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Summary

The objective of this study was to assess the effects of replacing soybean meal with a novel high-protein corn co-product (HPCC) as a protein source in dairy calf starter grains. Forty-two Holstein calves were blocked by sex and birthdate and assigned to one of three starter grain treatments offered from 14 to 84 days of age. Assigned diets replaced 0 (CTRL), 50 (50HPCC), or 100% (100HPCC) of the soybean meal (16.6% of dietary dry matter (DM)) with HPCC. Supplemental methionine and lysine were added to starters as needed so that all diets met the theoretical requirements for limiting amino acids in young calves. Calves were fed waste milk based on birth weight until initiation of step-down weaning at 42 days of age, with all calves being completely weaned by 56 days of age. Weights, growth measurements, and blood samples were obtained for each calf every 14 ± 1 day. Fecal samples were collected from each calf on the last four days of the study to determine diet digestibility. Inclusion of HPCC quadratically affected starter grain intake during the preweaning period (14 to 41 days of age), with 100HPCC calves consuming the most and 50HPCC calves consuming the least. However, provision of HPCC increased preweaning body weight, and there was no evidence that HPCC treatment affected feed efficiency. After weaning (56 to 84 days of age), calves tended to consume more starter grain as HPCC inclusion increased. Body weight and average daily gain (ADG) increased with increasing HPCC inclusion. Wither height was reduced for 50HPCC calves compared to 100HPCC calves, but HPCC inclusion did not affect any other measures of structural growth. Apparent total tract digestibility of DM and crude protein (CP) tended to be greater for the HPCC diets than CTRL. In conclusion, results suggest that HPCC is a suitable replacement for soybean meal in starter grains that have been balanced for methionine and lysine supply.

Introduction

Due to their availability and cost-value, dried corn distillers' grains **(DDG)** are a popular source of protein and energy in the diets of ruminants. Previous attempts to replace soybean meal in starter grains with conventional DDG have resulted in reductions of ADG, feed efficiency, rumen development, and diet digestibility. However, innovations in ethanol fractionation technologies have allowed for the production of more specialized distillers' products. High-protein corn co-products are produced when ethanol plants remove the fiber fraction of corn before fermentation and add yeast protein obtained after distillation to the final product. The increased CP (~50%)

and reduced fiber content of HPCC compared to conventional DDG make HPCC an attractive potential option to replace soybean meal in calf starter grains.

When comparing typical protein sources, such as soybean meal, to novel or byproduct protein sources in cattle diets, few studies account for differences in amino acid profiles. Methionine and lysine have previously been identified as the first limiting amino acids in the diets of young calves. Soybean meal products are more likely to be limiting in methionine, unlike corn, which is most likely to be limiting in lysine. Therefore, when comparing corn-based protein sources to soybean meal, differences detected may be a result of differing amino acid profiles.

The objective of this study was to evaluate the effects of replacing soybean meal in calf starter grains with increasing amounts of HPCC on calf growth performance, blood metabolites, and starter grain digestibility when grains are balanced for methionine and lysine.

Experimental Procedures

Forty-two Holstein (21 female, 21 male) calves born between June and August 2023 at the Kansas State University Dairy Teaching and Research Center were utilized in a 70-d feeding trial. Calves were housed on sawdust in individual outdoor hutches. Male calves were castrated with a rubber band within the first 7 days of life. At 14 days of age, calves were blocked by week and sex and then randomly assigned to 1 of 3 texturized starter grain treatments. Starter grain treatments were formulated so that 0% (CTRL), 50% (50HPCC), or 100% (100HPCC) of the DM from soybean meal (16.6% of diet DM) was replaced by HPCC (Protomax, ICM, Inc.; Colwich, KS). Each starter grain treatment was supplemented with rumen-protected methionine and lysine as needed to meet estimated calf metabolizable protein requirements. Ingredients and chemical composition of the starter grains are presented in Table 1. Chemical composition of the HPCC is presented in Table 2.

Starter grains and water were offered *ad libitum* throughout the study. Pasteurized waste milk was fed twice a day at a volume based on birth weight until 42 days of age. Calves born weighing <36.3 kg were offered 2.8 L (0.75 gallons) of milk/d; calves born weighing between 36.4 and 38.6 kg were offered 3.8 L (1 gallon) of milk/d; and calves born weighing > 38.6 kg were offered 5.7 L (1.5 gallons) of milk/d. Step-down weaning began at 42 days of age when calves were reduced to half their milk volume allowance and fed once daily. Milk allocation was eliminated when calves consumed 3 lbs of starter grain for three consecutive days, with all calves being completely weaned by 56 days of age.

Milk and starter grain intakes were recorded daily for each calf. At enrollment and every 14 ± 1 days thereafter, calves were weighed and measured for hip height, wither height, and girth circumference. On the last four days of the trial (80 to 84 days of age), fecal grab samples were collected twice daily to estimate apparent total tract digestibility.

It was not determined until after the conclusion of the experiment that calves were being offered different amounts of milk by farm staff. Therefore, intake, growth, and blood metabolite data from the preweaning (14 to 41 days of age) and weaning (42 to 55 days of age) periods were analyzed as a complete randomized design and excluded two calves that received 2.8 L (0.75 gallons) of milk/d (1 CTRL and 1 100HPCC calf). Analysis of intake, growth, blood metabolite, and digestibility data from the postweaning period (56 to 84 days of age) included all 42 calves as a randomized complete block design with repeated measures. Treatment, sex, and week were used as fixed effects. Milk allowance was used as a covariate for preweaning period models. Post-weaning models utilized block or calf (block) as the random effect. Planned contrasts were used to assess CTRL vs. HPCC, linear, and quadratic effects of HPCC inclusion. Data were presented as least square means with 95% confidence intervals (CI).

Results and Discussion

Preweaning and weaning period

Intake and growth

Starter grain treatment and sex interacted for starter grain intake as a percentage of body weight (BW) both in the preweaning and weaning periods ($P < 0.01$; Figure 1; Figure 2). In the preweaning period, there was no evidence of difference across treatments for starter grain intake in males, but 100HPCC females consumed more starter grain than 50HPCC females (Figure 1). The effects of HPCC on starter grain intake within the female calves are likely also why a quadratic effect of dose on overall starter grain intake was detected during the preweaning period (0.76 lbs/day [0.64, 0.89] for CTRL, 0.58 lbs/d [0.47, 0.69] for 50HPCC, 0.89 lbs/day [0.76, 1.03] for 100HPCC; $P < 0.01$).

Calves fed HPCC had greater BW than CTRL calves ($P = 0.02$; Table 3) in the preweaning period, and BW linearly increased with increasing HPCC inclusion ($P = 0.05$; Table 3). As is reported elsewhere in the literature, males grew heavier, taller, had greater heart girth, and had greater ADG than female calves during the preweaning period (Table 3). Calf weight and structural growth were unaffected by treatment or sex during the weaning period (Table 4).

Postweaning period

Intake and growth

After weaning, starter grain intake relative to BW continued to increase over time, and there was an interaction of treatment, sex, and week, which resulted in different rates of increasing intake ($P = 0.02$; Figure 3). Males fed 100HPCC increased their starter grain intake over time more than CTRL or 50HPCC males; however, 100HPCC females increased their intake over time less than CTRL or 50HPCC females. Increasing HPCC inclusion tended to linearly increase daily starter grain intake (6.4 lbs/d [5.9, 6.9] for CTRL, 6.7 lbs/d [6.2, 7.2] for 50HPCC, and 6.8 lbs/d [6.4, 7.4] for 100HPCC; $P = 0.08$).

Body weight and ADG linearly increased with increasing HPCC inclusion ($P = 0.05$; Table 4). Average daily gain of calves (approx. 2.2 lbs/d) was greater than the maximum recommendation of 1.98 lbs/d. Rates of gain greater than 1.98 lbs/d in prepubertal Holstein heifers have been associated with decreased first lactation milk production because of excess adipose deposition. In a practical setting, the addition of a forage component to this diet could have helped regulate energy intake and produced more desirable ADG. Treatment and sex interacted on feed efficiency, whereby 100HPCC females were less feed efficient than 100HPCC males ($P = 0.04$; Figure 4). The lack of differences in feed efficiency among other treatment groups, along with the absence of significant contrasts, suggests that HPCC inclusion did not reduce feed efficiency of weaned calves. There was a quadratic effect of HPCC on wither height, whereby CTRL calves were intermediate, 50HPCC calves were shortest, and 100HPCC calves were tallest ($P = 0.02$; Table 4). After weaning, males' growth only exceeded growth of females in hip height and ADG ($P < 0.05$; Table 4).

Digestibility

All three starter grains were highly digestible (≥80% of DM), as is expected for calf grains. Inclusion of HPCC tended to improve apparent total tract digestibility of DM and CP ($P = 0.09$; Table 5). This was unexpected as the replacement of soybean meal with DDG in calf diets has previously reduced DM digestibility and not affected CP digestibility. Apparent total tract digestibility of starch did not differ between treatments ($P > 0.05$; Table 5).

Conclusions

Altogether, the growth performance of calves during the first three months of age was maintained or improved by the substitution of soybean meal with HPCC in starter grains balanced to meet methionine and lysine requirements. Provision of HPCC increased the body weights of calves both before and after weaning without reducing feed efficiency. Starter grains containing HPCC tended to be more digestible than the CTRL diet. Overall results suggest that HPCC is a suitable replacement for soybean meal as a protein source in dairy calf starter grains supplemented to meet methionine and lysine requirements.

Acknowledgments

Funding for this project was provided by the Kansas Corn Commission (Manhattan, KS). The HPCC was donated by ICM Inc. (Colwich, KS).

Table 1. Starter grain ingredients and analyzed chemical composition

	Treatment		
Ingredient, % DM	**CTRL**	**50HPCC**	**100HPCC**
Not in pellet			
Cracked corn	20.9	20.9	20.9
Soybean meal, 44%	16.6	8.3	-
High protein corn co-product[1]	-	8.3	16.4
Oats	11.1	11.1	11.1
Molasses	10.5	10.5	10.5
Ajipro-L[2]	-	0.05	0.27
Within pellet			
Wheat middlings	24.6	24.6	24.6
Blood meal	7.0	7.0	7.0
MKC B1800[3]	3.7	3.7	3.7
Ground corn	3.5	3.5	3.5
Calcium carbonate	1.8	1.8	1.8
Vitamin E	0.05	0.05	0.05
Vitamin D	0.10	0.10	0.10
MetaSmart[4]	0.06	0.05	0.04
Nutrient, % DM			
DM	90.5	90.9	91.0
CP	23.7	24.3	25.6
AD-ICP	0.52	0.73	1.02
aNDFom	21.2	19.6	21.5
Starch	26.5	25.6	24.6
Ether extract	4.0	4.0	4.3
ME, Mcal/kg[5]	2.92	2.91	2.87

[1]Protomax (ICM Inc., Colwich, KS).
[2]Ajinomoto Health & Nutrition North America, Chicago, IL.
[3]Trace Mineral Premix (MKC Cooperative, Moundridge, KS); Guaranteed analysis: 2.0 g/kg lasalocid; 220,500.0 I.U./kg vitamin A; 22,050.0 I.U./kg vitamin D; 275.6 I.U./kg vitamin E; 11.0 ppm selenium; 25% min calcium; 16% min sodium chloride; 1% min magnesium.
[4]Adisseo Inc., Antony, France.
[5]Calculated from NASEM (2021).

Table 2. Chemical composition of the high-protein corn co-product

Nutrient, % DM	
Dry matter	95.1
Crude protein	47.74
Acid detergent insoluble crude protein	4.14
Neutral detergent fiber[1]	24.22
Starch	8.08
Ether extract	11.2

[1]amylase-treated and ash free (aNDFom).

Table 3. Physical growth and feed efficiency of dairy calves fed starter grains with increasing amounts of soybean meal replaced by high protein corn co-product (HPCC) during the preweaning period[1]

	Treatment			Sex		P-values			
Item	CTRL*	50HPCC*	100HPCC*	Female	Male	Trt*	Sex	Week	Contrasts[2]
Body weight, lb	111.3 [107.8, 114.8]	116.2 [112.7, 120.2]	116.8 [113.1, 120.8]	110.5 [107.6, 113.5]	119.3 [116.0, 122.7]	0.07	<0.01	<0.01	L, CvH
Wither height, in	32.6 [32.4, 32.9]	32.7 [32.4, 33.0]	32.9 [32.6, 33.2]	32.5 [32.2, 32.7]	33.0 [32.8, 33.2]	0.46	<0.01	<0.01	
Hip height, in	34.3 [34.0, 34.6]	34.6 [34.3, 35.0]	34.6 [34.2, 34.9]	34.2 [33.9, 34.4]	34.9 [34.6, 35.2]	0.37	<0.01	<0.01	
Girth, in	35.2 [34.8, 35.6]	35.4 [35.0, 35.8]	35.5 [35.1, 35.9]	34.8 [34.5, 35.1]	35.9 [35.6, 36.3]	0.58	<0.01	<0.01	
Average daily gain, lb/d	1.4 [1.2, 1.6]	1.2 [1.1, 1.4]	1.4 [1.2, 1.6]	1.2 [1.1, 1.4]	1.5 [1.3, 1.6]	0.22	0.04	-	q
Feed efficiency[3]	0.08 [0.07, 0.09]	0.07 [0.06, 0.09]	0.07 [0.06, 0.08]	0.07 [0.06, 0.08]	0.08 [0.07, 0.09]	0.35	0.07	-	

*CTRL = control starter grain containing no high protein corn co-product; 50HPCC = starter grain with 50% of the soybean meal replaced by high protein corn co-product on a dry matter basis; 100HPCC = starter grain with 100% of the soybean meal replaced by high protein corn co-product on a dry matter basis; Trt = treatment.

[1]Data presented at least square means with 95% confidence intervals.

[2]L: linear dose of HPCC ($P \leq 0.05$); l: linear tendency ($0.05 \leq P \leq 0.10$); Q: quadratic dose of HPCC ($P \leq 0.05$); q: quadratic dose of HPCC tendency ($0.05 \leq P \leq 0.10$); CvH: CTRL vs. HPCC ($P \leq 0.05$); cvh: CTRL vs. HPCC tendency ($0.05 \leq P \leq 0.10$).

[3]Feed efficiency calculated as g of gain/g of feed.

Table 4. Physical growth of dairy calves fed starter grains with increasing amounts of soybean meal replaced by high protein corn co-product (HPCC) during the postweaning period[1]

	Treatment			Sex		P-value			
Item	**CTRL***	**50HPCC***	**100HPCC***	**Female**	**Male**	**Trt***	**Sex**	**Week**	**Contrasts[2]**
Body weight, lb	207.9 [201.9, 214.1]	212.3 [206.4, 218.5]	214.1 [208.1, 220.2]	208.6 [202.8, 214.3]	214.3 [208.6, 220.2]	0.14	0.06	<0.01	L, cvh
Wither height, in	36.8[ab] [36.3, 37.3]	36.4[a] [35.9, 36.9]	36.9[b] [36.4, 37.4]	36.7 [36.3, 37.2]	36.7 [36.2, 37.1]	0.05	0.62	<0.01	q
Hip height, in	38.6 [38.2, 38.9]	38.5 [38.2, 38.9]	38.7 [38.3, 39.0]	38.4 [38.1, 38.7]	38.8 [38.5, 39.1]	0.71	0.02	<0.01	
Girth, in	41.9 [41.3, 42.5]	42.2 [41.6, 42.8]	42.3 [41.7, 42.9]	41.9 [41.3, 42.4]	42.4 [41.8, 43.0]	0.32	0.07	<0.01	
Average daily gain, lb/d	2.1 [1.9, 2.4]	2.2 [2.1, 2.4]	2.4 [2.2, 2.6]	2.1 [1.9, 2.2]	2.4 [2.2, 2.6]	0.14	<0.01	-	L, cvh

*CTRL = control starter grain containing no high protein corn co-product; 50HPCC = starter grain with 50% of the soybean meal replaced by high protein corn co-product on a dry matter basis; 100HPCC = starter grain with 100% of the soybean meal replaced by high protein corn co-product on a dry matter basis; Trt = treatment.

[1]Data presented at least square means with 95% confidence intervals.

[2]L: linear dose of HPCC ($P \leq 0.05$); l: linear tendency ($0.05 \leq P \leq 0.10$); Q: quadratic dose of HPCC ($P \leq 0.05$); q: quadratic dose of HPCC tendency ($0.05 \leq P \leq 0.10$); CvH: CTRL vs. HPCC ($P \leq 0.05$); cvh: CTRL vs. HPCC tendency ($0.05 \leq P \leq 0.10$).

[a,b,c]Means within row with separate letters differ.

Table 5. Apparent total tract digestibility of dry matter, crude protein, and starch in starter grains fed to weaned calves[1]

	Treatment			Sex		P-value		
Item	**CTRL***	**50HPCC***	**100HPCC***	**Female**	**Male**	**Trt***	**Sex**	**Contrasts[2]**
Apparent total tract digestibility, %								
Dry matter	80.1 [76.8, 83.3]	83.4 [80.2, 86.6]	83.4 [80.0, 86.8]	80.0 [77.3, 82.7]	84.5 [81.8, 87.1]	0.25	0.02	cvh
Crude protein	85.8 [83.4, 88.2]	88.2 [85.8, 90.5]	89.0 [86.5, 91.5]	86.1 [84.1, 88.1]	89.2 [87.3, 91.1]	0.15	0.03	cvh, l
Starch	96.6 [95.3, 97.8]	96.2 [95.0, 97.5]	96.5 [95.2, 97.7]	96.1 [95.1, 97.1]	96.7 [95.7, 97.8]	0.93	0.40	

*CTRL = control starter grain containing no high protein corn co-product; 50HPCC = starter grain with 50% of the soybean meal replaced by high protein corn co-product on a dry matter basis; 100HPCC = starter grain with 100% of the soybean meal replaced by high protein corn co-product on a dry matter basis; Trt = treatment.

[1]Data presented at least square means with 95% confidence intervals.

[2]L: linear dose of HPCC ($P \leq 0.05$); l: linear tendency ($0.05 \leq P \leq 0.10$); Q: quadratic dose of HPCC ($P \leq 0.05$); q: quadratic dose of HPCC tendency ($0.05 \leq P \leq 0.10$); CvH: CTRL vs. HPCC ($P \leq 0.05$); cvh: CTRL vs. HPCC tendency ($0.05 \leq P \leq 0.10$).

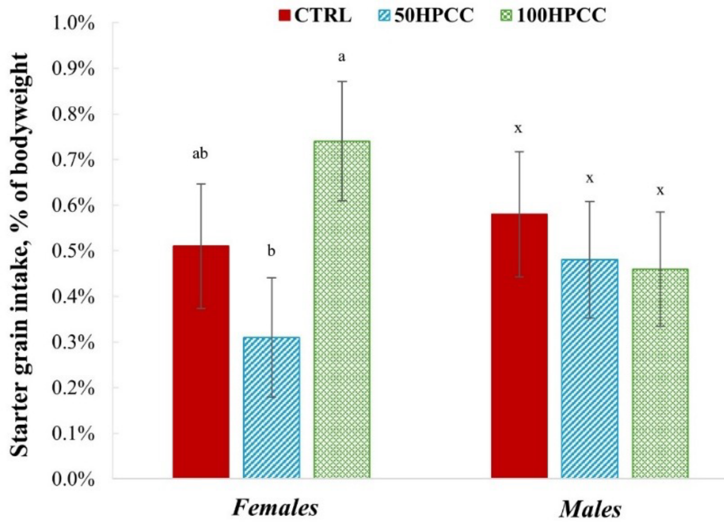

Figure 1. Starter grain as a percentage of body weight for dairy calves fed starter grains with increasing amounts of soybean meal replaced by high protein corn co-product (HPCC) during the preweaning period. Interaction of treatment and sex on starter grain intake as a percentage of body weight during the preweaning period ($P < 0.01$) presented as least square means with 95% confidence intervals (CI). Bars within sex without a common superscript differ ($P \leq 0.05$). A quadratic effect of dose was detected ($P < 0.01$).

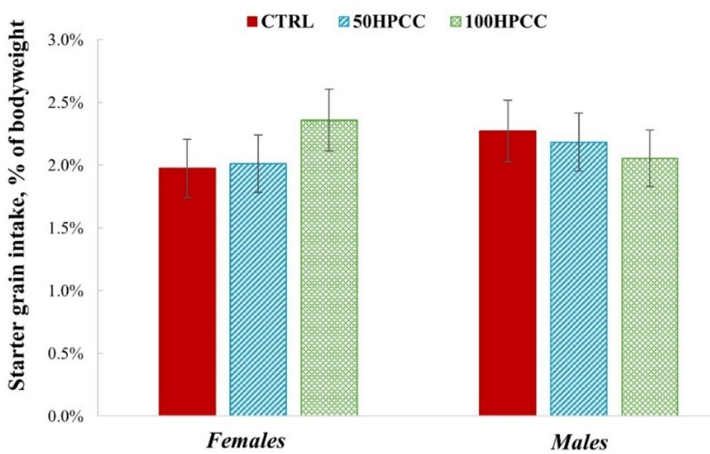

Figure 2. Starter grain intake as a percentage of body weight of Holstein dairy calves during the weaning period fed starter grains with increasing replacement of soybean meal with a high-protein corn product (HPCC). Interaction of treatment and sex on starter grain intake as a percentage of body weight during the weaning period (P < 0.05) presented as least square means with 95% confidence intervals (CI). Means did not separate after adjustment for multiple comparisons.

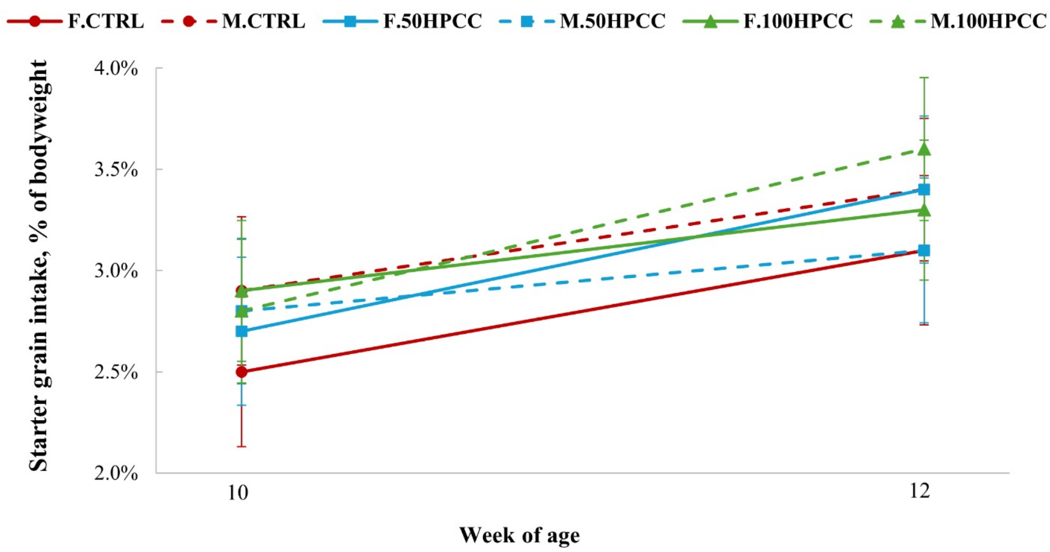

Figure 3. Starter grain as a percentage of body weight for dairy calves fed starter grains with increasing amounts of soybean meal replaced by high protein corn co-product (HPCC) during the postweaning period. Interaction of treatment, sex, and time on starter intake as a percentage of body weight during the postweaning period ($P = 0.02$) presented as least square means with 95% confidence interval (CI). Means did not differ within week. A quadratic effect of dose was detected ($P < 0.01$).

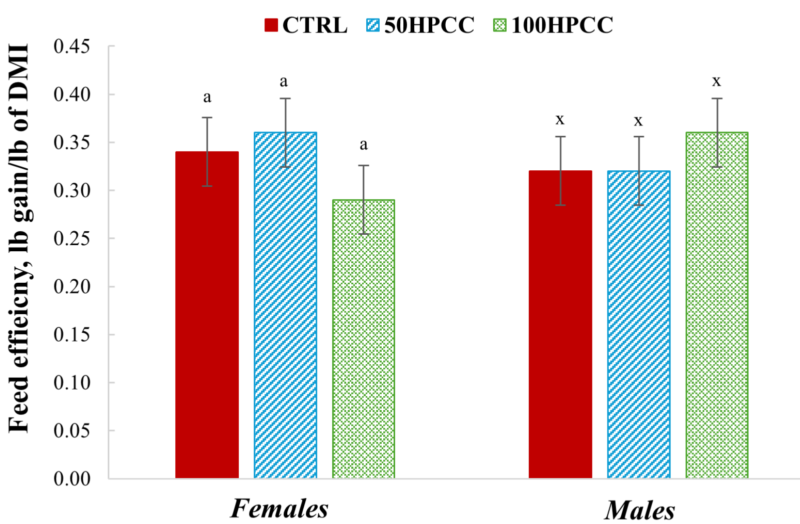

Figure 4. Feed efficiency of dairy calves fed starter grains with increasing amounts of soybean meal replaced by high protein corn co-product (HPCC) during the postweaning period. Interaction of treatment and sex on feed efficiency during the postweaning period ($P < 0.04$) presented as least square means with 95% confidence interval (CI). Bars within sex without a common superscript differ ($P \leq 0.05$).