

# Feeding a calf starter containing highly digestible corn may improve calf growth<sup>1</sup>

David P. Casper\*<sup>2</sup>, Shruti Srivastava†, and Brittney Strayer‡

\*Furst-McNess Company, Freeport, IL 61032; †South Dakota State University, Brookings, 57007; and ‡NutriQuest, Inc., Mason City, IA 50401

**ABSTRACT:** New corn hybrids have been developed by Masters Choice (MC) that vary in energy density due to an altered starch structure that improves ruminal and intestinal starch digestibility. Twenty-nine (1 to 3 d old;  $40.6 \pm 1.72$  kg) Holstein heifer and 2 Holstein bull calves (31 total) were randomly assigned to 1 of 2 calf starters (CS) to measure growth performance of Holstein calves through 8 wk of age. Treatments were: 1) Control CS (CN): containing 40% conventional ground corn dry matter (DM) basis and 2) MC CS: containing 40% MC corn (DM basis). Calf starters were formulated to contain 24% crude protein (CP; DM basis) and were fed for ad libitum consumption as a pellet starting on d 1. The study was conducted from April 22 through August 1, 2013. Body weights and body measurements were collected weekly. All calves were fed a 28% CP, 18% fat accelerated milk replacer (all milk protein) twice daily in 2 equal feedings at the rate of

0.64 kg/d from 0 to 14 d, 0.96 kg/d from 15 to 42 d and fed once daily at 0.48 kg/d from d 42 to 49. Data were analyzed using mixed procedure of SAS version 9.4. Body weight gains (26.2 and 28.8 kg for CN and MC, respectively) were similar ( $P > 0.10$ ) between treatments. No significant ( $P > 0.10$ ) differences in frame growth parameters as measured by change in body length (8.1 and 7.8 cm), heart girth (12.1 and 12.9 cm), hip height (10.9 and 11.1 cm), and wither height (10.9 and 10.9 cm). Calves fed MC CS were similar ( $P > 0.10$ ) in ADG compared to calves fed CN CS (0.46 and 0.51 kg/d). Calves fed MC CS tended to have greater ( $P < 0.10$ ) feed efficiency than calves fed CN CS. Calves fed MC CS demonstrated greater ( $P < 0.05$ ) total tract nutrient digestibility of several nutrients, which lead to the cost of gain being more economical for calves fed MC when corn is priced the same. The use of new corn hybrids has the potential to improve nutrient digestion and animal performance.

**Key words:** calf, calf starter, corn hybrid, growth performance, starch

© 2017 American Society of Animal Science. This is an open access article distributed under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Transl. Anim. Sci. 2017.1:343–350  
doi:10.2527/tas2017.0041

## INTRODUCTION

New corn hybrids have been developed by Masters Choice (MC) that vary in energy density due

to an altered starch structure that is softer (floury), which could improve ruminal and intestinal starch digestibility (Giuberti et al., 2014). The alteration in the ratio of amylose to amylopectin produces a less dense corn kernel that requires 20% lower electrical consumption for grinding through a hammer mill (Mark Kirk, Masters Choice, personal communication). Poultry work (Parsons, et. al., Univ. of Illinois, unpublished work) demonstrated a greater ( $P < 0.05$ ) metabolizable energy (ME) content of the corn on a dry matter (DM) basis. In agreement, beef heifers (Atkinson, et. al., Southern Illinois University, unpublished work) fed MC corn compared to conventional corn hybrid demonstrating greater ( $P < 0.07$ ) average daily gain (ADG) and improved feed efficiencies ( $P < 0.10$ ) which indicates a greater energy density.

<sup>1</sup>The authors would like to thank Masters Choice Seeds (Anna, IL), Diamond V (Cedar Rapids, IA), and the Director of the South Dakota Agricultural Experiment Station for financial support of this research project. The authors express their appreciation to the SDSU Veterinary Science Department and the Dairy Research and Training Facility for the care of the dairy animals. Also, appreciation is extended to the Dairy Science production graduate students for assistance in feeding, sample collection, and analyses.

<sup>2</sup>Corresponding author: david.casper@mcness.com

Received June 21, 2017.

Accepted August 9, 2017.

The hypothesis was that using a highly degradable starch source for the manufacture of a calf starter (CS) could increase nutrient (starch) digestibility and calf growth performance. It was further hypothesized that the MC CS with the less dense starch structure would be more digestible increasing the net energy content of the ration, thereby resulting in enhanced calf growth and feed efficiency. The research objective was to measure the growth performance of calves fed a normal corn CS compared to a less dense starch structure MC CS when fed an accelerated milk replacer program.

## MATERIALS AND METHODS

Calves were cared for according to the approved protocol by the South Dakota State University Institutional Animal Care and Use Committee.

### Calf Management

The experiment was conducted from April 22 to August 1, 2013. For this experiment, 9 Holstein calves from birth (1 d) were used at South Dakota State University Dairy Research and Training Facility (SDSU-DRTF) and 22 calves between 1 and 3 d of age were relocated from a local dairy farm (KC Dairies, LLC, Elkton, SD) and housed at the Animal Research Wing of SDSU Veterinary Science Department. The distance between these 2 research locations was less than 4 km, but both facilities are bio-secure. This situation occurred to complete the trial in a reasonable amount of time without having environmental influences due to insufficient calves available at the SDSU DRTF. There were 2 males (1 on each treatment) and 29 female calves. Calves were randomly assigned to 1 of the 2 treatments based on dairy farm source (i.e., DRTF and KC Dairy, LLC). Calves were fed 3.78 L of colostrum within 1 h of birth and again at 12 h after birth, if the colostrum reading of the mother's colostrum was > 50 mg/L, otherwise colostrum replacer (Colstrx, AgriLabs, St. Joseph, MO) was fed at the SDSU DRTF. Commercial dairy farm calves were fed pooled colostrum before their arrival at SDSU for the first 1 to 3 d of life.

Calves were kept in individual calf hutches (Calf-Tel, German Town, WI.) bedded with straw. All calves were fed milk replacer (MR; Mother's Pride Milk Replacer, Hubbard Feeds, Inc., Mankato, MN) that contained 28% CP and 18% fat from 1 to 49 d. The MR was fed once in the morning at 0500 h and in the evening at 1600 h. The MR feeding rate varied from 0.64 kg/d split into 2 feedings from 2 to 14 d and then increased to 0.96 kg/d fed in 2 feedings from 15 to 42 d and 0.48 kg/d fed in 1 feeding in the morning from 42 to 49 d. Water and CS were available ad libitum to the calves from the begin-

ning of the study. Initially, calves were given 0.113 kg CS/d and when no CS refusals were recorded, CS was increased to 0.226 kg at the next feeding. If there was no CS weigh-back the calf was being fed 0.226 kg or more, it was bumped up to 0.45 kg at the next feeding. The goal was to keep CS offered for ad libitum consumption but reduce the amount of wastage, i.e., limited CS weigh back amounts. Water was available in individual buckets and refreshed each morning (0600 h).

Calves were assigned to 1 of 2 experimental CS on the first d of the experiment by farm source. Treatments were control (CN): normal corn grain (Dekalb; Monsanto, St. Louis, MO) and Masters Choice (MC; Anna, IL): corn grain (MC-527) formulated into a pelleted CS (Table 1). The CS were formulated to be isonitrogenous and isocaloric containing 24.2% CP and 3.04 Mcal/kg ME and were formulated to meet or exceed NRC (2001) nutrient guidelines. The CSorts and feed amounts were measured daily at 0700 h. Weaning com-

**Table 1.** Ingredient composition for Control (CN) and Masters Choice (MC) calf starters

Ingredients	Calf starter	
	CN	MC
	% of Mix	
Corn, ground (DeKalb)	40.0	—
Corn, ground (MC-527)	—	40.0
Oats rolled	11.3	11.3
Molasses	8.0	8.0
SBM, 48% CP	30.0	30.0
Corn distillers	7.5	7.5
Rumensin 90	0.04	0.04
Limestone	1.65	1.65
Premium, VTM <sup>1</sup>	1.00	1.00
Super Micro <sup>2</sup>	0.50	0.50
Selenosource 2000 <sup>3</sup>	0.015	0.015

<sup>1</sup>Vitamin trace mineral premix: Agri-King Inc., Fulton, IL consisting of: yeast culture, rice hulls, magnesium mica, Manganese sulfate, zinc sulfate, vitamin E supplement, active dry yeast, copper sulfate, dried *Aspergillus oryzae* fermentation extract, zinc proteinate, iron sulfate, mineral oil, manganese proteinate, choline chloride, copper proteinate, vitamin A supplement, d-calcium pantothenate, thiamine mononitrate, iron proteinate, niacin, cobalt carbonate, zinc polysaccharide complex, zinc amino acid complex, copper amino acid complex, manganese amino acid complex, cobalt glucohepatonate, vitamin B<sub>12</sub> supplement, iron polysaccharide complex, manganese polysaccharide complex, copper polysaccharide complex, cobalt proteinate, riboflavin supplement, biotin, calcium iodate, vitamin D<sub>3</sub> supplement, pyridoxine hydrochloride, and folic acid.

<sup>2</sup>Vitamin premix: Agri-King Inc., Fulton, IL. Consisting of rice hulls, magnesium mica, calcium carbonate, yeast culture, corn distillers grains with solubles, zinc proteinate, magnesium oxide, mineral oil, manganese proteinate, vitamin E supplement, manganese sulfate, active dry yeast, copper proteinate, dried *Aspergillus oryzae* fermentation extract, *Yucca Schidigera* extract, d-calcium pantothenate, choline chloride, niacin supplement, thiamine mononitrate, cobalt proteinate, vitamin A supplement, ascorbic acid, vitamin B<sub>12</sub>, riboflavin supplement, natural and artificial flavors, biotin, vitamin D<sub>3</sub> supplement, pyridoxine hydrochloride, calcium iodate, folic acid, chromium propionate.

<sup>3</sup>Selenosource, Diamond V mills (Cedar Rapids, IA).

menced when calves were 6 wk of age and MR was reduced by half and fed in the morning (0600 h). Weaning was complete at the start of wk 7 of age.

### **Health Parameters**

Feces were monitored every day and fecal sores were assigned based on a 1 to 5 point scale (1 = stiff, 2 = pasty, 3 = normal, 4 = loose, 5 = watery; Stamey et al., 2012). Calves were vaccinated against viral diseases according to SDSU-DRTF and KC dairy vaccination protocols. Calves were monitored regularly for body temperature and respiration rate and if any abnormality was found were treated immediately. If a calf was found with loose feces, an electrolyte solution of 1.89 L was given orally for 3 consecutive d. Non-infectious diarrhea was treated with 90 mL Bismuth (Agrilabs, Saint Joseph, MO) given twice daily until diarrhea ceased. During the sixth week of the study, 1 calf was found with diarrhea mixed with blood. Fecal samples were examined at SDSU Veterinary Science department and results confirmed coccidiosis. The calf was treated with 30 mL Corid (Amprolium; Merial Inc., Duluth, GA) included in the MR for the rest of the MR feeding period. Many calves showed symptoms of clostridium toxicity. Two bloated and many had white pasty diarrhea. Thus, 5 cc Bacitracin mixed with water (Prairie Livestock Supply, Worthington, MN) in the morning and evening was administered in the milk of calves at 4 wk onward till cessation of milk feeding, as a clostridium treatment.

### **Sample Collection**

Samples of CS and MR were collected every 2 wk from the (random) bag opened at that time and were stored at  $-20^{\circ}\text{C}$  for further analysis. Daily CS refusals were weighed, recorded, and discarded. A fecal grab sample was collected from each calf on the last d of the study and stored at  $-20^{\circ}\text{C}$ . Body weight, hip height, wither height, body length, heart girth, and hip width was recorded weekly on Thursdays. A Hip-o-meter (Elanco Animal Health, Greenfield, IN) was used for measuring hip width, a weighing scale (Digi-Star, LLC, Fort Atkinson, WI) mounted on an all-terrain vehicle cart was used for BW, and a measuring tape (Ketchum Manufacturing Inc., Brockville, ON, Canada) were used for hip height, wither height, body length, and heart girth.

### **Laboratory Analysis**

Samples of CS and MR were composited by month and stored in foil lined bags and sent to a commercial laboratory (Analab, Fulton, IL) for nutrient analyses. Analyses included DM, CP, Soluble Protein,

NDF, ADF, neutral detergent insoluble protein (NDIP), Starch, Oil, Ca, P, Mg, K, S, Na Cl, Fe, and acid insoluble ash (AIA). All AOAC (2016) methods used were used for DM, CP, ether extract, ash, Ca, P, K, and Mg. Fecal samples were dried in oven at  $50^{\circ}\text{C}$  for 48 h (Style V-23, Despatch oven Co. Minneapolis, MN) and allowed to air equilibrate, then weighed and DM calculated. Due to limited fecal amounts, samples were composited in groups of three calves per treatment as they finished the study. Samples were then ground by passing through a 2 mm Willy mill screen (Model 3; Arthur H. Thomas Co. Philadelphia, PA) followed by grinding through a ultracentrifuge mill (Brinkman Instruments Co., Westbury, NY) having a 1 mm screen and then sent for nutrient analysis at the commercial laboratory, as described above.

Blood samples were collected on the fourth d via jugular venipuncture using a 10-mL serum Vacutainer separation tube with an 18 gauge needle (Animal Health International, Greeley, CO). Samples were allowed to clot, centrifuged at  $1000 \times g$  for 20 min, serum separated, and analyzed for total serum protein level using a refractometer (TS Meter Refractometer, American Optical Co., Buffalo, NY) to ensure an adequate concentration of passive immune status was achieved for each calf. No calves were below the threshold of 5.0 mg/dL.

### **Statistical Analysis**

All data were subjected to least square analysis of variance (ANOVA) using the PROC MIXED procedure of SAS (version 9.4, SAS Inst. Inc., Cary, NC) for a completely random design (Steele and Torrie, 1980). Fixed effects were treatment, wk and the interaction of treatment  $\times$  wk, while calf was considered a random effect. The study wk was analyzed as a repeated measure having an autoregressive covariance structure. Intake of CS, MR, and total DMI were first pooled by wk then analyzed. Significance was declared at  $P < 0.05$  and trends at  $0.05 \leq P < 0.10$ . Data was analyzed as individual wk and time periods of 1 to 42 d (pre-weaning), 42 to 56 d (post-weaning) and 1 to 56 d (overall; pre- plus post-weaning).

## **RESULTS**

The nutrient composition of CS and MR are given in Table 2. The MR composition for CP and other nutrients met or exceeded formulation specifications. The CN CS contained lower CP than the formulation specification, while MC CS met CP formulation specification. The nutrient composition for both CS for ADF and starch were higher, while NDF concentrations were lower for the MC CS and slightly higher for CN CS compared to formulation specifications. However, these two grain hy-

**Table 2.** Nutrient Composition (% of DM) of milk replacer (MR) and calf starter (CS) formulated with Control (CN) or Masters Choice (MC) corn

Nutrient <sup>1</sup>	MR 28:18	CN	MC
DM, %	94.50	88.7	87.4
CP, %	28.89	21.9	24.8
SP <sup>2</sup> , % of CP	—	26.8	26.5
ADF, %	—	8.7	7.0
NDF, %	—	14.1	10.6
NDIP <sup>3</sup> , %	—	1.3	0.9
Fat, %	—	3.1	3.3
Starch, %	—	36.8	35.4
Ash	—	5.9	5.9
Ca	0.94	0.74	1.01
P	0.72	0.40	0.43
Mg	0.14	0.22	0.23
K	2.17	1.26	1.37
ME, Mcal/Kg DMI	4.79	2.58	2.67

<sup>1</sup>Nutrient analysis conducted according to AOAC (2016) procedures by Analab (Fulton, Illinois).

<sup>2</sup>Soluble protein.

<sup>3</sup>Neutral detergent insoluble protein.

brids were grown and harvested in different regions and the slight differences in nutrient composition would be confounded with differences in starch structure.

### Body Weight and Average Daily Gain

The total serum protein (TSP) values were similar ( $P > 0.10$ ) at 5.85 and 5.70 mg/dl for CN and MC, respectively which indicated that either treatment was given an advantage via colostrum quality and that all calves received adequate amounts of colostrum within the recommended time periods. A TSP value equal to or greater than 5.0 to 5.2 mg/dl is correlated with successful passage of immunity in healthy calves that are not dehydrated (Tyler et al., 1996). Calves fed CN or MC CS were similar ( $P > 0.10$ ) in growth rates (Table 3) when measured via several parameters. Average daily gains (kg/d) were similar ( $P > 0.10$ ) while, the pre- and post-weaning ADG were similar ( $P > 0.10$ ) for calves fed both CS, however, calves fed MC demonstrated numerically better growth rates (0.46 and 0.51 kg/d, respectively). Calves fed both CS gained BW till 6 wk of age when weaning was initiated, which demonstrated that calves fed both CS reduced BW gain (Post-weaning slump in wk 7 and 8; Fig. 1). The decrease in BW gain is typical when weaning calves off an accelerated MR program (Hill et al., 2007).

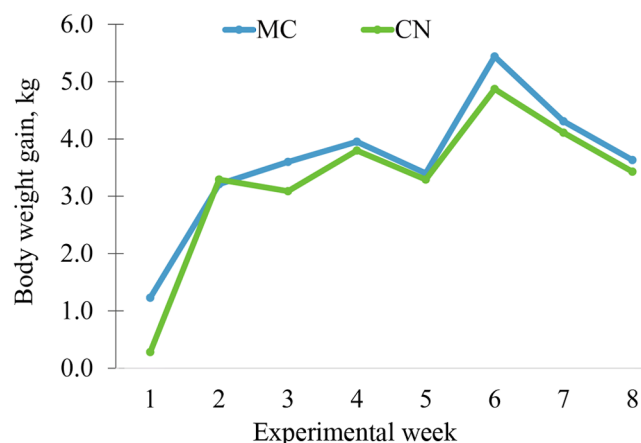
### Fecal Scores

Calves fed both CS were similar ( $P > 0.10$ ) in fecal scores throughout the 8 wk study (Table 4). However, calves fed the CN CS had greater ( $P < 0.05$ ) number of

**Table 3.** Body weight (BW), average daily gain (ADG), pre-weaning (PreWG) and post-weaning (PWG) gain for calves fed Control (CN) or Masters Choice (MC) calf starters

Measurement	Diets <sup>1</sup>		SE	<i>P</i> -value	
	CN	MC		Trt	Trt × wk
Average BW, kg	51.7	52.3	0.47	NS <sup>1</sup>	NS
Initial BW, kg	40.3	39.4	1.12	NS	NS
Final BW, kg	66.5	68.2	1.87	NS	NS
BW Gain, kg	26.2	28.8	1.23	NS	NS
ADG, kg/d	0.46	0.51	0.02	NS	NS
PreWG, kg	22.7	25.1	1.05	NS	NS
PWG, kg	3.4	3.6	0.50	NS	NS
PreW_ADG, kg/d	0.46	0.51	0.02	NS	NS
PW_ADG, kg/d	0.49	0.52	0.07	NS	NS

<sup>1</sup>NS = Nonsignificant,  $P > 0.10$ .

**Figure 1.** Body weight gain × week for calves fed Control (CN) or Masters Choice (MC) calf starters.**Table 4.** Fecal scores (FS) and days having FS of 1 to 5 for calves fed Control (CN) or Masters Choice (MC) calf starters

Measurement	Diets <sup>1</sup>		SE
	CN	MC	
Fecal score	1.5	1.6	0.053
Days, FS = 1	35.9	29.0*	1.99
Days, FS = 2	12.3	16.6*	1.43
Days, FS = 3	4.2	4.8	0.58
Days, FS = 4	2.5	2.2	0.50
Days, FS = 5	1.5	1.6*	0.053

\*Means differ,  $P < 0.05$ .

days when fecal scores were a 1 than calves fed MC CS, while the number of days calves having a fecal score of 2 or 5 were greater ( $P < 0.05$ ) for calves fed MC compared to CN CS calves. These data indicate that calves fed highly digestible MC corn, may have softer feces than calves fed conventional ground corn due to more starch being more easily digested. Conversely, a less digestible

starch source may result in firmer feces, which may not be beneficial to the calf, due to less starch being digested.

### Skeletal Growth Parameters

Calves fed both CS were similar ( $P > 0.10$ ) in body frame measurements throughout the 8 wk study (Table 5). Using initial values as a covariate did not improve statistical precision ( $P > 0.10$ ).

### Dry Matter Intake and Feed Efficiency

Intake of milk powder (DM basis) was similar ( $P > 0.10$ ) for calves fed both CS as per study design (Table 6). No significant differences were detected for CS intake and DMI between CS treatments. A trend ( $P < 0.10$ ) was observed in the treatment  $\times$  wk interaction for CS intake at 8 wk, which indicated that calves fed MC CS were consuming more DMI (i.e., CS) compared to calves fed CN. There was a trend ( $P < 0.09$ ) observed in feed efficiency for calves fed MC compared to calves fed CN (Fig. 2) CS. The calculated cost per unit gain obtained was \$2.22 for calves fed CN CS and \$2.06 for calves fed MC CS.

### Nutrient and Mineral Digestibility

Calves fed MC CS demonstrated greater ( $P < 0.05$ ) nutrient digestibilities of most nutrients measured, ex-

**Table 5.** Hip height (HH), wither height (WH), body length (BL), heart girth (HG), and hip width (HW) for calves fed Control (CN) or Masters Choice (MC) calf starters

Measurement	Diet		SE	P-value	
	CN	MC		Trt	Trt $\times$ wk
HH Initial, cm	80.5	80.2	0.94	NS <sup>1</sup>	NS
HH Final, cm	91.4	91.3	0.73	NS	NS
HH Gain, cm	10.9	11.1	0.60	NS	NS
Average HH, cm	85.9	85.5	0.30	NS	NS
WH Initial, cm	75.8	75.9	1.00	NS	NS
WH Final, cm	86.7	86.8	0.73	NS	NS
WH Gain, cm	10.9	10.9	0.71	NS	NS
Average WH, cm	81.2	81.2	0.31	NS	NS
BL Initial, cm	64.0	63.5	1.16	NS	NS
BL Final, cm	72.0	71.3	1.04	NS	NS
BL Gain, cm	8.1	7.8	0.90	NS	NS
Average BL, cm	67.8	67.6	0.37	NS	NS
HG Initial, cm	81.4	81.6	1.21	NS	NS
HG Final, cm	93.6	94.5	1.10	NS	NS
HG Gain, cm	12.2	12.9	0.82	NS	NS
Average HG, cm	86.7	87.0	0.44	NS	NS
HW Initial, cm	26.0	25.6	0.35	NS	NS
HW Final, cm	32.4	32.3	0.54	NS	NS
HW Gain, cm	6.5	6.7	0.43	NS	NS
Average HW, cm	28.7	28.4	0.14	NS	NS

<sup>1</sup>NS = Nonsignificant,  $P > 0.10$ .

cept for NDF, hemicellulose and P (Table 7) compared to calves fed the CN CS. Certainly, it would be expected that increasing the digestibility of several nutrients would

**Table 6.** Intake of Milk Replacer (MR), calf starter (CS), dry matter intake (DMI) and feed efficiency (FE) for calves fed Control (CN) or Masters Choice (MC) calf starters

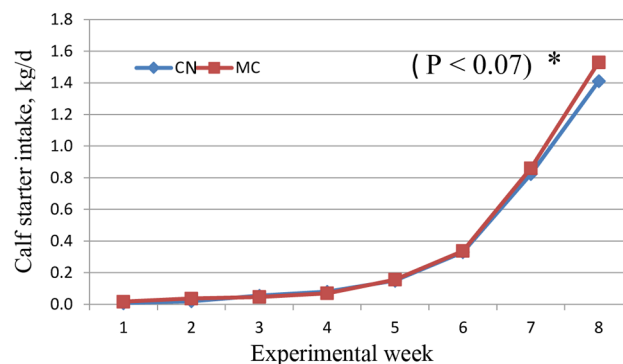
Measurement	Diets <sup>1</sup>			P-Values	
	CN	MC	SE	Trt	Trt $\times$ wk
Milk Intake, kg/d	0.72	0.72	0.01	NS <sup>1</sup>	NS
CS Intake, kg/d	0.36	0.38	0.03	NS	NS
PrewCSI <sup>2</sup> , kg/d	0.21	0.22	0.02	NS	NS
PWCSI <sup>3</sup> , kg/d	1.41	1.53	0.08	NS	NS
DM Intake, kg/d	0.99	1.01	0.03	NS	NS
FE, kg/kg	0.51	0.55	0.02	0.09 <sup>4</sup>	NS

<sup>1</sup>NS = Nonsignificant,  $P > 0.10$ .

<sup>2</sup>Pre-weaning calf starter intake.

<sup>3</sup>Post-weaning calf starter intake.

<sup>4</sup>Significant Trend at  $0.05 \leq P \leq 0.1$ .



**Figure 2.** Calf starter intake  $\times$  week for calves fed Control (CN) or Masters Choice (MC) calf starters.

**Table 7.** Nutrient digestibility by calves fed Control (CN) or Masteers Choice (MC) calf starters

Nutrient <sup>1</sup>	CN	MC	SE	P-value
DM	86.2	94.5	1.08	0.01
CP	85.2	91.1	1.17	0.01
NDF	55.6	65.2	4.42	0.11
ADF	54.2	68.5	3.49	0.02
Hemicellulose	58.0	58.7	6.28	0.92
P	82.4	87.2	2.46	0.20
Mg	53.1	71.6	4.65	0.01
S	79.2	87.3	1.82	0.01
Mn	65.3	77.0	4.67	0.06
Fe	39.1	51.6	4.45	0.05
Cu	81.8	65.7	5.85	0.06
Zn	47.4	63.6	6.20	0.04

<sup>1</sup>Nutrient digestibility conducted according to AOAC (2016) nutrient analysis procedure using acid insoluble ash as an internal marker by Analab (Fulton, Illinois).

also increase digestibility of other nutrients due to the corn kernel matrix being more completely digested.

## DISCUSSION

### *Body Weight and Average Daily Gain*

Initial BW measures were 44 kg for Brown et al. (2005) and for our calves it was 40 kg, which are similar to that of calves used by Bach et al. (2007) and Rinckretret al. (2013). According to Heinrichs and Hargrove (1987) the standard BW for heifers at 4 wk of age is 62.1 kg and 82.1 kg at 8 wk, which is higher than the current study. The BW at 4 wk are similar to those obtained by Ragsdale (1934) and Matthews and Fohrman (1954), which are 50.8 kg and 54.8 kg, respectively.

The ADG obtained by Brown et al. (2005) for their high diet containing 30.3% CP in MR and 25% CP in CS was 0.68 kg/d, which is higher than ADG reported here. This discrepancy is due to ad libitum MR intake, while MR intake was highly controlled in this study. Bach et al. (2007) reported an ADG value of 0.766 kg/d for their pelleted diet. Rincker et al. (2011) reported an ADG of 0.44 kg/d on a conventional MR and CS diet, which is similar to the CN diet in this study. However, Rincker et al. (2011) reported an ADG of 0.64 kg/d on intensive MR + CS diet, which is higher than data reported here. These differences can be explained by a higher MR feeding rate of 1.12 kg/d from d 31 to 37 than the MR feeding rate in this study. Stamey et al. (2012) obtained an ADG of 0.80 for a high MR and high CP CS, which is much greater than this study, which could be due to higher amount of MR intake and favorable weather conditions. The ADG reported in this study were slightly lower than those reported by others for calves where the increased amounts of MR were fed with CS (Cowles et al., 2006; Hill et al., 2008). The ADG reported in this study is greater than ADG reported by Ferreira et al. (2012) when feeding different corn types with different grinding degrees. The low ADG might be the result of using cross bred Holstein calves. Aita et al. (2006) reported an ADG of 0.47 kg/d for Jersey calves weaned at 56 d of life, which is similar to the current study for calves fed the CN CS. In a study involving Holstein calves fed milled grains in a suckling period, Schalch et al. (2001) observed an ADG of 0.45 kg/d for animals through 42 d. In a study involving calves fed mashed, pelleted, and textured concentrate, Franklin et al. (2003) observed gains on the order of 0.50, 0.44, and 0.55 kg/d, respectively. Cunha et al. (2007) reported ADG of 0.47 kg for crossbred animals through 8 wk of age fed a commercial concentrate. Akayezu et al. (1994) observed ADG of 0.56 kg/d and 0.62 kg/d for CS containing 16.8% and 19.6% CP, respectively. Hill et al. (2009) had ADG values of 0.50 kg/d and 0.53 kg/d for calves weaned at 28

and 42 d of age, respectively, for 26% CP, 17% fat at MR feeding rate of 0.68 kg/d, which is similar to the results of this study. Gain per wk by calves in both groups were higher up to 6 wk, until the post-weaning slump observed in wk 7 and 8. Several researchers have indicated that over 0.70 kg DM from MR will result in a post-weaning reduction in ADG by depressing CS intake (Bar-Peled et al., 1997; Davis and Drackley, 1998; Hill et al., 2006, 2007; Strzetelski et al., 2001; Terré et al., 2007; and Tikofsky et al., 2001). The lower ADG obtained could be due to post-weaning slump due to lower CS intake, which is due to higher feeding rate and feeding duration of MR. Basically trading CS DMI with MR DMI.

### *Skeletal Growth Parameters*

During the second wk of age calves in the study of Rincker et al. (2011) fed an intensive MR diet had WH of 78 cm, which was similar to the WH reported by Brown et al. (2005) for calves on a high diet containing 30.3% CP in MR and 25% CP in CS, which are similar to the WH of calves in this study fed both treatments. At 6 wk, calves in this study demonstrated WH that were lower than calves in Rincker et al. (2011) study fed an intensive diet, but were similar to their calves fed the conventional diet, which was around 83 cm. This difference could be due to calves fed the intensive diet receiving higher feeding rates of MR. Stamey et al. (2012) also had taller calves when fed high MR and high protein CS with WH of 86 cm, body length of 71 cm and heart girth of 93 cm at 5 wk and WH 90 cm, body length 75 cm and heart girth 100 cm at 8 wk of age. Calves in this study are similar, but slightly less than the results obtained by Stamey et al. At 8 wk, Brown et al. (2005) obtained a WH of 85.9 cm, which is slightly shorter than this study, which were 87 cm. According to Heinrichs and Hargrove (1987) the standard WH for heifers at 4 wk of age is 80.1 cm and 85.6 cm at 8 wk, which are similar to the current data, as wither height at 4 wk was found to be 79.8 cm and at 8 wk, 87 cm. Ferreira et al. (2012) obtained WH gain of 15 cm for dent corn and 14 cm for flint corn, which is a bit higher than current calves at 10.9 cm for both CN and MC. This study demonstrated greater WH than reported by Brisola and Lucci (1998). Stamey et al. (2012) reported mean increase in hip height of 16 cm, which is greater than the 10.9 cm for CN and 11.1 cm for MC.

The increase in heart girth reported by Ferreira et al. (2012) was of 20.7 cm, which is greater than the 12.18 cm for CN and 12.92 cm for MC. Schalch et al. (2001) reported HG gains of 18 cm, in a study involving pure Holstein calves receiving full cream milk and concentrate with 15, 30, and 45% of corn replaced with citrus pulp during 70 d. Maiga et al. (1994) had found highest increase in HG for all treatments compared to all other

skeletal growth parameters which is similar to the results of this study reporting a numerical increase in HG compared to increased body length, WH, or hip height. The increase in HH should be approximately 10.2 cm in 56 d (Chester-Jones and Broadwater, 2009). This study demonstrates a HH gain of 10.9 cm for CN group and 11.1 for MC group in 56 d. Body length measurements were very irregular for most calves in this study. The problem is the difference in anatomical location and anatomical points in measuring body length are always not specifically stated. The measurement of body length is least often used and difficult to use for comparisons among experiments (Heinrichs et al., 1992).

### **Dry Matter Intake and Feed Efficiency**

Intake of pre-weaning DM and MR by calves of Stamey et al. (2012) were 0.99 kg/d and 0.88 kg/d when calves were fed an intensive diet, which is slightly higher than the result reported here, which have DMI and MR intakes of 0.84 kg and 0.72 kg, respectively. Intake of CS is slightly higher by this study's calves compared to calves of Stamey et al. (2012), which was 0.15 kg versus 0.12 kg at 5 wk. Intake of CS at the pre-weaning period was similar between calves in this study and Rincker et al. (2011) for calves fed an intensive MR and high protein CS, which were 0.22 and 0.20, respectively. Lower CS intake in pre-weaning phase occurs due to higher feeding rate of MR (Tikofsky et al., 2001; Hill et al., 2006, 2007; Rincker et al., 2011). This was observed in this study as well. Terré et al. (2007) reported CS intake of 0.36 kg/d for enhanced feeding compared to 0.68 kg/d for conventional feeding during the pre-weaning phase. In the post-weaning phase, CS intake was 1.90 versus 2.52 for enhanced feeding compared to conventional feeding, respectively. The current study in pre-weaning and post-weaning CS intake is slightly lower than data reported by Terré et al. (2007).

Rincker et al. (2011) reported a FE of 0.55 kg/kg for calves fed an intensive diet with high protein CS which is similar to the results reported here for MC CS. Hill et al. (2006) obtained a feed efficiency (FE) of 0.72 kg/kg when calves were fed 0.68 kg of a 28% CP 20% fat MR, which is greater than the FE reported here. Hill et al. (2006) observed FE of 0.53 kg/kg for calves fed a 28% CP 20% MR with average MR intake of 0.88 kg/d and CS intake of 0.41 kg/d, which is similar to results reported here fed a CS containing MC corn. Hill et al. (2007) also obtained FE of 0.55 kg/kg and pre-weaning CS intakes of 0.22 kg/d for calves fed at 0.88 kg/day of a MR containing 26% CP, 17% fat. Numerically, higher DMI and ADG for calves fed MC compared to calves fed CN CS led to a trend ( $P = 0.09$ ) being observed in better FE for MC fed calves compared to CN fed calves. Having a greater number of calves (i.e., 20/

treatment) may have resulted in statistical significance. Cost per pound gain was \$0.16 lower for calves fed MC CS compared to calves fed CN CS evaluating both corn sources at the same price per kg. The MC group is thus economically more advantageous.

### **Fecal Scores, Nutrient, and Mineral Digestibility**

Feeding calves MC CS resulted in significant improvements in digestibilities of several nutrients compared to calves fed CN CS and the hypothesis is that this affected the number of days with a fecal score of 1, 2, and 5. The softer starch with its floury starch structure is the proposed mechanism of enhancing nutrient digestibility and also influencing the fecal consistency by having feces that are softer and looser than CN fed calves. The hypothesis is improving starch digestion could lead to improved rumen development in MC fed calves compared to CN fed calves. Apparent nutrient digestibility values are somewhat higher than previously reported by others (Terré et al., 2007; Hill et al., 2010; Castells et al., 2012; Porter et al., 2007). The higher sulfur digestibility for calves fed MC compared to calves fed CN suggests higher digestibility of CP in the MC CS than in the CN CS. Further work is warranted evaluating soft starch grain hybrids and rumen development.

### **Conclusions**

Feeding MR at higher rates and for a longer duration has resulted in less CS intake in the pre-weaning phase, which resulted in a slump in BW gain during the transition to post-weaning. Masters Choice CS, though not significantly different compared to CN CS did show numerically higher BW gains and a statistical trend for improved feed efficiency. Had the sample size been larger (i.e., 20 calves/treatment), significant differences may have been detected. The conclusion reached is that MC corn is energetically more efficient and nutrients are more digestible than CN corn, which will help meet the animal's nutrient requirements. Economically, this study demonstrated that feeding MC CS resulted in reduced feed costs per unit body weight gain when compared to calves fed the CN CS. The use of new corn hybrids has the potential to improve nutrient digestion and animal performance.

### **LITERATURE CITED**

- Akayezu, J. M., J. G. Linn, D. E. Otterby, and W. P. Hansen. 1994. Evaluation of calf starters containing different amounts of crude protein for the growth of Holstein calves. *J. Dairy Sci.* 77:1882–1889. doi:10.3168/jds.S0022-0302(94)77130-7
- AOAC. 2016. *Official Methods of Analysis*. 18th ed. Association of Official Analytical Chemists, Gaithersburg, MD.

- Aita, M. F., V. Fischer, and W. Stumpf. 2006. Effects of levels of lipids in milk replacer of milk on body development of Jersey calves. *Rev. Bras. Zootec.* 35:193–202. doi:10.1590/S1516-35982006000100025
- Bach, A., A. Gime'nez, J. L. Juaristi, and J. Ahedo. 2007. Effects of Physical Form of a Starter for Dairy Replacement Calves on Feed Intake and Performance. *J. Dairy Sci.* 90:3028–3033. doi:10.3168/jds.2006-761
- Bar-Peled, U., B. Robinson, E. Maltz, H. Tagari, Y. Folman, I. Bruckental, H. Voet, H. Gacitua, and A. R. Lehrer. 1997. Increased weight gain and effects on production parameters of Holstein heifer calves that were allowed to suckle from birth to six weeks of age. *J. Dairy Sci.* 80:2523–2528. doi:10.3168/jds.S0022-0302(97)76205-2
- Brisola, M. L., and C. S. Lucci. 1998. Weaning of calves with utilization of extruded whole soybean in calf starters. *Braz. J. Vet. Res. Anim. Sci.* 35:134–138.
- Brown, E. G., M. J. VandeHaar, K. M. Daniels, J. S. Liesman, and L. T. Chapin. 2005. Effect of increasing energy and protein intake on body growth and carcass composition of heifer calves. *J. Dairy Sci.* 88:585–594. doi:10.3168/jds.S0022-0302(05)72722-3
- Castells, L. L., A. Bach, G. Araujo, C. Montoro, and M. Terré. 2012. Effect of different forage sources on performance and feeding behavior of Holstein calves. *J. Dairy Sci.* 95:286–293. doi:10.3168/jds.2011-4405
- Chester-Jones, H., and N. Broadwater. 2009. Milk replacer. Accessed Jun. 18, 2014. <http://www.extension.umn.edu/agriculture/dairy/calves-and-heifers/milk-replacer-feeding-and%20management.pdf>
- Cowles, K. E., R. A. White, N. L. Whitehouse, and P. S. Erickson. 2006. Growth characteristics of calves fed an intensified milk replacer regimen with additional lactoferrin. *J. Dairy Sci.* 89:4835–4845. doi:10.3168/jds.S0022-0302(06)72532-2
- Cunha, D. N. F. V., O. F. De Campos, J. C. Pereira, M. F. A. Pires, R. S. Lizieire, and J. A. Martuscello. 2007. Performance, physiological variables and behavior of calves kept in different facilities: Rainy season. *Rev. Bras. Zootec.* 36:1140–1146. doi:10.1590/S1516-35982007000500022
- Davis, C. L., and J. K. Drackley. 1998. *The Development, Nutrition, and Management of the Young Calf*. Iowa State Univ. Press, Ames.
- Ferreira, C. S. F. F. da Silva, C. M. Veloso, P. Bonomo, J. S. Oliveira, V. L. da Silva, A. R. Schio, and L. C. V. Itavo. 2012. Type of corn and grinding degree in a concentrate supplied to suckling calves. *R. Bras. Zootec.* 41:1484–1489. doi:10.1590/S1516-35982012000600024
- Franklin, S. T., D. M. Amaral-Philips, and J. A. Jackson. 2003. Health and performance of Holstein calves that suckled or were hand-fed colostrum and were fed one of three physical forms of starter. *J. Dairy Sci.* 86:2145–2153. doi:10.3168/jds.S0022-0302(03)73804-1
- Giuberti, G., A. Gallo, F. Masoero, L. F. Ferraretto, P. C. Hoffman, and R. D. Shaver. 2014. Factors affecting starch utilization in large animal food production system: A review. *Starke* 66:72–90. doi:10.1002/star.201300177
- Heinrichs, A. J., and G. L. Hargrove. 1987. Standards of weight and height for Holstein heifers. *J. Dairy Sci.* 70:653–600. doi:10.3168/jds.S0022-0302(87)80055-3
- Heinrichs, A. J., G. W. Rogers, and J. B. Cooper. 1992. Predicting body weight and wither height in Holstein heifers using body measurements. *J. Dairy Sci.* 75:3576–3581. doi:10.3168/jds.S0022-0302(92)78134-X
- Hill, T. M., J. M. Aldrich, R. L. Schlotterbeck, and H. G. Bateman, II. 2006. Effects of feeding calves different rates and protein concentrations of twenty percent fat milk replacers on growth during the neonatal period. *Prof. Anim. Sci.* 22:252–260.
- Hill, T. M., J. M. Aldrich, R. L. Schlotterbeck, and H. G. Bateman, II. 2007. Effects of the feeding rate of high protein calf milk replacers. *Prof. Anim. Sci.* 23:649–655.
- Hill, T. M., H. G. Bateman, II, J. M. Aldrich, and R. L. Schlotterbeck. 2008. Effects of feeding different carbohydrate sources and amounts to young calves. *J. Dairy Sci.* 91:3128–3137. doi:10.3168/jds.2007-0950
- Hill, T. M., H. G. Bateman, II, J. M. Aldrich, and R. L. Schlotterbeck. 2009. Effects of weaning age of dairy calves fed a conventional or more optimum milk replacer program. *Prof. Anim. Sci.* 25:619–624.
- Hill, T. M., H. G. Bateman, II, J. M. Aldrich, and R. L. Schlotterbeck. 2010. Effect of milk replacer program on digestion of nutrients in dairy calves. *J. Dairy Sci.* 93:1105–1115. doi:10.3168/jds.2009-2458
- Maiga, H. A., D. J. Schingoethe, F. C. Luden, W. L. 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. doi:10.3168/jds.S0022-0302(94)76952-6
- Matthews, C. A. and M. H. Fohrman. 1954. Beltsville growth standards for Holstein cattle. *US Dep. Agric. Tech. cattle. Bull.* 1099.
- NRC. 2001. *Nutrient Requirements of Dairy Cattle*. 7th rev. ed. Natl. Acad. Sci., Washington, DC.
- Porter, J. C., R. G. Warner, and A. F. Kertz. 2007. Effect of fiber level and physical form of starter on growth and development of dairy calves fed no forage. *Prof. Anim. Sci.* 23:395–400.
- Ragsdale, A. C. 1934. Growth standards for dairy cattle. *Missouri Agric. Exp. Stn. Bull.* 336.
- Rincker, L. E. D., M. J. Vandehaar, C. A. Wolf, J. S. Liesman, L. T. Chapin, and M. S. Weber Nielsen. 2011. Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield, and economics. *J. Dairy Sci.* 94:3554–3567. doi:10.3168/jds.2010-3923
- Schalch, F. J., E. Schalch, M. A. Zanetti, and M. L. Brisola. 2001. Corn replacement in grand ground by citrus pulp in early weaning of dairy calves. *Rev. Bras. Zootec.* 30:280–285. doi:10.1590/S1516-35982001000100039
- Stamey, J. A., N. A. Janovick, A. F. Kertz, and J. K. Drackley. 2012. Influence of starter protein content on growth of dairy calves in an enhanced early nutrition program. *J. Dairy Sci.* 95:3327–3336. doi:10.3168/jds.2011-5107
- Steele, R. G. D., and J. H. Torrie. 1980. *Principles and procedures of statistics*. 2nd ed., New York, NY: McGraw-Hill Book Co., New York, NY.
- Strzetelski, J., B. Niwinska, J. Kowalezyk, and A. Jurkiewicz. 2001. Effect of milk replacer feeding frequency and level of concentrate intake and rearing performance of calves. *J. Anim. Feed Sci.* 10:413–420. doi:10.22358/jafs/67995/2001
- Terré, M., M. Devant, and A. Bach. 2007. Effect of level of milk replacer fed to Holstein calves on performance during the preweaning period and starter digestibility at weaning. *Livest. Sci.* 110:82–88. doi:10.1016/j.livsci.2006.10.001
- Tikofsky, J. N., M. E. Van Amburgh, and D. A. Ross. 2001. Effect of varying carbohydrate and fat content of milk replacer on body composition of Holstein bull calves. *J. Anim. Sci.* 79:2260–2267. doi:10.2527/2001.7992260x
- Tyler, J. W., D. D. Hancock, S. M. Parish, D. E. Rea, T. E. Besser, S. G. Sanders, and L. K. Wilson. 1996. Evaluation of 3 assays for failure of passive transfer in calves. *J. Vet. Intern. Med.* 10:304–307. doi:10.1111/j.1939-1676.1996.tb02067.x