMI.

⁴Days with feces scores of 3 (runny) or 3 (runny) and 4 (watery); Larson et al. (1977).

NS = $P > 0.05$.

Table 4. Least squares means for structural growth measurements of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans¹

Item	Calf starter			SEM	P-value
	GCS	SFCS	ECS		
Hip height					
Initial (cm)	75.71	75.14	76.71	1.501	NS ¹
Final (cm)	88.86	88.29	90.14	1.131	NS
Change (cm/d)	0.188	0.188	0.192	0.014	NS
Wither height					
Initial (cm)	80.43	80.14	80.86	1.160	NS
Final (cm)	98.00	96.71	99.14	1.426	NS
Change, cm/d	0.251	0.237	0.261	0.015	NS
Hip width					
Initial (cm)	9.857	10.286	9.357	0.374	NS
Final (cm)	12.714	12.857	12.643	0.181	NS
Change (cm/d)	0.041	0.037	0.047	0.005	NS
Heart girth					
Initial (cm)	88.43	86.57	87.14	1.432	NS
Final (cm)	112.57	109.86	111.29	1.496	NS
Change (cm/d)	0.345	0.333	0.345	0.019	NS

¹All of the data for each index were sampled from 10 calves.

NS = $P > 0.05$.

with the observation of Quigley et al. (1991), indicating that an increase in blood BHBA is closely related to availability of calf starter. The BHBA concentrations in calves fed the SFCS and GCS starters increased dramatically from 0.135 mmol/L to 0.344 mmol/L during wk 6 to 9, whereas BHBA concentrations in calves fed the ECS starter increased from 0.140 mmol/L to 0.253 mmol/L.

The concentration of plasma glucose (Figure 4) decreased significantly with advancing age of calves. The concentration was characteristic of nonruminants (248.3 mg/dL), but reached a nadir at 54.44 mg/d from wk 9 to 13 in this study. The difference among weeks

reflected a difference in feed intake, especially from wk 3 to 8. Plasma glucose approached a concentration typical of mature ruminants (Swenson, 1984) during the postweaning period and did not differ among treatments. When compared among weeks, no significant difference ($P > 0.05$) except wk 11 was observed for plasma glucose concentration among starter treatments. Because blood samples were taken within 30 min after the a.m. feeding, this result cannot reflect the development of ruminal functions (Reid, 1953).

The concentration of plasma NEFA was not significantly affected by starter treatments within preweaning (wk 3–4) and postweaning (wk 11–13) periods, but was

Figure 1. Least squares means for BW of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans.

Figure 2. Least squares means for blood hematocrit (HEM) of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans.

higher ($P < 0.05$) in calves receiving the SFCS treatment during wk 5 to 9. Average concentration of NEFA in calves fed the GCS, SFCS, and ECS starters was 368.54, 505.08, and 322.73 $\mu\text{Eq/L}$, respectively, during wk 5 to 8. The plasma NEFA was affected by treatment weeks (Figure 5) and increased from 291.71 $\mu\text{Eq/L}$ at wk 3 to 432.02 $\mu\text{Eq/L}$ at wk 5, decreased to 183.88 $\mu\text{Eq/L}$ at wk 11, and did not differ thereafter. These results were consistent with those reported for mature ruminants (Kronfeld, 1965) and lambs (Leat, 1967), but higher than those reported for sheep (Trenkle and

Kuhlemeier, 1966) sampled within 4 h of feeding. The sampling time may affect NEFA concentrations because NEFA is sensitive to plasma glucose and VFA (Trenkle and Kuhlemeier, 1966). During wk 5 to 9, NEFA in calves fed the SFCS starter was higher than in those fed the other 2 treatments.

The correlations among selected blood parameters and starter intake in this study are summarized in Table 5. Significant correlations of glucose with starter intake ($r = -0.71$) support the viewpoint of Quigley et al. (1991) that early weaning has a significant effect

Figure 3. Least squares means for blood BHBA of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans.

Figure 4. Least squares means for plasma glucose of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and soybeans.

on plasma glucose concentration in so far as source of glucose is altered. Relationship between plasma glucose and NEFA concentrations ($r = 0.22$) is significant, suggesting that changes in plasma glucose may have induced concomitant changes in NEFA throughout the study. This result was consistent with the report of Trenkle and Kuhlemeier (1966).

CONCLUSIONS

Steam-flaked corn and soybeans included in the calf starter had no effect on ADG, BW, DMI, and calf body

structural growth compared with GCS and ECS, but feed efficiency was improved by SFCS. Calf starter intake for the SFCS treatment was numerically lower but did not differ significantly from the GCS and ECS treatments. Based on disease incidences, there were indications that feeding SFCS improved calf health compared with the other starter treatments. The performance of all calves in 3 treatments fell in the normal range with the variation of some blood parameters. All of the selected blood parameters changed with the calves' age, indicating the transition from neonatal calf stage to mature ruminant. The differences in HEM, BHBA,

Figure 5. Least squares means for plasma NEFA of Holstein calves receiving calf starter containing ground (GCS), steam-flaked (SFCS), or extruded (ECS) corn and raw soybeans.

Table 5. Coefficients¹ of correlation of starter intake (SI), blood hematocrit (HEM), blood BHBA, plasma glucose (GLU), and plasma NEFA

Item	HEM	BHBA	GLU	NEFA
SI	−0.199*	0.567	−0.712	−0.501
HEM		0.287	−0.358	0.193*
BHBA			−0.742	−0.070**
GLU				0.219

¹All coefficients are significant ($P < 0.05$) except data with an asterisk.

* $P < 0.10$; ** $P > 0.10$.

and NEFA concentrations among treatments indicated that calf metabolism is influenced by heat processing of corn grain and soybeans. These data suggest that the steam-flaking of corn and soybeans can influence the growth performance and selected blood parameters of calves and that, in this study, the extrusion of corn and soybeans had no beneficial effect on growth performance of calves.

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