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Study of the Effect of Feeding Highly Digestible Corn Based Calf Starter on the Growth Performance of Calves

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STUDY OF THE EFFECT OF FEEDING HIGHLY DIGESTIBLE CORN BASED CALF STARTER ON THE GROWTH PERFORMANCE OF CALVES

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABBREVIATIONS

ADF: Acid Detergent Fiber.

ADG: Average Daily Gain

BCS: Body Condition score

BHBA: Beta Hydroxy Butyric Acid

BL: Body length

BLG: body Length Gain

BW: Body Weight

BWG: Body Weight Gain

CP: Crude Protein

CS: Calf Starter

DDGS: Dried Distillers Grains with Solubles

DM: Dry Matter

DMD: Dry Matter Digestibility

DMI: Dry Matter Intake

DHIA: Dairy Herd Improvement Association

DW: Dried Whey

EE: Ether Extract

ESBM: Extruded Soybean meal

FE: Feed Efficiency

FCR: Feed Conversion Ratio

HG: Heart Girth

HGG: Heart Girth Gain

HH: Hip Height

HHG: Hip Height Gain

HS: Hard Starch

HW: Hip Width

HWG: Hip Width Gain

ME: Metabolizable Energy

MS: Mashed Starter

MR: Milk Replacer

NCGA: National Corn Growers Association

NDF: Neutral Detergent Fiber

NRC: National Research Council

OM: Organic Matter

PS: Pelleted Starter

Prew_ADG: Pre-weaning Average Daily Gain

PW_ADG: Post-weaning Average Daily Gain

R. Bras. Zootec: Revista Brasileira de Zootecnia

RUP: Rumen Undegradable Protein

SBM: soybean meal

SCC: Somatic Cell Count

SME: Standard Mature Equivalent

SROC: Southern Research and Outreach Center

SS: Soft Starch

TMR: Total Mixed Ration

TS: Texturized Starter

US: United States

USDA: United States Department of Agriculture

VFA: Volatile Fatty Acid

WH: Wither Height

WHG: Wither Height Gain

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ABSTRACT

STUDY OF THE EFFECT OF FEEDING

HIGHLY DIGESTIBLE CORN BASED CALF STARTER

ON THE GROWTH PERFORMANCE OF CALVES

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2016

New corn hybrids have been developed by Masters Choice (MC) that vary in energy density and starch digestibility. These MC hybrids have lower starch densities due to an altered starch structure, which allows for greater ruminal and intestinal starch digestion. The altered starch structure of these new hybrids results in reduced feed manufacturing costs (i.e., grinding). Thirty (30) 1 to 3 d old (40.6 ± 1.72 kg) Holstein heifer calves were randomly assigned to 1 of 2 calf starters to measure growth performance of Holstein heifer calves through 8 weeks of age. Treatments were: 1) Hard starch (HS) corn calf starter: containing 40% DM basis conventional ground shelled corn and 2) Soft starch (SS) corn calf starter: containing 40% DM basis MC corn. Experimental calf starters were formulated to contain 24% CP (DM basis) and were fed for *ad libitum* consumption as a pellet starting on day 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) 2X/d at the rate of 0.68 kg/d from 0 to 14 d, 0.85 kg/d from 15 to 42 d and fed 1X/d at 0.425 kg/d from d 42 to 49. Data were analyzed using mixed procedure of SAS version 9.4. Body weight gains (26.16 kg and 28.77 kg) were similar between treatments. No differences were detected *(P* > 0.10) in frame parameters as measured by change in body length (8.05 and 7.8 cm), heart girth (12.1 and 12.92 cm), hip height (10.91 and 11.11 cm) and wither height (10.87 and 10.93 cm). Calves fed SS corn calf starter were numerically higher in ADG compared to calves fed HS corn calf starter (0.46 Vs 0.51 kg/d, $P = 0.15$). Trend was observed in greater feed efficiency for calves fed soft starch corn CS compared to calves fed HS corn CS (0.55 Vs 0.51, $P < 0.10$). The use of new corn hybrids has the potential to improve nutrient digestion and animal performance.

Keywords: corn hybrids, calf starter, starch.

INTRODUCTION

At birth, the abomasum of the calf is the predominant compartment of the ruminant stomach constituting approximately 50% of the total tissue weight of the stomach. At the pre-ruminant stage, liquid feeding meets the dietary requirement for energy and protein. In replacement heifers, early consumption of dry feed is encouraged for the development of a functional rumen. Concentrate feeds are digested to propionic and butyric acids in the rumen to stimulate growth of rumen papillae. After concentrate feeding begins, it takes 3 to 4 weeks before the rumen becomes fully functional which at that time is 67% of the tissue weight of the stomach. Increasing the protein and energy intake of calves during the pre-weaning period increases body size and mammary growth, which may improve milk yield (Bar-pealed et al., 2007, Shamay et al., 2005). Increasing energy and protein concentrations in milk replacer and calf starter can optimize calf growth (Brown et al., 2005, Davis Rincker et al., 2011). In the current study, a high protein calf starter was evaluated with an accelerated milk replacer. The experimental calf starter contained more digestible starch to be used as the energy source.

The United States is the largest producer of corn in the world. Corn is grown over on more than 400,000 US farms. Corn harvested for commercial grain accounts for approximately 1/4th of the total crop and for silage accounts for 2% of total harvested cropland. About 80% of total corn grown is used for livestock, poultry and fish production (NCGA, 2013). Corn is fed as ground grain, silage, high moisture and high oil corn. The starch content of corn is about 70%, which is a rich source of energy. Based on the hardness of corn endosperm, corn can be divided as soft or dent corn and flint or hard or vitreous corn. Based on starch property many soft, intermediate and hard corn varieties are available for the beef and dairy industry and its efficacy for calf growth needs further evaluation. A higher proportion of soft starch is assumed to increase net energy content. If more starch is digestible that should result in more growth and greater feed efficiency. Corn can be processed to increase starch digestibility in the rumen and intestine (Galyean, 1996, Huntington, 1997). Steam flaking, steam rolling, grinding, dry rolling, coarse rolling, roasting, pelletizing, texturizing are common corn processing methods.

Masters Choice (Anna, IL) has developed new corn hybrids that vary in energy density and starch digestibility. The starch structure is less dense i.e. softer, which allows for greater ruminal and intestinal starch digestibility. It is hypothesized that this variety of Masters Choice having soft starch would result in better growth and metabolic performance in calves compared to a hard starch corn hybrid. The objective of this trial is to measure the growth characteristics and metabolic performance of calves fed a calf starter containing soft starch corn.

CHAPTE 1:

LITERATURE REVIEW

Protein Requirements and Milk Replacer Feeding for Calves

The optimum level of crude protein (CP) in a calf starter (CS) diet depends on the constituents of the diet, age and rate of gain. According to Crowley et. al. (1983) CS for dairy replacements should contain 15 to 20% CP. The Nutrient Requirements of Dairy Cattle (NRC) recommendation for CP is 18 % (NRC, 1989). Field reports suggest CP concentrations higher than recommended by NRC (2001), but beneficial effects have not been clearly shown. A study conducted by Akayezu et al. (1994) used 124 calves from 4 d of age and fed a CS containing 15, 16.8, 19.6, or 22.4% CP on a DM basis. The average daily gain (ADG) obtained for the pre-weaning dairy calves were 0.37, 0.39, 0.38, and 0.44 kg/d for 15, 16.8, 19.6 and 22.4 % CP respectively. Weaning occurred at 28 d of age. In the post weaning period, calves fed the 19.6% CP had the highest ADG (0.86 Vs 0.71, 0.75, and 0.79 kg/d) compared to 15, 16.8 and 22.4% CP, respectively. Calf starter consumption tended to increase as CP content of the diet increased. Highest CS intake and maximum growth occurred with the diet containing 19.6% CP.

Stobo et. al. tested 19.2% CP versus 11.5% CP in the concentrate. They reported that when concentrate intake was restricted to 2 kg/d, Friesian heifer calves weaned at 5 wk of age had significantly higher live-weight gain when the higher level of CP was fed. The increases in relative BW and WH are the most rapid and cost efficient during the first 6 months of life (Kertz, et al., 1998). So diet manipulation to achieve efficient BW and WH growth can be achieved. In order to determine the effect of increasing the CP and energy intake on growth of calves, Brown et al. (2005) conducted a research trial where they fed high CP diet. Seventy-four (74) heifers were selected and grouped into four treatments having a 2 X 2 factorial design. From 2 to 8 week calves were grouped into two treatments: moderate (M) group containing 21.3% CP in the milk replacer (MR) and 20.5% CP in CS and high group (H) containing 30.3 % CP in MR and 25% CP in CS. From 8 to 14 weeks the calves in each group were again divided into a low group (L) containing 16.5 % CP in CS and a high group (H) containing 21.3% CP CS. The H CS diet resulted in higher BW, ADG, wither height and feed efficiency: 72.1 kg, 0.668 kg/d, 85.9 cm and 0.550 respectively versus 60.0 kg, 0.379 kg/d, 83.5 cm and 0.439 respectively in period 1. In period 2, ADG and feed efficiency were greater for calves fed the H CS compared to L CS diet.

Lower CS intake by calves fed enhanced MR (Cowles et al., 2006; Hill et al., 2006, 2008) may potentially limit rumen development and decrease gains as the calf transitions at weaning, through both lower total nutrient intake and lower ruminal digestibility of food (Terré et al., 2006, 2007; Hill et al., 2010). Quigley et al. (2006) compared feeding a 20% CP, 20% fat MR at 0.45 kg daily to feeding a 28% CP, 16% fat MR at up to 0.9 kg daily and observed greater gains, less CS intake, and more health challenges when feeding the 28% CP MR. One approach to counteract this response could be to increase the concentration of metabolizable protein (MP) from the CS. Stamey et al. (2012) conducted research to examine effect of increased CS CP content on the growth of dairy calves from birth to 10 weeks of age in an enhanced early nutrition program and to compare early nutrition program to conventional MR program. Higher CS CP concentration would maintain growth at and after weaning for calves fed an enhanced early nutrition program. Treatments used for the study were low milk replacer (LMR) (20% CP, 20% fat), high milk replacer (HMR) (28.5% CP, 15% fat), conventional calf starter (CCS, 19.6% CP, DM basis), high CP enhanced CS (HCS, 25.5% CP, DM basis). Three treatment combinations were: 1) LMR + CCS 2) HMR + CCS and 3) HMR + HCS. Calves were weighed at birth, at d 3 and each Wednesday. Wither height, body length and heart girth were also measured. Calculation of ADG from the BW and stature were made from the measurements. Total CP intake and ME intake were greater for calves fed HMR and within HMR calves fed the HCS had higher pre-weaning and post-weaning intake. Mean intake of CS was highest for calves fed LMR + CCS followed by HMR + HCS and then HMR+ CCS. Calves fed HMR + HCS had greater body weight at wk 8 then calves fed HMR + CCS. Calves fed HMR + HCS tended to have greater final BW ($P = 0.06$) and had greater heart girth ($P = 0.03$) than calves fed HMR + CCS. Mean ADG was greater for calves fed HMR than calves fed LMR. Mean ADG over the 10-wk study were 0.64, 0.74, and 0.80 kg/d for treatments LMR + CCS, HMR + CCS, and HMR + HCS, respectively.

Another approach to solve the problem of less CS intake would be to decrease feeding rate of MR. Hill et al. (2006) in their trial found that the magnitude of CS intake reduction for calves fed 0.68 kg of the 28% CP MR relative to calves fed 0.45 kg of 20% CP MR was 11% vs. 48% when 1.13 or 1.36 kg of the 28% CP MR was fed daily. The ADG was significantly higher for 0.68 kg of 28% MR compared to others and feed efficiency also tended to be higher for this group compared to others. Hill et al. (2007) conducted 3 trials where he compared 26% CP 17% MR at different feeding rates. In trial 1, feeding rate was low (0.681 kg/d), moderate (0.794 kg/d) or high (0.908 kg/d). No difference was found in 0 to 56 days in body weight gain and feed efficiency. Significant difference in CS intake was found in 0 to 56 days with greater starter intake with lower feeding rate followed by moderate and then lowest intake in high feeding rate. In trial 2, two feeding rates 0.681 kg/d and 0.908 kg/d were compared. No difference in body weight gain and feed efficiency in 0 to 56 days were found, but calves fed at the lower feeding rate consumed more CS to achieve similar rates of body weight gain and feed efficiency with lower consumption of MR. In trial 3, a 26% CP, 17% fat MR at feeding rates of 0.681 kg/d (P681), 1.135 kg/d (P1135), 28% CP, 20% fat MR powder at feeding rate of 1.135 kg/d (PF1135) and 20% CP, 20% fat at feeding rate of 0.454 kg/d (C454) were compared. Calves in both 1.135 kg/d groups had lower CS intake compared to calves fed in the other two groups from 0 to 56 d. Calves on 0.681 kg/d maintained CS intake similar to 0.454 kg/d group and had the greatest hip width gain compared to all other groups. This MR feeding program does not maximize ADG during the first month of life, but does maximize ADG during the second and third months of life.

Another way of decreasing the post-weaning slump could be gradual weaning evaluated by Khan et al. (2007) by slowly increasing the amount of milk offered by 23 days and then slowly decreasing by the 49 days. But increase of high feeding rate of MR time won't be sufficient for gradual weaning as it takes time to increase the feeding rate. For growth rates of more than 700 g/d, increased amount of milk is necessary, which also has an impact on future lactation performance (Batch et al. 2012; Soberon et al. 2012). The immune status of the animal is also maintained by feeding an enhanced MR. According to Batch et al. (2013), the optimum age to reduce MR allowance and to enhance solid feed intake is approximately 45 days of age. To overcome the growth slump in the post-weaning phase by maintaining MR feeding rate could be to introduce a highly degradable CS so that it would be degraded sufficiently in the rumen even at lower intake to provide VFAs for rumen development. Calf starter intakes, and specifically those with high starch concentrations, serve to develop the rumen epithelium via the yield of volatile fatty acids produced during ruminal fermentation (Roy et al., 1963).

Energy and Protein Requirement and Synchronization

Protein to energy ratios are affected by numerous factors, like rate of gain, body size, age, composition of diet. At a low rate of gain, protein is deposited, while at a high rate of gain fat is deposited (Jacobson et al., 1969). High quality CP in a CS is used more efficiently (Whitelaw et al. 1963). The digestible CP requirement for 50 kg ruminating calf suggested by Roy et al. (1963) for maintenance is 50 g/kg and for 0.5 kg gain it is 135g/kg. The digestible energy (DE) requirement for maintenance is 2,427 kcal/d for a 50 kg calf and for 0.5 kg gain it is 4,489 kcal/kg. According to the NRC (2001), the DE requirement for 0.5 kg gain is 4,400 kcal/day. The ratio of DE to DP declines sharply as the rate of gain increases. At maintenance, maintenance + 0.5 kg gain and maintenance + 1 kg gain ratios DP to DE are 1:75, 1:35, and 1:29 respectively. As growth increases, the optimum ratio of CP to energy increases markedly.

Studies have shown that as energy content of the ration increase, CP content also increases (Winchester et al., 1961, Zimmerman et al., 1961). Brown et al. (1962) conducted an experiment to determine energy and CP ratio of the calf. For this study, 72 Holstein and Guernsey calves were chosen. Three CP levels 14, 16 and 18% were formulated as CS and three CP to energy ratios were used, which were 1:46, 1:48 and 1:50 for each group. Calves fed at 14 and 18% CP level tended to grow faster than calves fed the 16% CP level. From 2 to 86 d, ADG was highest for 14% and 18% CP level which was 0.53 lbs/day. Within 18% CP level ADG was highest for 1:48 energy level. Again from 43 to 86 d, the ADG was highest for 14% and 18% CP level and within 18% 1:48 protein to energy ratio had the highest ADG.

The two most common MR feeding programs are conventional and intensive, also known as accelerated. Conventional feeding programs involve feeding MR containing 20 to 22% CP with 15 to 20% fat at 12.5% solids. Intensive MR feeding involves greater than 25% CP with fat content similar to conventional MR. The solids content of intensive MR at feeding ranges from 12.5 to 17.5% (Cowles et al., 2006). The benefits of intensive feeding program are increased weight gain, without increased fat deposition (Bascom et al., 2007), improved feed efficiency, increased stature during the pre-weaning period (Brown et al., 2005; Cowles et al., 2006) and enhanced immune status (Foote et al., 2007).

Raeth-Knight et al. (2009) conducted a study to determine the impact of conventional and intensive MR feeding program on heifer calf performance through 6 months of age, age at first calving and first lactation performance. Holstein heifer calves (133) were raised from 2 to 180 days at Southern Research and Outreach Center (SROC) and then moved to second stage grower and returned to their respective farms 1 month before calving. Calves were randomly assigned to five treatments: 1) Conventional MR (CNA) (20 % fat, 20% protein, 13.9% DM, non-acidified), 2) Conventional MR acidified (CA), 3) IHS: Intensive MR high solid (28% CP, 16% fat, 16.7% DM), 4) ILS: Intensive MR low solids (28% CP 16% fat, 12.5% DM), 5) IHSHF: Intensive MR high solid high feeding rate (28% CP, 16% fat, 16.7% DM). Amount of MR fed was reduced to half on d 36 and fed once daily until weaning at d 42. Calves on CNA and CA MR were given CS containing 20.2% CP. Calves on IHS, ILS and IHSHF were fed CS with 25% CP. After 2 months of age, heifers were kept in group pens and offered whole shelled corn and pelleted concentrate mixture containing 18.1% CP to CA and CNA groups and 21.2% CP to intensive MR group. Heifers were fed for 112 days. Body weights were taken per week from week 1, 2, 4, 6, 7, 8, 12 and 16 and hip height on day 1 and 56. First weaning lactation performance was determined using Dairy Herd Improvement Association (DHIA) records. Data collected included age at calving, 305 d standardized mature-equivalent milk, average fat and protein percentages and first test day Somatic Cell Count (SCC). Calf BW fed conventional MR was lower on d 14, 28 and 42 (44.5, 52.8 and 63.4 kg) than BW of calves on intensive MR (47.8, 58.2 and 69.8 kg, respectively). Calves fed IHSHF gained 17.6% more BW than calves fed IHS or ILS and 30% more BW than CNA or CA treatment at d 42 and on d 56 and were 5.8 kg and 9.7 kg heavier than other groups respectively. Final HH was 1.8 cm greater for IHSHF compared with CNA, CA, IHS or ILS treatments. Calves on IHSHF treatment gained 0.12 kg more BW per kg of DMI daily than calves fed conventional MR treatment and 0.07 kg more BW per kg of DMI daily than calves fed IHS treatment. Calves were heavier at day 56 of the pre-weaning period and early post-weaning period but growth advantage was not maintained in the post-weaning period. The IHSHF group calves had tendency for increased 305 d Standardized Mature Equivalent Milk (SME) and decreased age at first calving as compared to calves on conventional MR.

Some research studies have indicated that increasing the energy and CP intake of calves during the pre-weaning period increases body size and mammary growth and improves milk yield (Bar-Peled et al., 1997, Shamay et al., 2005). Rincker et al. (2011) reported that increasing energy and CP intake in the MR of pre-weaned calves would affect long term body growth, age at puberty, age at calving, and first lactation milk yield. Eighty (80) calves were chosen for the study and randomly assigned to either a conventional MR program consisting of 21.5% CP, 21.5% fat fed on a DM basis at 1.2% of BW based on weekly BW and CS (19.9% CP) to achieve 0.45 kg of ADG or an intensive program, which consisted of high CP MR (30.6% CP, 16.1% fat) fed on a DM basis of 2.1% of BW on weekly weighing and CS (24.3% CP) fed to achieve 0.68 kg of ADG. Calves were gradually weaned by 42 d of age. Body weight, hip width and wither height were measured once weekly. Calves were retained in the study if they grew at the targeted ADG for their dietary treatment from 2 to 42 d of age. Calves were transitioned from CS grain fed during the treatment period to CS grain fed during the post-weaning period by mixing 50% of grain received during treatment period with 50% of another grain mixture for the first 5 days after weaning. At 8 weeks of age calves were moved into group pens. Measurements of BW, WH and HW were taken weekly during wk 7 and 8 and were taken once every 4 wk until parturition. From 8 weeks until 3 months of age heifers were fed 2.7 kg starter per day and were allowed ad libitum access to alfalfa hay. At 3 months of age heifers were transitioned to total mixed ration (TMR). Heifers were fed TMR and during warmer months, pregnant heifers were allowed to graze pasture. Close-up and lactating primiparous heifers were individually fed to allow for 10% refusal. To determine age and body weight at onset of puberty heifers were weighed weekly once they reached 204 kg of BW. Heifers were ready for breeding at 397kg of BW. Body weight, wither height and BCS were recorded before calving. The ADG between conventional and intensive diets were 0.44 and 0.64 kg between treatments. Increasing the protein and energy intake during pre-weaning period resulted in larger calves at 1 wk of age and taller and wider calves at 2 to 6 wk of age. Calves remained taller and wider through 8 wks of age when fed the intensive diet. Heifers fed the intensive diet were taller from 12 to 40 wk and at 68 wk of age and tended to be taller at 44 and 72 through 84 wk of age. Heifers on the intensive diet were wider at 12 wk of age and wider at 16 through 24 wk of age. Heifers on the intensive diets were 31 days younger, lighter and narrower at the onset of puberty ($P \leq 0.01$). At conception, the heifers fed the intensive diets were 15 d younger than heifers fed the conventional diet ($P = 0.09$). Age at calving, though not significant, was 14 d earlier for heifers fed the intensive diet.

Young calves have high energy and CP requirements, while consuming limited amounts of DM. Efforts to increase energy content of CS by addition of animal or vegetable fats have been associated with decreased DMI, probably because of palatability problems (Abdelgadir et al. 1984). Roasted corn resulted in improved feed efficiency and better body weight gains than calves fed unroasted corn (Thomas et al., 1975). Synchronization of CP and energy yielding substances in the rumen can improve microbial protein synthesis and its flow to the intestine (Sinclair et al., 1993). Abdelgadir et al. (1996) evaluated the effect of varied RUP protein supplements, increased starch gelatinization of corn, and their interactions using 132 Holstein calves. Calves were blocked by sex and birth date and assigned to one of six pelleted isonitrogenous CS: Soybean meal, roasted soybean meal at 136ºC (RSB136) and roasted soybean meal at 146 ºC (RSB146) mixed with either raw corn (RC) or corn roasted to an exit temperature of 135°C (C135). Calf starter consumption and body weights were recorded weekly, while ADG, daily feed consumption, feed efficiency and energetic efficiency were determined during the post weaning period. Heart girth and wither height were recorded at the beginning and end of the trial. Body condition score (BCS) were recorded at the end. Rumen fluid and blood samples were collected at 3 d post weaning and at 8 week of age. Body weight gains were greater for calves fed C135 at week

1 and 4 (0.9 vs. 0.4 kg/wk and 3.8 vs. 3.3 kg/wk). At wk 4; calves fed SB146 and SB138 had more BW than those fed SBM (3.8, 3.9, and 3.1 kg/wk, respectively). Total body weight gains were higher for SB146 + C135 or SB138 + C135 than for SBM + RC. Heart girth gains were higher for SB146 + RC and SB138 + C135 compared to SBM + RC. Height gain was higher for calves fed SB146 than those fed SB138 or SBM (8.8, 7.7 and 7.3 cm, respectively). Calves fed SB146 + RC were weaned an average of 4 d earlier than those fed SBM + RC. Calves fed the C135 performed better with SBM or SB138 compared to calves fed SB146. Average daily gains were higher for calves fed SB146 + RC or SBM + C135 than for calves fed SB146 + C135. Feed efficiency was higher for SB146 + RC or SBM + C135 than for calves fed SBM + RC. Energetic efficiency was improved with C135 + SBM and SB138 + C135. Calves fed the treatment SB146+RC that were less ruminally available and SBM+C135 that were both ruminally available performed better than calves fed SB146+C135 in which CP was less ruminally available than carbohydrate.

Abdilgadir et al. (1996) conducted research to study effect of synchronous and asynchronous protein and starch source on performance, ruminal, and plasma metabolites of 75 Holstein dairy calves from 0.5 to 8 weeks of age. Calves were blocked by birth date and sex, and randomly assigned to one of eight pelleted isonitrogenous CS: Soybean meal(SBM), roasted soybean meal(RSB), each were again supplied with either raw corn (RC) or conglomerated corn (CC) and were further supplied with or without urea in 2 X 2 X 2 factorial design. The ADG, daily feed consumption, energetic efficiency, gross protein efficiency were determined for the post weaning period for the calves that were above 6 weeks of age. Heart girth and wither height were recorded at the beginning and end of the study period. Ruminal fluid and blood samples were collected at 5, 6, 7 and 8 weeks of age. Overall CS consumption was higher for calves fed RSB, CC with no urea, SBM, RC, no urea, SBM, CC, no urea. Maximum body weights were observed for calves fed RSB, CC and no urea, SBM, RC and no urea, RSB, RC and urea, SBM, CC and no urea, SBM, RC and urea. Calf starter containing CC resulted in greater heart girth gain. Calves consuming CS containing SBM and CC, without urea, were weaned earlier than others. Urea supplementation of SBM and CC CS and of RSB and RC CS resulted in depressed feed consumption. Calves consuming RSB CS tended to use metabolizable energy less efficiently than those consuming SBM CS.

Maiga et al. (1994) evaluated the synchronous utilization of carbohydrate and CP in calves using 84 Holstein calves (42 females) for the study. Treatments included 3 types of nonstructural carbohydrate sources that differed in ruminal degradability: barley, corn and dried whey (DW) and one of the two sources of CP that varied in ruminal degradability of nitrogen (SBM and ESBM). Calves were blocked by sex and assigned randomly to one of the six treatment diets. Feed consumption was measured daily. Calves were weighed at birth, 3 d of age and weekly thereafter. Height at withers and heart girth were measured at birth, weaning, and at the end of the trial (wk 12). During week 1 to 12 consumption of DM was greatest for corn diet compared to barley and DW diets, which were 1.5, 1.3 and 1.3 kg/d for corn, barley and DW, respectively, and BW gain was highest for corn diet (0.80 kg/d) compared to barley (0.70 kg/d) and DW diets (0.70 kg/d). The DMI and BW gains tended ($P < 0.09$) to be higher when calves were fed pellets containing less ruminally degradable CHO and CP, i.e. corn and extruded soybean meal, than calves fed other diets.

Corn in Calf starter

Corn is the major food grain accounting for more than 90% of total food grain production and use. Total land use for corn production is about 80 million acres (USDA, 2014). Most of the corn production is used for livestock feed. It is also processed into feed and industrial products like starch, sweeteners, corn oil, beverage, industrial alcohol, and fuel ethanol (Wikipedia, 2011). Corn is used for ethanol production and dried distillers grains with solubles (DDGS) is one of the co-products of ethanol production, which is used as a feed ingredient for livestock production. Corn silage, corn gluten feed, corn gluten meal are other corn products used in livestock feeds.

Corn comprises about 30 to 35% of total DM of Mid-West lactating cow rations (Garcia et. al., 2007). Corn grain due to high starch content (70-75%) (Hungtington et al., 1997) formulates an energy dense ration required for maintenance and milk production of dairy cows and for the maintenance and growth of heifers and calves. Starch in corn grain promotes the growth of ruminal bacteria and protozoa. The VFA produced from the ruminal fermentation of corn aids in the development of rumen papillae and epithelium. The physical form of starch, its relationship to proteins, and the cellular integrity of starch-containing units affect starch's availability to microbes and nutrient digestibility (Theurer et al., 1999). The corn kernel is comprised of an outer pericarp, followed by horny endosperm or floury endosperm. Within the endosperm is the aleurone layer. Aleurone layer contains essential enzymes and enzyme inhibitors. Beneath the aleurone layer is the peripheral and corneous endosperm. They contain starch granules embedded in a protein-rich matrix. Floury endosperm lies beneath these layers. It has the highest concentration of starch granules that are not embedded in a protein matrix. Starch in the floury endosperm is the most susceptible to external forces, such as digestion or grain processing. Starch granules are composed mainly of amylopectin (a1-4 and a1-6 linkages) and amylose (a1-4 linkages). The proportions of the two polysaccharides vary among species and varieties, with amylose contributing from 0 to about 20% of the total (Rooney and Pflugfelder, 1986; Kotarski et al., 1992). Relatively small amounts of pectins and sugars are present.

Starch, sugar, and pectin compose the nonstructural carbohydrates fraction (Nocek and Tamminga, 1991). Differences in relative abundance of endosperm layers are the basis for differences like vitreous, flinty, waxy, nonwaxy, and opaque used to categorize grains and varieties. In vitro and in vivo digestion differs among grain sources and there are differences in animal performance due to these difference in starch structures within the grain. (Rooney and Pflugfelder, 1986; McAllister et al., 1990b; Streeter et al., 1990 a, b, 1991; Kotarski et al., 1992; Wester et al., 1992).

Corn grains are slowly fermented in the rumen compared to wheat and barley. The physical form of starch, its relation to proteins, and the cellular integrity of starch-containing units affect grain availability to ruminal microbes and nutrient digestibility (Theurer et al., 1999). Khan et al. (2007) evaluated the effect of different starch sources like corn, wheat, barley and oat in calf starter on feed consumption, body weight gain, skeletal growth and selected blood metabolites using 64 Holstein calves: 32 males and 32 females during pre-weaning and post-weaning periods. Feed intake, body weight and skeletal growth were measured till 84 d of age. Intake of CS and mixed grass hay were recorded weekly on two consecutive days. Body weight and body measurements were recorded at birth, at weaning (d 49) and at post-weaning (d 84). During both the pre-weaning and post-weaning period, CS intake was highest for calves fed the corn based diet

(287.20 g, 1,402.02 g) followed by calves fed wheat (251 g, 1,187.42 g), oat (226.71 g, 1017.17 g) and barley (215.69 g,976.83 g). Hay, NDF, CP and starch intake were higher for calves fed the corn diet during the pre-weaning and post-weaning periods. Body weight at postweaning (d 84) was the greatest ($P < 0.05$) in calves fed the corn diet (110.2 kg) followed by those calves fed the wheat diet (105.0 kg) and then followed by calves fed oat (90.59 kg) and barley diets (88.33 kg). Body length, HG, WH, and HH at postweaning were greater ($P < 0.05$) for calves fed the corn and wheat diets compared to calves fed barley and oat diets.

Hill et al. (2008b) compared the effects of replacing corn with soy hulls in a CS using 48 Holstein bull calves. Completely pelleted starters containing A) 0% or B) 62.75% soy hulls (replacing mostly corn and soybean meal with minerals balanced between starters were used) were fed for 56 days of the study. Hip widths were measured on day 0, day after weaning and on day 56. Calves fed a CS with soy hulls had 10% lower ADG (0.808 Vs 0.727) and 8% lower feed efficiency (0.526 Vs 0.484) from 28 to 56 days than calves fed the control CS.

Khan et al (2008) researched the effect of corn, oat, wheat and barley in CS on ruminal parameters, rumen development, nutrient digestibility, and N utilization in Holstein calves. Wheat, barley and oat are more readily fermented than corn (Khan et al., 2007). 64 Holstein calves: 32 males and 32 females were used for the study. Calf starter were randomly allocated to calves, 16 calves per treatment (8 males and 8 females). Rumen samples were collected at d 35, 50 and 70 and analyzed for pH, VFA and NH_3. Blood samples were taken at day 35, 50 and 70 and BHBA was determined. At d 70, 24 male calves were selected and euthanized and rumen tissue samples were analyzed for papillae length (PL), papillae width (PW), rumen wall thickness (RWT). Full and empty weight of rumen, reticulum, omasum, abomasum measured and papillae concentration were determined. Urine and feces were collected from d 77 to 84 for analysis and calculation of nitrogen balance and digestibility. Total tract apparent DM, CP, NDF, starch, Ca, and P digestibility was calculated. Ruminal VFA concentration was greatest in corn (99.40, 84.46, 111.17 µmoles/L) and wheat diet (101.68, 89.09, 118.07 µmoles/L) at day 35, 50 and 70 of age followed by barley (84.09, 64.83 and 88.433 µmoles/L) and oat (76.16, 68.52 and 90.05 µmoles/L). At d 70 ruminal propionate and butyrate concentrate was greatest in calves fed corn (30.21 and 21.08 µmoles/L) and wheat (31.28 and 20.23 µmoles/L) diet than in barley (21.11 and 15.53 µmoles/L) and oat (23.04 and 16.04 µmoles/L) diet. Body weight gains were greater in calves consuming the corn diet (100.90 kg) followed by calves fed the wheat (95 kg), oat (83.50 Kg) and barley (82.83 kg) diets. Full and empty weights of rumen, reticulum, omasum and abomasum were greater for calves fed corn (15.35, 1.53, 1.11, 0.51, 1.95, 0.54 Kg) and wheat diets (14.59,1.45,1.03, 0.48,1.82, 0.47 Kg) than in calves fed barley (12.05, 1.28, 0.76, 0.39, 1.50, 0.40) and oat diets (11.40,1.21,0.61,0.35,1.35,0.36 kg). Ruminal papillae concentration was greater for calves fed corn (88 no. /cm^2) and wheat diets (91 no. /cm^2) than for calves fed barley (74 no. /cm^2) and oats (70 no. /cm^2). Ruminal papillae length and papillae width were greatest for calves fed the corn diet (1.95 cm, 1.11 cm) than calves fed wheat (1.71, 0.92 cm), barley (1.53, 0.78 cm) and oat diets (1.45, 0.70 cm). Intake of DM was greater for calves fed corn and wheat diets than in calves fed barley and oat diets. Phosphorus, energy and NDF intake were greatest for calves fed the corn diet followed by calves fed wheat, oat and barley. More Ca and P consumption occurred for calves fed corn and wheat then calves fed barley and oat diets. Phosphorus digestibility was greatest in calves fed corn diet followed by barley and wheat diet and then oat diet. Nitrogen balance (as a percentage of N intake) was greatest in the calves fed corn followed by calves fed wheat, followed by calves fed diet barley and oat.

Maiga et al. (1994) studied effect of diet containing corn, barley and dried whey on DMI and growth response of 84 Holstein dairy calves assigned to one of 6 CS that also varied in sources of CP or in ruminal degradability using a 3 X 2 factorial arrangement. Calves were weighed at birth, 3 d of age and weekly thereafter. Hearth girth and wither height were measured at birth, weaning and end of the trial. Calves fed the corn CS consumed the greatest amount of DM with the greatest body weight gains.

Corn Type and Processing

Corn endosperm is the region in the corn kernel where the starch granules are located. Endosperm can be divided into two parts on the basis of physical structure: dent or soft, in which the predominant endosperm is mealy or porous versus flint or hard corn in which the predominant endosperm is vitreous or hard. The ratio of vitreous to mealy is the major factor defining kernel hardness of corn. Based on this hardness of endosperm different corn varieties can be found consisting of: hard, intermediate and soft varieties on which this research is being performed to evaluate which one would be better for enhancing calf growth. Some researchers have found a decrease in starch availability in the rumen and speculated that a decrease in intestinal availability of starch occurs as vitreous property increases (Bal et al., 1997; Philippeau and Michalet-Doureau, 1997; Philippeau et al., 1999). McEwen (2000) conducted research with the objective to compare corn with hard and soft starch in combination with the ionophores, monensin and lasalocid compared to a control group (no ionophore) using 54 Holstein bull calves divided into 6 groups and randomly allotted to one diet combination from 2 grain types by 3 ionophore treatments. Calves were weighed on 2 consecutive d at the start of the experiment and every 14 d for the duration of the 91 d experiment and then again for 2 consecutive d at the end of the feeding period. Hot carcass weight, fat cover thickness, ribeye area measurements were recorded after the slaughter. Growth rates (ADG) were similar for calves fed all diets. Hot carcass weight, dressing percentage, fat thickness, and ribeye area measurements were similar. Dry matter intake per kg gain was higher for the hard starch fed calves. Feed conversion ratio was 6.4% higher for calves fed soft endosperm. No difference in ADG, feed intake or carcass composition was found due to ionophores. Both corn types were similar in starch content, so the structure of endosperm was probably responsible for observed differences in energy utilization and efficiency. On the dairy side, Ferreira et al. (2012) examined flint (hard) versus dent (soft) corn at different grinding screens (1, 3 or 5 mm) fed to dairy heifers to examine intake, digestibility and production performance using 54 crossbred Holstein heifers in 2X3 factorial arrangement of treatments. Chemical analysis was performed on feed and milk samples. Body weighing and measurements of wither height and thoracic perimeter were performed on 1st, 30th and 60th days of life. Fecal samples were collected for five days at the end of the trial period, composited and chemical analysis was performed. Heifers consumed more concentrate containing flint corn (674 g/d) compared to dent corn (578g/d). The grinding screens (3 mm and 5 mm) resulted in greater concentrate intake (657g/d and 651 g/d) compared to 1 mm (582g/d). The CP and EE intake were higher for corn grind at 5 mm and 3 mm compared to 1 mm. Heifers fed all treatments were similar in body weight, body measurements and feed conversion. The DMD was 78.9% for dent corn, which was lower than digestibility of flint corn, which was 84.3%. The highest DMD was found for 5 mm grinding compared to 3mm and 1mm, which were 84.2%, 79.1% and 78.1%, respectively.

The primary reason for processing grain containing starch, more vitreous like corn for livestock, is to enhance its nutritional value. Whole grains are protected by their pericarp, which is resistant to microbial digestion. The processing of grains through heat, moisture and mechanical action for fracturing the seed pericarp, which increases surface area, disrupts the starch-protein matrix, and gelatinize starch granules (Hale, 1973; Huntington, 1997; Joy et al., 1997; Owens et al., 1997; Rooney and Pflugfelder, 1986; Theurer, 1986). The processing of cereal grains has been found to increase starch digestion and other nutrients in the rumen and intestine (Owens, 1997, Huntington, 1997). Grain processing increases starch digestibility, which has been reported to increase ruminal, intestinal, and total tract starch digestion (Chen et al., 1994; Crocker et al., 1998; Galyean et al., 1981; Huntington, 1997; Knowlton et al., 1998; Owens et al., 1997; Plascencia and Zinn, 1996; Theurer, 1986; Yu et al., 1998; Zinn, 1990). Steam flaking and roasting gelatinizes the corn starch, thereby increasing the ability of microbes and enzymes to penetrate and hydrolyze the starch granule. Fine grinding increases the surface area of the grain, thus increasing the potential attachment sites for microbes or enzymes. Pelleting and extrusion are an even more extensive processing method. For whole and dry rolled corn, very fine grinding of grain with a floury endosperm, a thin or loose pericarp, and a low amylose: amylopectin ratio will all help to maximize starch digestion. Steam flaking, steam rolling, grinding, dry rolling, coarse rolling, pelleting, texturizing and grinding are common processing methods (Huntington, 1997). Pellets, textures and meals are all common forms used in CS (Bateman, et al., 2009; Franklin et al., 2003). Starch digestibility varies with the different processing methods, decreasing from greatest to least, appears to be steam-flaked, finely ground, dry-rolled, with whole grains having the lowest digestibility (Chen et al., 1994; Crocker et al., 1998; Galyean et al., 1981; Huntington, 1997; Knowlton et al., 1998; Plascencia and Zinn, 1996; Theurer, 1986; Yu et al., 1998; Zinn, 1990). Processing increased ruminal disappearance of high moisture corn by 91%, steam flaked corn by 85% compared to whole corn, which is only 75% (Owens, 1997). Also intestinal digestion of starch for high moisture corn increased to 89%, steam flaked corn was 94%, dry rolled corn was 72% compared to whole corn, which is only 42% (Owens, 1997). Total tract disappearance was 99% for high moisture and steam flaked, 91% for dry rolled and 85% for whole corn (Owens et al., 1997).

Dry rolling corn increased ruminal butyrate concentrations, at the expense of acetate and propionate, when compared to whole corn (Murphy et al., 1994). Starch digestion was found not to decline as intake increased of these processed corns. Processing of grain has been reported to increase metabolizable energy value of the grains with the highest value found in steam flaked grain, whole grain, and then dry rolled grain (Owens et al., 1997). Dry matter intake has been influenced by processing with the DMI decreasing in following order: dry rolled, whole, steam rolled, steam flaked and finely ground (Owens et al., 1997; Reinhardt et al., 1998). Increased ADG have been reported for steam-flaked or steam-rolled corn, despite decreased DMI, possibly indicating an advantage in feed efficiency for extensively processed grains (Owens et al., 1997; Reinhardt et al., 1998). Increase in the starch digestibility of grains typically associated with increasing processing level, may be advantageous to the neonatal calf. The opportunity for greater butyrate and propionate production may enhance ruminal development.

Bateman et al. (2009) compared a texturized calf starter with coarsely rolled corn versus a pelleted calf starter with finely rolled corn. The texturized CS had geometric mean particle size of 2,103 µm with 82% of the particles > 1,180 µm and the pelleted CS had geometric mean particle size of 735 µm with 2% of the particle > 1,180 µm. Forty-eight (48) Holstein bull calves, less than 1 wk old, were randomly assigned to one of 2 treatments for 8 wk. Body weight were measured every wk and hip width and BCS every 2 wk. Measurements of body weight, hip width, BCS and serum protein did not differ between the treatments ($P > 0.10$). Nejad et al. (2013) used 24 Brown Swiss calves and offered treatments containing mashed (MS), pelleted (PS) and texturized (TS) starter containing 21% CP from birth to 90 d. Body weight and body measurements like HH, WH, HW, BL, and HG were taken every 2 wk. Calves fed the PS and TS demonstrated higher ADG, DM intake, DM, CP and OM digestibility compared to calves fed MS CS. No differences were observed for calves fed PS and TS CS. No difference in body measurements were found among all treatments. Batch et al (2007) evaluated two treatments, one containing cracked corn, whole oats, cracked carob and rest of the ingredients ground, multi-particle CS and in another CS all the ingredients were ground and pelleted, pelleted starter using 106 Holstein female calves for 9 weeks. Calves were weighed at the beginning of the study, at d 49 ± 0.5 and then again at d 64 ± 0.2 of age. Calves receiving pelleted CS had lower consumption than calves receiving multi-particle CS (863.9 ± 32.04 g/d Vs 944.8 ± 30.01 g/d). The ADG (g/d) was numerically higher for the multi-particle CS (780, 766.8), while feed efficiency (%) was significantly higher for calves fed pelleted CS (61.3, 58.6%). Feeding pelleted CS proved to be economically more advantageous.

Future Development

A review of the literature shows that there is a lot of research evaluating calf nutrition to enhance their optimum growth. Research is on-going to evaluate conventional and intensive MR feeding programs. Intensive MR feeding programs enhance pre-weaning growth, but CS intake is reduced. This might be the reason for the slower growth rates in the post-weaning phase. To overcome this depressed CS intake, research focused on using semi intensive or moderate MR feeding program in which feeding rate of MR is reduced compared to intensive MR feeding program. This program has been found to be more effective in maintaining growth in the second and third month, but not in the first month. Another way of maintaining weaning and post-weaning growth is by feeding a modified CS by increasing CP level of the CS and making it more digestible. Many corn hybrids for CS of soft, hard and intermediate varieties are being tested. Calf starter processing is another research area where texturized, pelleted, ground and mashed forms of calf starters are being evaluated.

Masters Choice has developed soft starch seed corn varieties having a less dense starch structure, which requires less force for grinding and is found to be more digestible than normal corn varieties. For this trial, a modified intensive MR feeding program was chosen in which MR is fed slightly lower than the normal intensive feeding rate in conjugation with a CS having a less dense starch structure. This combination is assumed to provide an optimum combination of CP and energy that will enhance the growth rate of calves.

CHAPTER 2:

STUDY OF THE EFFECT OF FEEDING HIGHLY DIGESTIBLE CORN BASED CALF STARTER ON THE GROWTH PERFORMANCE OF CALVES

Abstract

New corn hybrids have been developed by Masters Choice (MC) seeds that vary in energy density and starch digestibility. These Soft starch (SS) hybrids have lower starch densities due to an altered starch structure, which may allow for greater ruminal and intestinal starch digestion. Altered starch structure of these new hybrids results in reduced feed manufacturing (i.e. grinding) costs. Thirty 30 calves (1 to 3 d old) (40.6 ± 1.72 kg) were randomly assigned to 1 of 2 calf starters to evaluate the growth performance of Holstein heifer calves through 8 weeks of age. Treatments were: 1) Hard Starch (HS) corn starter: containing 40% DM basis conventional ground shelled corn and 2) Soft starch (SS) corn starter: containing 40% DM basis MC corn. The experimental calf starters were formulated to contain 24% 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 2x/d @ of 0.68 kg/d up to d 14, @ 0.85 kg/d from d 15 to 42 and fed 1x/d @ 0.425 kg/d from d 42 to 49. Data were analyzed as a completely random design using the mixed procedure of SAS version 9.4. Body weight gains (26.17 and 28.77 kg for HS and SS respectively) were similar between treatments (P = 0.15). No differences were detected in frame parameters as measured by change in body length (8.05

and 7.8 cm, $P = 0.84$), heart girth (12.18 and 12.93 cm; $P = 0.54$), hip height (10.91 and 11.11 cm; $P = 0.82$) and wither height (10.87 and 10.93 cm; $P = 0.95$). Numerically, ADG was greater for SS fed starter (0.46 and 0.51 kg/d; $P = 0.15$) compared to HS fed calves. A trend was observed in feed efficiency value which was higher for SS fed calves compared to HS fed calves (0.50 and 0.55kg/kg; $P = 0.09$). Dry matter (94.5 and 86.2; $P < 0.01$), CP (91.1 and 85.2; $P < 0.01$), ADF (68.5 and 54.2; $P < 0.02$), starch (99.4 and 98.4; $P < 0.04$), Ca (80.3 and 67.1; P < 0.20), Mg (71.6 and 53.1; $P < 0.01$), S (87.3 and 79.2; $P < 0.01$), Fe (51.6 and 39.1; $P < 0.20$), and Zn (63.6 and 47.4; $P < 0.04$) digestibilities were significantly greater for SS fed calves compared to HS fed calves. Thus SS variety has better digestibility and energetic efficiency compared to control variety.

Keywords: corn hybrids, calf starter, starch, corn

Introduction

In dairy heifers, 50% of total height growth occurs during the first 6 months of life and 25% of BW gains occurs from birth to first 6 months of age (Kertz et al., 1998). The growth rates of BW and WH are the most rapid and cost efficient during the first 6 months of life (Kertz et al., 1998). Calf starter (**CS**) is the first solid feed, which calves receive, which aids in the transition of calves from being a non-ruminant to a functioning ruminant.

Accelerated MR are commonly found in the market, which are high in CP and low fat, with respect to composition of traditional MR, Donnelly and Hutton (1976) demonstrated that a higher-protein low fat MR fed to bull calves increased carcass protein, while reducing carcass fat content. Diaz et al. (2001) observed a similar effect that was more pronounced, possibly because of increased mature size of Holsteins and their potential for lean growth. Rincker et. al. (2012) demonstrated that calves on an intensive

MR diet with high CP CS were numerically younger at puberty, conception and calving. Accelerated MR enhances growth in the pre-weaning period and can be beneficial for immunity (Rincker et al., 2012). There are some issues with feeding an accelerated MR in the weaning and post-weaning period of feeding calves. One issue is that an accelerated MR program with high feeding rates has resulted in a slump in weight gain in during the weaning and post-weaning phases due to a decrease in CS intake (Bar-peled et al., 1997, Hill et al., 2006a). The Post-weaning slump in ADG is due to the decreased CS intake resulting in slower rumen development and function (Terre et al., 2006). In the pre-weaning period, when calves were fed an intensive MR diet the CS consumed was lower than calves fed a conventional MR diet (Rincker et al., 2011, Shamey et al., 2012).

One possible way to reduce the slump in BW gains during the post-weaning phase could be to increase the CS metabolizable protein (MP) when feeding an intensive MR. Shamey et. al. (2012) compared calves fed a low MR (LMR; 20% CP, 20% fat) with conventional CS (CCS; 19.6% CP), high MR (HMR; 28.5% CP, 15% fat) with conventional calf starter (CCS) and a high MR (HMR) with high-CP enhanced CS (HCS; 25.5% CP). Though CS intake was low for calves fed the HMR diet, total DMI, BW and other growth parameters, and ADG were higher for calves fed the high HMR diet compared to calves fed the LMR diet. Feeding calves, the higher CP HCS diet modestly improved intake and growth compared to calves fed the CCS diet. Another option of decreasing the weaning and post-weaning slump would be to decrease the feeding rate of MR. Hill et al. (2006) reported in their trial, that the magnitude of CS intake reduction for calves fed 0.68 kg of the 28% CP MR relative to calves fed 0.45 kg of 20% CP MR was 11% versus 48% when 1.13 or 1.36 kg of the 28% CP MR was fed daily. Calves fed 0.68 kg of the 28% CP

MR gained 55% faster from 0 to 49 d ($P < 0.01$) than did calves fed 0.45 kg of the 20% CP MR and were the heaviest ($P < 0.01$) group of calves by d 49. The ADG was significantly higher for calves fed 0.68 kg of 28% MR compared to other treatments and feed efficiency also tended to be higher for calves fed 28% MR compared to calves fed the other treatments.

Another option to reduce the post-weaning slump in weight gain could be to modify the CS. There are different CS forms available based on hardness of the grain endosperm used in manufacturing. These starch forms are soft, intermediate and hard. Masters Choice has developed a soft starch corn variety (floury), which has a less dense starch structure. While feeding an accelerated MR could result in a low intake of CS in calves during the pre-weaning and post-weaning phase. However, good results with calf growth have been demonstrated in the pre-weaning phase, this advantage is not maintained in the post-weaning phase due to a low intake of CS. The hypothesis is that by decreasing the amount of accelerated MR intake during the pre-weaning phase, CS intake could be enhanced. Also, by introducing a highly degradable starch source in the CS could increase nutrient digestibility, thereby increasing the net energy value of the CS and ruminal development. The objective of the research was to measure the growth performance of calves fed corn with less dense starch structure CS compared to hard starch structure corn CS. It is hypothesized that the CS with less dense starch structure would be more digestible. This would increase the net energy content of the ration, thereby resulting in enhanced growth and feed efficiency.

MATERIALS AND METHODS

Calf Management

The experiment was conducted from the 3rd week of April and until the first week of August, 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 21 calves between d 1 to 4 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. Calves were cared for according to the approved protocol of the South Dakota State University Institutional Animal Care and Use Committee. There were 2 male calves and 29 female calves. Calves were randomly assigned to one of the two treatments. Calves were fed 3.78 L of colostrum within 1 h of birth and also 12 h after birth, if the colostrometer showed green color, otherwise colostrum replacer was fed.

Calves were kept in individual calf hutches (Calf-Tel, Germantown, WI) bedded with straw. All calves were fed 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 500 h and in the evening at 1600 h. The feeding rate of MR varied from 0.34kg @ 2x/d up to 14 d to 0.425 kg @ 2x/d from 15 to 42 d and 0.425 kg @ 1x/d in the morning only from 42 to 49 d. Water and CS were available *ad libitum* to the calves from the beginning of the study. Calves were assigned to 1 of 2 experimental CS on the first d of the experiment. Treatments were hard starch (HS) corn grain and soft starch (SS) corn grain 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. Initially, calves were given 0.227 kg CS/d. If there was no CS refusal, 0.113kg CS was added to make 0.340 kg total

CS. If there was no CS refusal and the calf was being fed 0.340 kg, the CS was bumped up to 0.45 kg. If no CS refusal and calf was on 0.45 kg, the CS was bumped up to 0.91 kg and so on. Water was available in individual buckets and refreshed each morning (0600 h). The amount of orts was measured daily at 0700h. Weaning commenced when calves were 6 wks. of age and MR was reduced to half and provided once in the morning (0600 h). Weaning was complete at the start of 7 wks of age.

Health

Feces were monitored every day and fecal scores were recorded based on 1 to 5 points scale (1= stiff, 2 = pasty, 3 = pudding like, 4 = loose, 5 = watery) (SDSU-DRTF). 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 i.e. scours, an electrolyte solution of 1.89 liters was given orally for 3 consecutive d. Noninfectious diarrhea was treated with 90 ml Bismuth (Agrilabs, St Joseph, MO) given twice daily. On the 6th wk of the trial, one of the calves was found with diarrhea mixed with blood. Fecal samples were examined at SDSU Veterinary Science department and results confirmed coccidiosis. The calves were treated with 30 ml Corid (Amprolium) included in the MR for 10 days. Many calves showed symptoms of clostridium toxicity. Two calves bloated and many had white pasty diarrhea. So, 5 cc CABB (Prarie Livestock supply, Worthington, MN) in the morning and evening was administered in the MR of calves at 4 wks onward until cessation of milk feeding, as a clostridium treatment.

Table 1. Ingredient Composition of Hard Starch (HS) and Soft Starch (SS) calf starter

Ingredients	Calf Starter	
	HS	SS
	.......% 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	1.2	1.2
Premium, VTM[1]	1.0	1.0
Super Micro[2]	0.5	0.5
Selenosource®2000[3]	0.015	0.015

[1] Vitamin trace mineral premix: Agri-King Inc.
[2]Vitamin premix: Agri-King Inc.
[3]Selenosource, Diamond V mills.

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Sample collection:

Samples of CS and MR were collected every two weeks and stored at -20^{o} C for later nutrient analysis. Daily CS refusals were weighed, recorded and discarded. A fecal grab sample was collected from each calf on the last day of the study and stored at -20^{o}C. Body weight, hip height, wither height, body length, heart girth and hip width were recorded every week on Thursdays. Hip-o-meter (Elanco Animal Health, Larchwood, IA) was used for measuring hip width. A weighing scale (Digi-Star, Fort Atkinson, WI) mounted on an all-terrain vehicle (ATV) cart for body weight and measuring tape (Ketchum Manufacturing Inc., Brockville, ON) were used for other body measurements.

Laboratory Analysis:

Samples of CS and MR were composited by month and sent to a commercial laboratory (Analab, Fulton, Illinois) for nutrient analyses. Analyses included DM, CP, Soluble Protein, NDF, ADF, NDIP, Starch, Oil, Ca, P, Mg, K, S, Na Cl, Fe, Cu and AIA. All AOAC (2000) methods used were used for DM (935.29), CP (976.06), ether extract (989.05 for MR and 920.39 for CS), ash (942.05), Ca, P, K, and Mg (985.01). Fecal samples were dried in an oven at 50^{0} C for 48 h (Style V-23, Dispatch Oven Co., Minneapolis, MN) and allowed to air equilibrate. Samples were then weighed again and DM determined. Due to limited fecal amounts, samples were composited in lots of three calves as they finished the study. Samples were then ground by passing through a 2 mm screen of a Willey mill (Model 3; Arthur H. Thomas Co., Philadelphia, PA) and ground through an ultracentrifuge mill (Brinkman Instruments Co., Westbury, NY) having a 1 mm screen and then sent for nutrient analysis as described above.

Blood samples were collected on d 4 via jugular venipuncture using a 10-mL serum Vacutainer® separation tube. Samples were allowed to clot, centrifuged at 1,000 x g for 20 minutes, serum was separated and analyzed for total serum protein (TSP) level using a refractometer (TS Meter Refractometer, American Optical Co., Buffalo, NY) to ensure adequate immune status of each calf.

Statistical Analysis:

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

RESULTS

Feed Analysis:

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 HS corn CS contained lower CP than the formulation specification, while SS corn CS met the CP formulation specification. The nutrient composition for both CS for ADF and starch were higher, while NDF concentrations were lower for the SS corn CS and slightly higher for HS corn CS compared to formulation specifications.

Total Serum Protein:

The TSP values were 5.85 and 5.70 mg/dl for HS and SS, respectively which indicated that all calves received adequate amounts of colostrum to ensure adequate passive immunity within 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).

BW and ADG:

Calves fed HS or SS were similar in growth rates ($P > 0.10$; Table 3). Although ADG (kg/d) were similar, calves fed SS corn CS were had numerically greater ADG compared to calves fed HS corn CS (0.46 and 0.51 kg/d, respectively, $P = 0.15$). Pre and post-weaning ADG were similar for calves fed both CS. Calves fed both CS gained BW until 6 wks of age when weaning was initiated; demonstrating the decrease in BW gain when weaning calves off an accelerated MR program (Figure 1).

Skeletal Growth Parameters:

Calves fed both CS were similar (P > 0.10) in body frame measurements throughout the 8 wk study (Table 4). Using initial values as a covariate did not improve statistical precision (P > 0.10). The only advantage in body frame measurements was that SS fed calves gained numerically more heart girth than HS fed calves.

Dry Matter Intake and Feed Efficiency:

Intake of MR (DM basis) was similar (P > 0.10) for calves fed both CS as per study design (Table 5). No differences were detected (P > 0.10) for CS intake and DMI between CS treatments. A trend (P < 0.10) was observed in the treatment by wk interaction for CS intake at 8 wk, which indicated that calves fed SS corn CS were consuming more DM compared to calves fed HS. There was a tendency (P < 0.09) observed in feed efficiency for calves fed SS compared to calves fed HS corn CS.

Nutrient and Mineral Digestibility:

Calves fed SS corn CS demonstrated greater digestibility (P<0.05) of all nutrients measured except for NDF, hemicellulose and Cu (Table 6 and 7) compared to calves fed HS corn CS.

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 is similar to that of calves used by Bach et al. (2007) and Rincker et al. (2013). According to Heinrichs et al. (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's at 4 wk are similar to what was reported by Ragsdale et al. (1934) and Matthews and Fohrman et al. (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, 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. (2013) reported an ADG of 0.44 kg/d on a conventional MR and CS diet, which is similar to the HS corn CS diet in this study. However, Rincker et al. (2013) reported an ADG of 0.64 kg/d on intensive MR + CS diet, which is higher than data reported here. This difference 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's 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, which was of 0.284 kg/d. 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 a similar ADG to the current study for calves fed the HS corn CS. In a study involving Holstein calves fed milled grains during the suckling period, Schalch et al. (2001) observed an ADG of 0.45 kg/day 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 0.550 kg/day, respectively. Cunha et al. (2007) reported ADG of 0.471 kg for crossbred animals through 8 weeks of age fed a commercial concentrate. Akayezu et al. (1994) observed ADG of 0.56 and 0.62 for calf starter containing 16.8% and 19.6% CP respectively. Hill et al. (2009) had ADG values of 0.50 and 0.53 for calves weaned at 28 and 42 days of age respectively for 26% CP, 17% fat at MR feeding rate of 0.681 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 0.7 kg DM from MR will result in a post-weaning reduction in ADG by depressing CS intake (Bar-Peled, 1997; Davis and Drackley, 1998; Hill et al. 2006, 2007; Strzetelski et al., 2001; Terre 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 longer feeding duration of MR.

Skeletal Growth Parameters:

During the 2nd wk of age calves in the study of Rincker et al. (2011) fed an intensive MR diet had a wither height (WH) of 78 cm, which was similar to that reported by Brown et al. (2005) of WH 78 cm 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, BL of 71 cm and HG of 93 cm at 5 weeks and WH 90 cm BL 75 cm and HG 100 cm at 8 wk of age. Calves in this study are similar, but slightly lower than results obtained by Stamey et al. At 8 wk, Brown et al. (2005) obtained WH of 85.9 cm, which is slightly shorter than this study, which were 87 cm. According to Heinrichs et al. (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 WH 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 which are 10.87 cm for C and 10.93 cm for MC calves. This study demonstrated greater WH than reported by Brisola and Lucci (1998). Ferreira et al. (2012) reported mean increase in hip height of 16 cm, which is greater than 10.91 cm for HS and 11.11 cm for SS obtained by us.

The increase in HG reported by Ferreira et al. (2012) was of 20.7 cm which is greater than the 12.18 cm for HS and 12.92 cm for SS. 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 for 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 BL, WH or HH. The increase in HH should be approximately 10.16 cm in 56 d (H. Chester-Jones, 2009). This study demonstrates a HH gain of 10.91 cm for HS group and 11.11 cm for SS 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 that are not always stated specifically. The measurement of body length is least often used and difficult to use for comparisons among experiments (Heinrichs et al., 1992).

DMI and FE:

Intake of pre-weaning DM and MR by calves of Stamey et al. (2012) were 0.994 kg and 0.876 kg 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 0.153 kg versus 0.118 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 (Rincker et al. 2011, Hill et al. 2006, 2007; Tikofsky et al. 2001). This was observed in this study as well. Terré et al. (2007) got 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 post-weaning phase CS intake was 1.90 versus 2.52 for enhanced feeding compared to conventional feeding. 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 for calves fed an intensive diet with high protein CS, which is similar to the results reported here for SS corn CS. Hill et al. (2006) obtained FE value of 0.72 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 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 SS corn. Hill et al. (2007) also obtained FE of 0.55 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 SS corn compared to calves fed HS corn CS led to trend ($P < 0.10$) being observed in better FE (0.55 Vs 0.51) for SS group calves compared to HS group calves.

Nutrient and Mineral Digestibility:

Feeding calves SS corn CS resulted in significant improvements in digestibilities of several nutrients compared to calves fed HS corn CS. The softer starch with its floury starch structure enhanced nutrient digestibility. The hypothesis is, improvement in starch digestion could lead to improved rumen development in SS corn CS fed calves compared to HS corn CS 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 SS compared to calves fed HS suggests higher digestibility of CP in the SS corn CS than in the HS corn CS.

CONCLUSIONS

Feeding MR for a longer duration has resulted in less CS intake in the pre-weaning phase, which resulted in a slump in BW gain during transition to post-weaning. Calves on SS corn CS showed a trend for improved FE compared to HS corn CS. Had the sample size been larger, significant differences may have been detected. The conclusion is that SS corn is energetically more efficient and nutrients are more digestible than HS corn, which will help meet the animal's nutrient requirements.

Table 2. Nutrient composition (% of DM) of milk replacer (MR) and experimental calf starter (CS) formulated with hard starch (HS) or soft starch (SS) corn

		Calf Starter	
Nutrient[1]	MR 28:18	HS	SS
DM%	94.50	88.70	87.40
CP%	28.89	21.89	24.80
Sol Prot	....	26.75	26.49
ADF%	....	8.72	6.98
NDF%	....	14.13	10.59
NDIP	....	1.27	0.92
Fat%	....	3.06	3.34
Starch%	....	36.80	35.39
Ash	....	5.86	5.88
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

[1]Nutrient Analysis Conducted according to AOAC (2000) procedures by Analab (Fulton, Illinois).

Table 3. Body weight (BW), average daily gain (ADG), pre-weaning (PreWG) and post-weaning (PWG) gain for calves fed hard starch (HS) or soft starch (SS) calf starters (CS)

	CS			*P*-<
	HS	SS	S.E.	Trt
Average BW, kg	51.70	52.29	0.67	0.37
Initial BW, kg	40.34	39.43	1.59	0.57
Final BW, kg	66.51	68.20	2.72	0.54
BW Gain, kg	26.16	28.77	1.76	0.15
ADG, kg	0.47	0.51	0.03	0.15
PreWG, kg	22.74	25.14	1.49	0.12
PWG, kg	3.43	3.63	0.71	0.78
PreW_ADG, kg/d	0.46	0.51	0.03	0.12
PW_ADG, kg/d	0.49	0.52	0.10	0.78

Table 4. Hip height (HH), Wither height (WH), body length (BL), Heart girth (HG), and Hip width (HW) for calves fed Control (C) or Masters choice (MC) calf starters

	Treatments[1]			*P*-<
	HS	SS	S. E	Trt
HH Initial, cm	80.45	80.24	1.33	0.88
HH Final, cm	91.36	91.35	1.05	0.99
HH Gain, cm	10.91	11.11	0.85	0.82
Average HH cm	85.53	85.90	0.43	0.38
WH Initial, cm	75.80	75.88	1.42	0.95
WH Final, cm	86.67	86.81	1.03	0.90
WH Gain, cm	10.87	10.93	1.00	0.95
Average WH, cm	81.21	81.23	0.43	0.97
BL Initial, cm	63.98	63.54	1.65	0.79
BL Final, cm	72.03	71.34	1.48	0.65
BL Gain, cm	8.06	7.80	1.28	0.84
Average BL, cm	67.75	67.60	0.53	0.77
HG Initial, cm	81.40	81.55	1.77	0.93
HG Final, cm	93.58	94.48	1.64	0.59
HG Gain, cm	12.18	12.93	1.21	0.54
Average HG, cm	86.67	87.07	0.62	0.57
HW Initial, cm	25.97	25.59	0.50	0.46
HW Final, cm	32.43	32.31	0.78	0.88
HW Gain, cm	6.45	6.71	0.61	0.67
Average HW, cm	28.70	28.38	0.20	0.13

[1]Treatments are HS and SS corn CS

Table 5. Intake of Milk Replacer (MR), calf starter (CS), dry matter intake (DMI) and feed efficiency (FE) for calves fed soft starch (SS) or hard starch (HS) CS

	Treaments[1]			*P*-<
	HS	SS	S. E	Trt
Milk Intake	0.72	0.72	0.01	0.87
CS Intake	0.36	0.38	0.03	0.53
PrewCSI	0.21	0.22	0.03	0.76
PWCSI	1.41	1.53	0.13	0.39
DM Intake	0.99	1.01	0.02	0.37
FE	0.51	0.55	0.02	0.10[2]

[1]Treatments are SS corn CS and HS corn CS
[2]SignificantTrend at $0.05 \leq P \leq 0.1$.

Table 6. Digestibility of Nutrients when calves were fed hard starch(SS) or soft starch (SS) calf starters (CS)

Nutrient[1]	HS	SS	SEM	*P*<
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
Starch	98.4	99.4	0.28	0.04
Ca	67.1	80.3	3.01	0.01
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

[1]Nutrient digestibility conducted according to AOAC (2000) nutrient analysis procedure using acid insoluble ash by Analab (Fulton, Illinois).

Figure 1. Body weight by week for calves fed soft starch(SS) or hard starch (HS) calf starters.

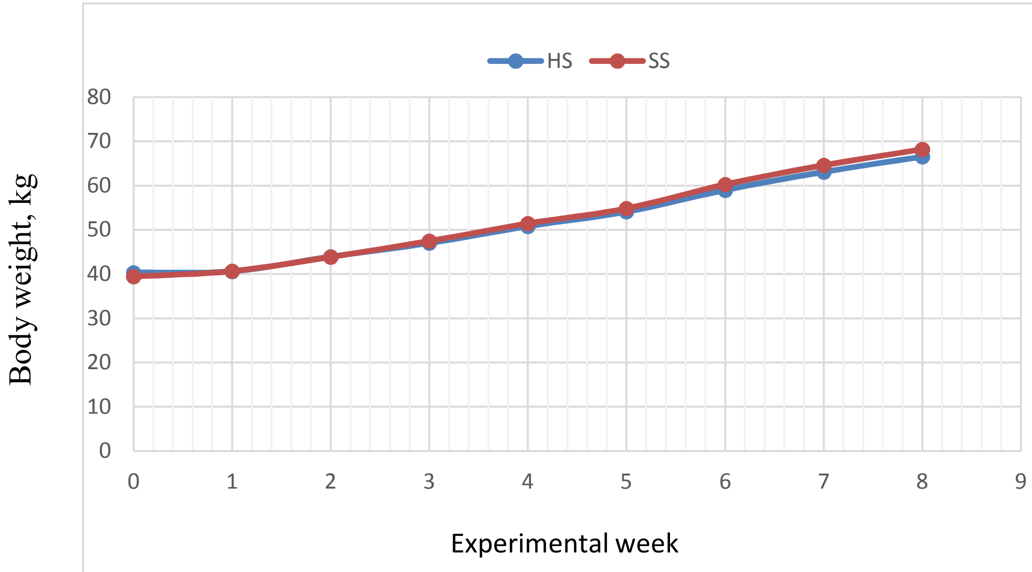


Figure 2. Body weight gain by week for calves fed soft starch(SS) or hard starch (HS) calf starters.

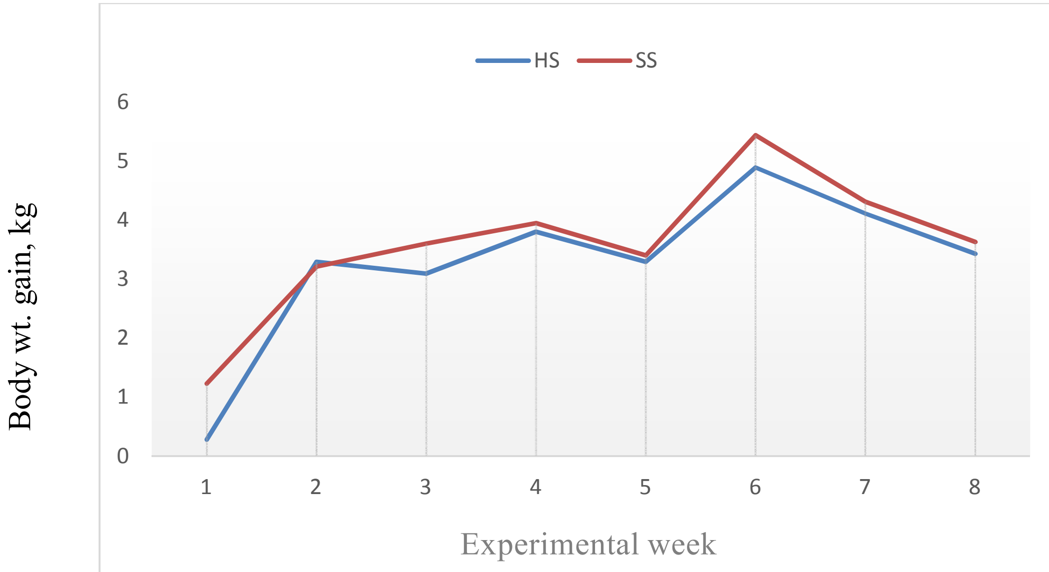
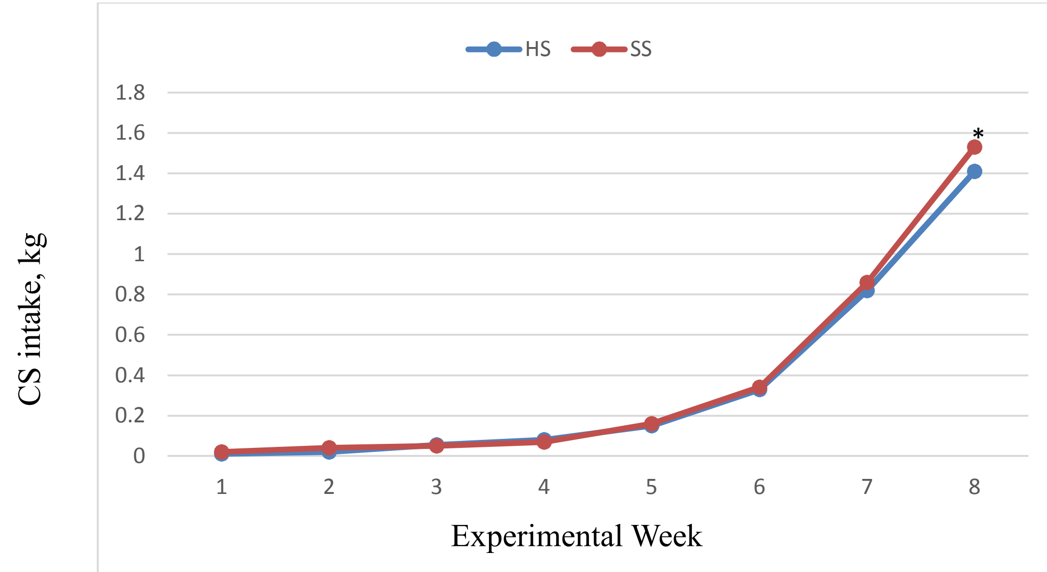


Figure 3. calf starter intake by week for calves fed soft starch (SS) or Hard starch (HS)



*Trend observed for gain in body wt. at week 8 which was higher for SS compared to HS CS (1.53 Vs 1.41 kg; $P < 0.08$)

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