

Ruminant Nutrition: Dairy: Calves and Heifers

M285 Crude glycerin as a replacement for corn in starter concentrate for dairy calves: Ruminant and blood parameters. G. G. O. Napoles^{1,2}, C. E. Oltramari^{1,3}, J. T. Silva^{1,3}, G. B. Mourão^{1,3}, and C. M. M. Bittar^{*1,3}, ¹*Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, SP, Brazil*, ²*Fapesp, São Paulo, SP, Brazil*, ³*CNPq, Brasília, DF, Brazil*.

The purpose of the study was to evaluate the effects of crude glycerin inclusion in starter concentrate, as a replacement for corn, on dairy calves ruminant and blood parameters. Study was conducted with 24 male Holstein calves allocated into blocks according to age (3–7 d of life) and initial weight (36.7 kg). Animals were individually housed and fed milk replacer (Servamilk, 22% CP; 18% EE, 4L/d) and starter concentrate (21% CP; 80% TDN) with increasing levels of crude glycerin, replacing corn in the formulation (0, 5, 10%, dry matter basis). Blood samples were collected weekly until 8 weeks of age for glucose, lactate, β -hydroxybutyrate (BHBA) and total protein (TP) determination. In wk 4, 6 and 8 of age, ruminal fluid samples were collected using an oro-ruminal probe and a suction pump for pH, acetate, propionate, butyrate, and total short chain fatty acids (SCFA) determination. Plasma glucose (96.5; 90.7; 94.0 mg/dL for 0%, 5% and 10% glycerin, respectively), lactate (11.66; 11.66; 11.7 mg/dL for 0%, 5% and 10% glycerin, respectively), BHBA (0.13; 0.13; 0.12 mmol/L for 0%, 5% and 10% glycerin, respectively) and TP (6.23; 6.40; 6.33 g/dL for 0%, 5% and 10% glycerin, respectively) were not affected ($P > 0.05$) by the replacement of corn by crude glycerin. However, concentrations of BHBA and TP were significantly increased with age ($P < 0.05$). Most of the ruminal parameters were also not affected by the replacement of corn by crude glycerin in the starter concentrate, except for propionic acid which presented lower molar concentrations for the 5% crude glycerin treatment (46.95; 36.03; 44.28 mmol/mL for 0%, 5% and 10% glycerin, respectively). An age effect was observed for pH and propionic acid molar concentration, but there were no significant effects for the interaction of age and treatment for these parameters. Averages were 5.25, 5.11, 5.10 for rumen pH; and 130.46; 107.86; 115.29 mmol/mL for total SCFA, for 0%, 5% and 10% glycerin treatments, respectively. The replacement of corn by crude glycerin does not affect ruminal or blood parameters of calves, being a good alternative for dairy calves solid feed formulation. Support by FAPESP.

Key Words: by-products, volatile fatty acids, solid feed

M286 Effect of feed presentation on pre- and post-weaning performance of dairy calves. E. K. Miller-Cushon¹, R. Bergeron², K. E. Leslie³, G. J. Mason⁴, and T. J. DeVries^{*1}, ¹*Dept. of Animal and Poultry Science, University of Guelph, Kemptville Campus, Kemptville, ON, Canada*, ²*Dept. of Animal and Poultry Science, University of Guelph, Campus d'Alfred, Alfred, ON, Canada*, ³*Dept. of Population Medicine, University of Guelph, Guelph, ON, Canada*, ⁴*Dept. of Animal and Poultry Science, University of Guelph, Guelph, ON, Canada*.

Dairy calves are typically offered feed types separately, despite commonly being fed a total mixed ration (TMR) later in life. The objective of this study was to determine how early feed presentation affects feed intake and performance of dairy calves both before and after weaning and once transitioned to a TMR. Twenty Holstein bull calves were randomly assigned at birth to 1 of 2 feed presentation treatments: they were offered chopped hay (3–4 cm) and concentrate at a ratio of 3:7, either

as a mixture (MIX) or in separate buckets (COM). All calves received 8L/d of milk replacer for the first 4 wks. The amount of milk fed was reduced incrementally in wks 5–7 to facilitate weaning by the end of wk 7. Calves remained on their respective feed presentation treatments for 8 wks. In wk 9–11, all calves were offered the MIX diet to assess whether early feed presentation affected intake of the mixed feed. In wks 12–13, all calves were offered a novel TMR (containing haylage, corn silage, high moisture corn, and protein supplement) to assess how early feed presentation may impact acceptance of a novel feed type. Calves were weighed 2x/wk and intake was recorded daily. Data were analyzed in a repeated measures general linear mixed model. Calves had similar ADG both pre-weaning (0.75 kg/d, $P = 0.4$) and post-weaning (1.19 kg/d, $P = 0.13$), and similar weights throughout the study ($P = 0.8$). While on their respective treatments, MIX and COM calves had similar total feed intakes (average 0.54 kg/d in wks 2–8, $P = 0.8$). COM calves consumed a greater ratio of hay:concentrate than the offered ratio in wk 3, 4, and 5 (7.06:7 vs. 3:7; $P < 0.04$), a similar ratio in wk 6 (3.30:7, $P = 0.3$), and a lower ratio in wks 7 and 8 (1.83:7 vs. 3:7; $P < 0.007$). When all calves were offered the MIX diet in wk 9, intake was similar between treatments (2.67 kg/d, $P = 0.7$), indicating that familiarity with feed presentation did not influence intake. Intake remained similar between treatments upon transition to the novel TMR (average 3.97 kg/d in wks 12–13, $P > 0.6$). These results suggest that dietary selectivity associated with early feed presentation may be transient, without statistically significant effects on longer-term calf intake or growth.

Key Words: dairy calf, feed presentation, growth

M287 Interactive effects of feeding frequency and feed bunk space on the feeding behavior of limit-fed dairy heifers. A. M. Greter¹, T. F. Duffield², B. W. McBride³, T. M. Widowski³, and T. J. DeVries^{*1}, ¹*Dept. of Animal and Poultry Science, University of Guelph, Kemptville Campus, Kemptville, ON, Canada*, ²*Dept. of Population Medicine, University of Guelph, Guelph, ON, Canada*, ³*Dept. of Animal and Poultry Science, University of Guelph, Guelph, ON, Canada*.

Limit feeding may improve feed efficiency, while reducing feed costs and nutrient excretion, but also poses health and welfare concerns. The objective of this study was to determine the effects of feeding frequency and feed bunk space on the behavior of limit-fed replacement dairy heifers. Sixteen Holstein dairy heifers (183.4 \pm 9.1 d of age), divided into groups of 4, were exposed to 4 treatments, using a 2-factor 4 \times 4 Latin square design with 21-d periods. The treatments were: 1) feeding 1x/d (at 1200 h) with ample feed bunk space (0.40 m/heifer), 2) feeding 1x/d with reduced feed bunk space (0.34 m/heifer), 3) feeding 2x/d (at 1200 and 1400 h) with ample feed bunk space, and 4) feeding 2x/d with reduced feed bunk space. The ration was formulated to meet nutrient requirements of a dairy heifer growing at 0.8 kg/d and fed at a rate of 2.0% of BW. Feeding and lying behavior were recorded for the last 7 d of each period. Competitive behavior was recorded on d 16, 18, and 20 of each period. DMI was recorded daily and ADG was recorded weekly. Data were analyzed in a general linear mixed model. DMI was similar between treatments (5.5 kg/d). Heifers fed 1x/d spent more time feeding than heifers fed 2x/d, regardless of feed bunk space (70.5 vs. 58.9 min/d; SE = 4.0, $P = 0.001$). Additionally, heifers fed 1x/d displaced each other more often than heifers fed 2x/d (4.8 vs. 2.4 displacements/d; SE = 1.3, $P = 0.008$). Feed bunk space allowance did not affect competition between heifers. Interestingly, regardless of feed bunk space or feeding frequency, all heifers maintained similar ADG

(0.9 kg/d), lying time (835.6 min/d), inactive standing time (539.8 min/d), and unrewarded time (when no feed was present) at the feed bunk (28.9 min/d). No interactions between feed bunk space and feeding frequency were found. Results suggest that feed bunk space does not affect feeding behavior or growth if heifers are allowed sufficient space to feed simultaneously. The lack of interactive effects of feeding frequency and bunk space suggests that behavioral concerns associated with limit feeding may not be addressed by increased feeding frequency when limit-fed dairy heifers are provided with reduced feed bunk space.

Key Words: dairy heifer, feeding behavior, limit feeding

M288 Effect of physical form of forage on performance, feeding behavior, and digestibility of Holstein calves. C. Montoro¹, E. K. Miller-Cushon^{*2}, T. J. DeVries², and A. Bach^{1,3}, ¹Department of Ruminant Production, IRTA, Barcelona, Spain, ²Department of Animal and Poultry Science, University of Guelph, Kemptville, ON, Canada, ³ICREA, Barcelona, Spain.

The physical form of forage may influence rumen development, and consequently BW gain, DM consumption, digestibility, and welfare of dairy calves. The objective of this study was to determine the effect of different physical forms of forage on performance, apparent digestibility, and feeding behavior of young calves. Twenty Holstein male calves (46.8 ± 1.2 kg) were randomly assigned at birth to 1 of 2 feeding treatments, in which they were exposed to a mixed ration containing (on a DM basis) 90% crumb starter concentrate and either 1) 10% chopped (3–4 cm) grass hay (COARSE; n = 10), or 2) 10% ground (2 mm) grass hay (FINE; n = 10). All calves were offered 8 L/d of milk replacer (MR; 1.2 kg of DM) from birth, which was incrementally reduced after 5 wk to enable weaning by the end of wk 7. The study finished after wk 8. Consumption of mixed ration, MR, and water was recorded daily, and calves were weighed twice weekly. Samples of feed and orts were taken in wk 7 and 8 for nutrient content analysis. Behavioral data of each calf were obtained 2 h per day during wk 6 and 8. Total feces were collected during wk 8 to determine apparent digestibility. Calves exposed to COARSE had a greater ($P < 0.05$) DMI than FINE calves (2.70 vs. 2.45 kg/d, respectively) during the week after weaning (wk 8). Body weight gain was similar between treatments, despite COARSE calves having a numerically greater gain than FINE calves (0.94 vs. 0.89 ± 0.03 kg/d). Interestingly, COARSE calves tended ($P = 0.09$) to have a greater gain to feed ratio than FINE calves (0.68 vs. 0.63 ± 0.02 kg/kg). No differences were observed in CP, soluble protein, and ADF consumption between treatments; however, COARSE calves tended ($P = 0.09$) to consume more NDF than FINE calves during the last week of study (719.2 vs. 610.5 ± 25.84 g/d). Calves receiving COARSE sorted in favor of NDF to a greater extent than FINE calves ($P < 0.05$), whereas FINE calves sorted in favor of CP to a greater extent than COARSE calves ($P < 0.05$). Apparent DM, CP, NDF, and ADF digestibilities were greater ($P < 0.05$) in COARSE than in FINE calves (72.3, 77.4, 40.7, and 42.7% vs. 69.2, 74.5, 34.0, and 35.6%, respectively). Calves fed FINE spent more ($P < 0.05$) time performing non-nutritive oral behaviors than those fed COARSE, and FINE calves tended to spend less time idle (either lying or standing) than COARSE animals. In conclusion, providing chopped hay to young calves improves feed intake, improves DM, CP, NDF, and ADF digestibility after weaning, and reduces non-nutritive oral behaviors.

Key Words: feeding behavior, forage, physical form

M289 Effects of age on gene expression of transport proteins in ruminal epithelia of milk-fed calves. M. Oba,* T. B. McFadden, and L. L. Guan, University of Alberta, Edmonton, AB, Canada.

The objective was to evaluate effects of age of milk-fed calves on expression of genes coding for epithelial transport proteins that facilitate absorption of fermentation acids from the rumen. Eighteen Holstein bull calves were individually housed and fed whole milk twice daily (4L/d) and offered texturized calf starter ad libitum. The calves were harvested at week one (n = 6), 3 (n = 5), or 6 (n = 7) after birth, and ruminal epithelial tissue was harvested; the epithelium was manually peeled off from the muscle layer, rinsed in PBS (pH 7.4), snap-frozen in liquid nitrogen, and kept at -80°C until analysis. Total RNA was extracted, and real-time RT-PCR was performed for monocarboxylate transporter isoform 1 (*MCT-1*; co-transporter exporting protons and dissociated VFA), Na⁺/H⁺ exchanger (anti-porter importing Na⁺ and exporting protons) isoforms 1 (*NHE-1*), 2 (*NHE-2*) and 3 (*NHE-3*), putative anion transporter isoform 1 (*PAT-1*; anti-porter importing dissociated VFA and exporting bicarbonate), and downregulated in adenoma (*DRA*; anti-porter importing dissociated VFA and exporting bicarbonate). The expression of each targeted gene was normalized using 3 internal control genes: ribosomal protein large P0, β-actin, and glyceraldehyde-3-phosphate dehydrogenase. Ruminal epithelia harvested from 3 or 6 wk old calves had higher mRNA abundance of *DRA* (0.44 and 0.39 vs. 0.07 units; $P < 0.05$) and *MCT-1* (1.08 and 0.81 vs. 0.26 units; $P < 0.05$) compared with samples from one-wk old calves. Abundance of *NHE-2* mRNA was greater for 6-wk old calves compared with one-wk old calves (0.72 vs. 0.21 units; $P < 0.05$). However, mRNA abundance of *NHE-1*, *NHE-3*, and *PAT-1* was not affected by age at harvest. Dissociated VFA are transported across apical membrane via *DRA* and basolateral membrane via *MCT-1*, and both *MCT-1* and *NHE-2* regulate intracellular pH by exporting protons generated from absorption of undissociated VFA. These results indicate that ruminal epithelia of calves initiate metabolic adaptations at a molecular level within 3 wk after birth to facilitate absorption of fermentation acids from the rumen.

Key Words: calf, rumen epithelia, transport protein

M290 Ruminal and blood parameters of dairy calves managed on different milk-feeding programs. M. R. Paula^{1,2}, G. G. O. Napoles^{1,3}, M. P. C. Gallo^{1,2}, M. C. Soares^{1,3}, and C. M. M. Bittar^{*1,2}, ¹Escola Superior de Agricultura, Piracicaba, SP, Brazil, ²CNPq, Brasília, DF, Brazil, ³Fapesp, São Paulo, SP, Brazil.

The objective was to evaluate the effect of different milk-feeding programs on dairy calves ruminal and blood parameters. After birth, 30 male Holstein calves were utilized in a randomized block design and assigned to 3 milk-feeding programs: 1) Conventional (C): 10% birth weight (BW) (4L/d); 2) Step-down (SD): wk 1: 10% BW (4L/d); wk 2 to 6: 20% BW (8L/d), and wk 7 and 8: 10% BW (4L/d); 3) Intensive (I): 20% BW (8L/d). Animals were individually housed, had water free-choice, starter concentrate fed ad libitum (18% CP; 80% TDN), and milk replacer (MR) (20% CP, 16% EE, 12.5% solids; Sprayfo Violeta, Sloten do Brasil Ltda.) fed according to milk-feeding program. Coast-cross hay was fed after weaning (eighth week). Blood samples were collected weekly until 10 weeks of age for glucose and β-hydroxybutyrate (BHB) determination. In wk 4, 8 and 10 of age, ruminal fluid samples were collected using an oro-ruminal probe and a suction pump for pH

and short chain fatty acids (SCFA) analysis. Plasma glucose (88.8; 89.8; 92.4 mg/dL for C, SD and I programs, respectively) were not affected ($P > 0.05$) by milk-feeding program, but concentrations decreased as animals aged ($P < 0.0001$). Concentrations of BHBA (0.155; 0.122; 0.101 mmol/L for C, SD and I, respectively) were affected ($P < 0.05$) by milk-feeding program, as well as by age ($P < 0.02$), with similar values up to the 6th week but increasing values thereafter; and by the interaction of age and milk-feeding program ($P < 0.02$). Observed effects for BHBA reflect the observed starter concentrate intake according to milk-feeding programs (722.5; 552.0; 435.7 g/d for C, SD and I, respectively), with higher concentrations of BHBA for treatments with higher starter intake. Average ruminal pH (5.47; 5.51; 5.46 for C, SD and I, respectively), and total SCFA (106.6; 112.5; 105.4 mmol/mL for C, SD and I, respectively) were not affected by milk-feeding program. However, an age effect ($P < 0.001$) was observed for pH, with decreasing values; and for acetate, propionate, butyrate and total SCFA, with increasing concentrations as calves aged. An interaction of age and milk-feeding program effect was observed for propionate ($P < 0.2$), butyrate ($P < 0.6$), and for the total SCFA ($P < 0.05$), with lower concentrations for calves on intensive milk-feeding program at wk 8. Effects of milk-feeding program on starter intake affect rumen and plasma parameters. Support by FAPESP.

Key Words: β -hydroxybutyrate, milk replacer, volatile fatty acids

M291 Effects of kelp meal on performance and structural growth of conventional and organic dairy calves. G. M. Soule,* A. F. Brito, A. Miranda, L. Chase, N. L. Whitehouse, E. S. Fletcher, and N. T. Antaya, *University of New Hampshire, Durham.*

Kelp meal (KM) is a dried seaweed product used in dairy farms particularly in organic operations. The current study examined the effects of KM (*Ascophyllum nodosum*) on performance and structural growth of 36 heifer calves [18 conventional Holsteins (Trial 1) and 18 organic Jerseys (Trial 2)]. We hypothesized that the high mineral content and salty flavor of KM enhances diet palatability and DMI in calves. Animals were blocked by calving date and, within breed, randomly assigned to 2 treatments: Control (calf starter) or KM (calf starter + 25 g of KM). Approximately 5.7 and 3.8 L of milk were fed daily to Holsteins and Jerseys, respectively. Grass hay was offered ad libitum and orts were collected daily. Body weight and growth were measured twice a week from wk 1–7 and wk 1–8 of age in Holsteins and Jerseys, respectively. Except for whiter height, which was higher ($P = 0.05$) for Holsteins fed the control vs. the KM diet, no other significant treatment differences were observed on Trial 1. However, data from Trial 2 showed that KM significantly increased DMI and ADG compared with the control. No differences ($P > 0.05$) in structural growth were observed for calves fed the control or the KM diet in Trial 2, suggesting that dietary energy was utilized for body fat deposition rather than skeletal growth. A 2-fold difference in ash concentration between the conventional (9.04%) and the organic starter (5.68%) suggests the latter was lacking minerals. Because KM is rich in minerals and adds a salty flavor to the diet, increased DMI in Jerseys may be explained by enhanced diet palatability and/or an animal need to meet mineral requirements. Research is needed to investigate the interaction between KM and the starter nutrient profile on body composition and structural growth of dairy calves.

Table 1. Effects of kelp meal (KM) on performance and growth of dairy calves

Item	Holsteins (Trial 1)				Jerseys (Trial 2)			
	Control	KM	SED	P>F	Control	KM	SED	P>F
DMI, kg/d	1.34	1.39	0.12	0.77	0.93	1.16	0.04	<0.01
ADG, kg/d	0.73	0.76	0.03	0.55	0.49	0.61	0.03	0.01
ADG:DMI	0.50	0.55	0.02	0.11	0.53	0.53	0.03	0.98
Final BW, kg	60.5	61.5	1.05	0.52	40.7	44.7	1.00	0.02
Whiter height, cm	85.3	84.4	0.31	0.05	74.8	75.0	0.60	0.73
Hip height, cm	89.1	88.3	0.35	0.11	77.1	77.8	0.44	0.36
Body length, cm	65.0	63.7	0.77	0.26	59.2	59.4	0.51	0.85

Key Words: dairy calves, kelp meal, organic dairy

M292 Total serum protein in calves is not correlated with future milk performance. B. Ozer*¹, A. Bach^{2,3}, and M. Chahine¹, ¹*University of Idaho, Twin Falls*, ²*IRTA, Caldes de Montbui, Spain*, ³*ICREA, Barcelona, Spain.*

It is well established that calves with poor passive transfer of immunoglobulins have increased risk of diarrhea, respiratory problems, and mortality. Furthermore, there are some studies that have linked plasma immunoglobulin concentrations or colostrum provision early in life with improvements in future performance. The improvements have been attributed to potential lactocrine mechanisms mediated by hormones present in the colostrum. The objective of this study was to determine whether total serum protein (TSP) in calves was correlated with future milk performance in the first lactation. A total of 6,172 calves born between 2005 and 2009 in the same herd were fed 3 L of colostrum within 1 h after birth followed by 2 additional liters 8 h later, and blood-sampled within 48 h of life to determine TSP. Determinations of TSP were performed by an experienced veterinarian using a refractometer (Jorvet J-351, Jorgensen Laboratories, Inc. CO). Then, total milk produced by the animals in their first lactation was recorded. A categorical variable was constructed including TSP below 5.4 (n = 1,962), between 5.4 and 6.4 (n = 2,324), and above 6.4 mg/dl (n = 1,886). A mixed-effects model that accounted for the random effects of year of birth and sire (father of each heifer considered) plus the fixed effects of the 3 TSP categories and the lactation length as a covariate was run to evaluate any potential relationship between TSP and milk yield in the first lactation. In the first lactation, calves that had TSP below 5.4 mg/d produced 10,551 \pm 230 kg, those with TSP between 5.4 and 6.4 mg/dl produced 10,499 \pm 229 kg, and those with TSP above 6.4 mg/dl produced 10,445 \pm 230 kg. There was no relationship ($P = 0.13$) between TSP and future milk production. These results indicate that either TSP is not a valid proxy to assess the adequacy of colostrum feeding, or that the amount of colostrum offered during the first 2 d of life has no impact on future animal performance.

Key Words: colostrum, metabolic imprinting, performance

M293 Intake and performance of Holstein heifers transitioned to group housing from individual pens using differing grain mixes with or without hay the first two weeks after moving. D. Ziegler*¹, D. Schimek², B. Ziegler², H. Chester-Jones¹, M. Raeth-Knight³, and G. Golombeski⁴, ¹University of Minnesota Southern Research and Outreach Center, Waseca, ²Hubbard Feeds Inc., Mankato, MN, ³University of Minnesota, St. Paul, ⁴Hubbard Feeds Inc., Iowa City, IA.

One-hundred twelve 57- to 60-d-old Holstein heifers (82.6 ± 1.32 kg) were assigned to 1 of 4 treatments in 4 replicate pens (7 heifers/pen) for 112 d. Treatments were fed d 1–14 and included 1) free choice (FC) 18% CP texturized grain mix without hay (TXT); 2) same as TXT but with FC hay (TXTH); 3) FC 16% crude protein whole corn/pellet grain mix without hay (WCP); 4) same as WCP but with FC hay (WCPH). Then from d 15–112 all heifers were fed a common diet of 16% CP GM (2.73 kg/d d 15–56 and 2.27 kg/d d 57–112) with FC hay. Intakes were taken daily from d 1–28 and then weekly from d 29–112. Daily grain mix dry matter intake and gain/feed did not differ from d 1–14, 2.30 ± 0.05 kg and 0.38 ± 0.006 kg gain/kg feed, respectively. Hay dry matter intake for d 1–14 was 0.06 and 0.11 kg/d for TXTH and WCPH, respectively. There were significant grain mix x hay interactions for ADG ($P < 0.05$) and total dry matter intake ($P = 0.0003$) but no differences in gain to feed from d 1–112 (0.29 ± 0.002 kg gain/kg feed). No differences were observed in body condition score (112 d avg. 3.25) or hip height (112 d avg. 112.2 cm; $P > 0.05$). Under conditions of this study feeding differing grain mixes with or without hay for 14 d in group pens after moving from individual nursery pens had minimal effect on heifer performance.

Key Words: grain mixes, Holstein heifers, performance.

M294 Precision-feeding dairy heifers with different levels of dietary fiber and F:C. Effects on protein utilization, N efficiency, and rumen fermentation. G. J. Lascano*¹ and A. J. Heinrichs², ¹The California Polytechnic State University, San Luis Obispo, ²The Pennsylvania State University, University Park.

The objective of this experiment was to determine the effects of manipulating dietary fiber level with differing forage to concentrate (F:C) ratios on protein rumen utilization of precision-fed dairy heifers. Six cannulated Holstein heifers (486.98 ± 15.07 kg BW) were randomly assigned to 2 levels of concentrate, HC (45% forage) and LC (90% forage) and to a forage type sequence [33% grass hay and wheat straw HS, 67% corn silage CS (Low fiber); 50% HS, 50% CS (Medium fiber); and 67% HS, 33% CS (High fiber)] within forage level administered according to a split-plot 3×3 Latin square design (21-d period). Similar N intake and rumen degradable protein (RDP) were provided (1.20 g N/kg BW 0.75), and casein was added to supply additional N to provide 1.80 g N/kg BW 0.75. Heifers fed HC had greater apparent total tract organic matter (OMD), neutral detergent fiber (NDF), and cellulose apparent digestibility (AD) than those fed LC diets ($P \leq 0.01$). Nitrogen AD was not different between F:C or with increasing levels of HS in diets, but N retention tended to decrease linearly as HS was increased in the diets ($P = 0.09$). Protozoa numbers were not different between F:C treatments, but HS interacted linearly. The HC-fed heifers had a greater VFA concentration ($P \leq 0.05$). Mean pH was not different among F:C rations. Increasing dietary fiber through HS affected RDP utilization and decreased DM, OM, NDF, ADF and cellulose AD linearly ($P \leq 0.05$). Microbial protein synthesis predicted from urinary purine derivatives decreased linearly with HS addition resulting in a linear decrease in N retention with HS addition ($P = 0.03$), which was opposite to rumen NH_3N and BUN, reflecting the inefficiency in N utilization as more HS was added to the diets. Rumen fermentation parameters, DM and fractional passages

(solid and liquid) rates support the reduction in protein utilization and retention, microbial protein synthesis and AD observed as more dietary fiber is added to the rations of precision-fed dairy heifers.

Key Words: heifers, fiber, protein degradability

M295 Insulin response is affected by the level of milk replacer offered to young calves. A. Bach*^{1,2}, Ll. Castells², C. Montoro², and M. Terre², ¹ICREA, Barcelona, Spain, ²Department of Ruminant Production, IRTA, Barcelona, Spain.

Eight male Holstein calves (40.6 ± 2.9 kg of BW and 7.8 ± 1.6 d of age) individually housed were allocated to either a LOW milk replacer (MR) allowance of 2 daily doses of 2 L each (478.5 g/d of DM from MR), or to a HIGH allowance of 2 daily doses of 4 L (957.0 g/d of DM from MR). In addition all calves had ad libitum access to the same starter feed and water. At d 7, 30, and 60 of experiment all calves were submitted to a glucose tolerance test (GTT) that consisted on an i.v. infusion of 180 mg/kg of BW of glucose at 4 h after the morning MR offer. Blood was harvested at -15, -5, 0, 4, 8, 12, 25, 35, 45, and 60 min relative to glucose infusions. Blood samples collected at -15 and -5, and 0 relative to glucose infusion were used as baseline concentrations of glucose and insulin. Then, the area under the curve (AUC; concentration/min) for glucose and insulin was calculated as the increase with respect to the baseline. Next, the clearance rates of insulin (CRI, %/min) and glucose (CRG, %/min) were computed. The increase in blood glucose following the GTT (assessed as AUC) was similar in both LOW and HIGH calves, which indicates that all animals were able to control glycemia effectively. Similarly, CRG and CRI were no different between LOW and HIGH calves. However, calves in the HIGH group needed a substantially greater ($P < 0.001$) serum insulin concentration (98.7 ± 13.2 $\mu\text{U/ml}$) than LOW calves (41.5 ± 13.2 $\mu\text{U/ml}$) to control glycemia. Furthermore, as age increased, the rise in serum insulin elicited by the GTT continued to increase ($P = 0.01$) in HIGH but not in LOW calves. Insulin to glucose ratio was greater ($P < 0.001$) in HIGH (157.5 ± 7.8 $\mu\text{U/mg}$) than in LOW (46.7 ± 7.8 $\mu\text{U/mg}$) calves. This ratio increased with age ($P < 0.01$) and in a more pronounced ($P = 0.03$) fashion in HIGH than in LOW calves. It is concluded that offering 8 L/d of MR in 2 separate doses decreases insulin sensitivity of young calves. Research is needed to assess whether the impaired glucose responsiveness of calves can be minimized by feeding milk more frequently.

Key Words: calf, glucose, metabolism

M296 Optimizing particle size and moisture in diets for dairy heifers. M. A. Khan¹, A. Bach*^{2,3}, Ll. Castells*³, D. M. Weary¹, and M. A. G. von Keyserlingk¹, ¹Animal Welfare Program, University of British Columbia, Vancouver, BC, Canada, ²ICREA, Barcelona, Spain, ³Department of Ruminant Production, IRTA, Barcelona, Spain.

Little research to date has addressed diets for growing dairy heifers. In 2 experiments involving 36 replacement heifers (181 ± 7 kg of BW and 175 ± 7 d of age) we tested the effects of forage particle length and DM of a TMR on DMI, feeding rate and feed sorting. Each experiment used a replicated 3×3 Latin square design, testing 9 heifers in each of 2 replications for 3 periods of 9 d each. Each group of heifers was housed in a pen with access to 3 electronic feed bins. In Exp. 1, a TMR was formulated using the same ingredients but where the hay component was provided at 3 different lengths resulting in a TMR with 72 (LONG), 64.2 (MEDIUM), or 60% (SHORT) of the particles above 19 mm. In Exp. 2, heifers were provided access to a TMR with different moisture contents (obtained by adding water): LOW (65% DM), MODERATE

(50% DM), and HIGH (35% DM). In both experiments, data from the last 5 d of each period were analyzed using a mixed-effects model accounting for the fixed effects of treatment and period, and the random effects of replication, animal within treatment, and period. In Exp. 1, DMI tended ($P = 0.09$) to increase and time spent feeding decreased ($P = 0.05$) as the particle size of TMR increased. Feeding rate also tended ($P = 0.07$) to increase as particle size of the TMR decreased. Heifers fed the LONG diet selected ($P < 0.05$) in favor of long particles (>19 mm) and against short (1.18–8mm) and fine (<1.18 mm) particles; heifers fed the SHORT diet selected ($P < 0.05$) against long particles and in favor of short and fine particles. In Exp. 2, heifers consuming the LOW moisture diet tended ($P = 0.09$) to have greater DMI than those fed the MODERATE and HIGH diets, with no differences in feeding behavior or sorting activity. We conclude that TMRs with particle sizes similar to the MEDIUM diet minimize sorting. Adding water to achieve moisture contents of a TMR $>35\%$ can reduce DMI in heifers.

Key Words: eating rate, feeding behavior, sorting

M297 Replacing processed grains with whole corn in starter diet did not affect the performance of dairy calves. M. A. Khan^{*1}, J. H. Kim², D. M. Veira², and M. A. G. von Keyserlingk¹, ¹*Animal Welfare Program, University of British Columbia, Vancouver, BC, Canada*, ²*Agriculture and Agri-Food Canada, Agassiz BC, Canada*.

We compared the effects of replacing processed grains in conventional texturized starter with whole corn on the performance of dairy calves. Individually housed Holstein heifer calves ($n = 24$) were fed whole milk (8 l/d) for 28 d of age and gradually weaned during d 29 to 39. At 7 d of age, calves were randomly assigned to one of the 2 starter diets i.e., conventional (textured; contain processed grains) starter ($n = 12$) or whole corn (whole corn replaced the grain component of conventional diet) starter ($n = 12$). Starter diets were fed ad libitum for 70 d. Daily starter intake in calves fed either conventional or whole corn starter was similar during pre-weaning (0.21 ± 0.02 vs. 0.22 ± 0.02 , kg; $P = 0.73$) and post-weaning (2.10 ± 0.07 vs. 1.99 ± 0.10 ; $P = 0.46$) periods. Overall during the experiment, total (milk solid plus starter) DMI (98.0 ± 3.0 vs. 95.7 ± 3.7 , kg; $P = 0.63$), BWG (53.5 ± 2.2 vs. 53.1 ± 2.4 , kg; $P = 0.92$) and feed efficiency (0.56 ± 0.01 vs. 0.57 ± 0.02 , BWG/DMI; $P = 0.67$) were similar in calves fed either conventional or whole corn starter. Calves fed whole corn starter visit the feeder more frequently (186.5 ± 9.4 vs. 153 ± 15.3 , visit/d; $P = 0.02$) than those fed conventional starter. However, daily time spent eating was not affected (3.57 ± 0.17 vs. 3.45 ± 0.19 , h/d; $P = 0.18$) by diet. Calves on both treatments did not ($P > 0.05$) preferentially select feed particles (grains or pellets) from the starter diet. Ruminant pH was similar (5.68 ± 0.16 vs. 5.43 ± 0.07 , $P = 0.20$) in calves fed whole corn based starter compared with those fed conventional starter. Concentrations of blood glucose and blood BHBA were similar ($P > 0.05$) in calves fed both starter diets. In conclusion, replacing processed grains with whole corn in starter diets did not affect the feed consumption, feed particle sorting, growth and feed efficiency in dairy calves however; it fails to alleviate the severe acidic conditions in the rumen of developing calves. Use of whole corn in starter could potentially lower the rearing cost of heifers by reducing the processing cost of grains.

Key Words: whole corn, starter, rumen development

M298 Performance of dairy calves managed on different milk-feeding programs. M. R. Paula^{1,2}, M. P. C. Gallo^{1,3}, M. C. Soares¹, G. B. Mourão^{1,2}, and C. M. M. Bittar^{*1,2}, ¹*Escola Superior de*

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The objective was to evaluate the effect of different milk-feeding programs on performance of calves until 10 weeks of age, abruptly weaned at 8 weeks of age. After birth, 30 male Holstein calves were utilized in a randomized block design and assigned to 3 milk-feeding programs: 1) Conventional (C): 10% birth weight (BW) (4L/d); 2) Step-down (SD): wk 1: 10% BW(4L/d); wk 2 to 6: 20% BW (8L/d), and wk 7 and 8: 10% BW (4L/d); 3) Intensive (I): 20% BW (8L/d). Animals were individually housed, had water free-choice, starter concentrate fed ad libitum (18% CP; 80% TDN), and milk replacer (MR) (20% CP, 16% EE, 12.5% solids; Sprayfo Violeta, Sloten do Brasil Ltda.) fed according to milk-feeding program. Coast-cross hay was fed after weaning (eighth week). Fecal scores, starter and milk replacer intake were evaluated daily. Calves were weighted and growth measurements were taken weekly until the tenth week of age. Starter daily intake was affected ($P < 0.05$) by the milk-feeding program with lower intake observed for the intensive fed calves as compare with calves fed by the conventional program, with no difference with the step-down program (722.5; 552.0; 435.7 g/d for C, SD and I, respectively). Measured average MR intake was 3.94; 6.02; 7.30 L/d for C, SD and I programs, respectively. Despite the higher MR intake for the step-down and intensive programs, weight gain (469.1; 455.0; 466.4 g/d for C, SD and I, respectively), average body weight (50.6; 51.6; 52.7 kg for C, SD and I, respectively), and final weight (69.7; 68.6; 69.6 kg for C, SD and I, respectively) were not affected by milk-feeding. Even though average and final body weight were not affected, heart girth was affected ($P < 0.05$) (84.3; 86.2; 87.2 cm for C, SD and I, respectively), suggesting effects on growth other than weight gain. However, other body measurements (hip width: 23.1; 23.4; 23.8 cm and withers height: 82.3; 82.1; 83.0 cm for C, SD and I, respectively), were not affected ($P > 0.05$). Average hay intake was affected ($P < 0.05$) with lowest intake for calves on the step-down program (461.0; 150.5; 307.4 g/week for C, SD and I, respectively). Fecal scores were higher for the step-down and intensive programs (1.44; 2.8; 2.1 for C, SD and I, respectively). Support by FAPESP.

Key Words: milk replacer, liquid feeding, weight gain

M299 Effect of increasing intake of linoleic acid in milk replacer on Holstein calf performance. M. Garcia,* J. H. Shin, A. Schlaefli, J. E. P. Santos, and C. R. Staples, *University of Florida, Gainesville*.

The aim was to evaluate the linoleic acid (LA) requirement of unweaned Holstein calves from birth to 60 d of age. Within 2 h of birth, calves ($n = 88$) were fed 4 L of colostrum (>60 g of IgG/L) harvested from cows delivering the experimental calves. Calves were blocked by gender and assigned randomly to 1 of 4 treatments. Soybean and coconut oils were mixed with an emulsifier and added to a basal milk replacer (MR; 7% fat and 28% CP) at the time of feeding (0600 and 1200 h) to supply 0.064, 0.128, 0.256, or 0.512 g of LA/kg of metabolic BW, T1 to T4, respectively. Final MR fed was 15% fat. Amount of MR fed was adjusted based on weekly BW. Blood was collected weekly. A low LA grain mix (18% CP, 2.87 Mcal of ME/kg, and 1.6% fat) was offered starting at 31 d of age. Birth weight and height were covariates for analysis of gain and growth respectively. During the period of feeding MR alone, T2 males gained more BW (5.3 kg) compared with males fed T1, T3, or T4 (2.8, 2.8, and 2.7 kg, respectively, SE = 0.5) whereas BW gain by females did not differ (2.6, 3.1, 3.3, and 3.4 kg; cubic by gender interaction, $P = 0.04$). Increased gain by T2 males was accompanied by increased intake of MR (19.7 vs. 19.2, 19.0, and 19.2 kg, SE = 0.2). Intake of grain mix (480 g/d; SE = 55) and BW gain (21.2 kg, SE = 1.4) between 31 and 60

d of life did not differ among treatments. At 60 d of life, calves fed diets T2 and T3 had greater wither height (82.6, 83.6, 84.0, and 83.2 cm, SE = 0.7, $P = 0.08$) and hip height (87.6, 88.7, 88.9, and 87.9 cm, SE = 0.7; quadratic effect, $P = 0.04$). Mean concentrations of plasma glucose (90.3 mg/dL, SE = 1.5) and insulin (2.2 ng/mL, SE = 0.3) were unaffected by diet. Total cholesterol concentrations in plasma increased linearly ($P = 0.05$) with increasing intake of LA (72.6, 75.2, 79.0, and 80.4 mg/dL, SE = 4.1) whereas plasma concentrations of BHBA tended ($P = 0.10$) to be greater for T1 calves compared with others (0.82 vs. 0.74, 0.72, and 0.76 mg/dL, SE = 0.05). Supplementing LA in MR at >0.064 g/kg of metabolic BW during the first 60 d of life improved growth but not BW of underperforming female Holstein calves.

Key Words: calves, milk replacer, linoleic acid

M300 Effect of feeding increasing amounts of linoleic acid on health and immunity of unweaned Holstein calves. M. Garcia,* J. H. Shin, A. Schlaefli, D. Wang, J. E. P. Santos, and C. R. Staples, *University of Florida, Gainesville*.

The aim was to evaluate the effect of increasing intake of linoleic acid (LA) on measures of health and immunity of Holstein calves from birth to 60 d of age. Within 2 h of birth, calves ($n = 88$) were fed 4 L of thawed colostrum (minimum of 60 g of total IgG/L) harvested from cows delivering the experimental calves. Calves were blocked by gender and assigned randomly to 1 of 4 treatments. Soybean and coconut oils were mixed with an emulsifier and added to a basal milk replacer (MR; 7% fat and 28% CP) at the time of feeding (0600 and 1200 h) to supply 0.064, 0.128, 0.256, or 0.512 g of LA/kg of metabolic BW, T1 to T4, respectively. Final MR fed was 15% fat. A grain mix of low LA concentration (18% CP, 2.87 Mcal of ME/kg, and 1.6% fat) was offered starting at 31 d of age. Blood was sampled weekly. Serum IgG (g/L) on the day after birth was used as a covariate for health measures. As LA intake increased, fecal firmness tended ($P = 0.07$) to increase linearly as well as age at first day of diarrhea (7.0, 7.3, 7.5, and 7.5 d, SE = 0.3). The % of days with fever ($>39.5^{\circ}\text{C}$) during the first 14 d of age did not differ (5.7%, SE = 2.3) nor did % of days (4.5%, SE = 1.0) with severe diarrhea throughout the 60-d study. Mean plasma concentration of acid soluble protein tended ($P = 0.06$) to decrease linearly (102.0, 96.5, 91.7, and 92.6 mg/L) with increasing LA intake. Mean plasma concentration of haptoglobin decreased (treatment by age, $P = 0.04$) to a greater extent at first evidence of diarrhea for T1 calves. Mean concentration of TNF α in mitogen-stimulated blood did not differ among treatments (375 pg/mL, SE = 64), but that of IFN γ tended to be greater in T2 and T3 calves (258, 342, 319, and 238 pg/mL, SE = 67; quadratic effect, $P = 0.09$). A similar quadratic response to LA supplementation was detected for % of blood neutrophils undergoing phagocytosis (62.1, 66.6, 64.1, and 62.8%, SE = 2.3; $P = 0.07$) and oxidative burst (51.5, 55.8, 53.6, and 50.4%, SE = 2.5; $P = 0.04$). Feeding LA in MR between 0.128 and 0.256 g/kg of metabolic BW appeared to increase several markers of pro-inflammatory response in unweaned Holstein calves.

Key Words: calves, linoleic acid, immunity

M301 Jersey calf blood metabolites in response to liquid feeds with varied fatty acid profiles. V. A. Swank,* W. S. Bowen, K. M. O'Diam, M. L. Eastridge, and K. M. Daniels, *Department of Animal Sciences, The Ohio State University, Columbus*.

Most commercially available Jersey calf milk replacers (MR) use edible lard as the primary fat source. Edible lard lacks medium chain fatty acids

(MCFA) whereas pasteurized saleable whole milk (pSWM) from Jersey cows contains many MCFA. The objective was to determine whether altering the FA profile of MR with the inclusion of coconut oil (CO), rich in MCFA, would alter blood metabolite profiles in Jersey calves over time. This trial was conducted as a randomized complete block design. Male ($n = 18$) and female ($n = 32$) Jersey calves were randomly assigned at birth to 1 of 4 liquid diets: pasteurized Jersey saleable whole milk (pSWM; 27.9% CP, 33.5% fat, DM basis); MR containing 100% of fat as edible lard (100:00; 29.3% CP, 29.1% fat); MR containing 20% of fat as CO (80:20; 28.2% CP, 28.0% fat); MR containing 40% of fat as CO (60:40; 28.2% CP, 28.3% fat). Calves were fed 2L of their respective liquid diet twice daily (0600h and 1800h) from 2d of age until 7wk of age, and once daily until weaning (8wk of age). Once a week, a subset of calves ($n = 34$) were fasted overnight for 12h and jugular blood samples were taken; immediately before morning feeding which occurred at 0600h, 0800h, 1200h, and immediately before the evening feeding at 1800h. These samples were collected at 1wk, 3wk, and 6wk of age. Blood samples were used to determine concentrations of triglycerides (TG), glucose, plasma urea nitrogen (PUN), and total protein (TP). Data were analyzed using the mixed procedure of SAS. TP was not different throughout the trial. The interaction of diet and week was significant for TG and glucose concentrations; both variables changed over time in a complex pattern for animals on a given treatment (significant linear and quadratic contrast effects). Treatment, week, and time of collection had a significant effect on intensive PUN concentrations, with all 3 having a linear effect. Moreover, pSWM was significantly different than 80:20, with 6.17mg/dl and 5.76mg/dl, respectively ($P = 0.036$). Given that calves on this trial grew the same (companion abstract) our results here measuring concentrations of blood metabolites are as expected.

Key Words: fatty acids, Jersey calf, milk replacer

M302 Ponderal development of dairy heifers fed sugarcane and increasing crude protein levels. M. F. S. Queiroz*¹, T. T. Berchielli², R. D. Signoretti³, and J. A. S. Morais⁴, ¹*Universidade Federal da Paraíba, CCHSA/UFPB, Bananeiras, Paraíba, Brazil*, ²*Faculdade de Ciências Agrárias e Veterinárias, UNESP, Jaboticabal, São Paulo, Brazil*, ³*Agência Paulista de Tecnologia dos Agronegócios, Colina, São Paulo, Brasil*, ⁴*Universidade Federal de Sergipe (UFS), São Cristóvão, Sergipe, Brazil*.

Twenty-four Holstein \times Zebu crossbred heifers with average age of 19 months and 250 kg fed sugarcane and four different protein levels diets were used. The sugarcane (IAC 862480) was evaluated during August to November (winter/spring) and the diets concentrate was compound by corn meal, soybean meal, urea, ammonia sulfate and mineral mix, in different proportions, to obtain the protein levels (13, 15, 19 and 22% of crude protein) in 70:30 relation forage and concentrate. The animals were maintained in an individual stall and ad libitum fed twice a day (8 and 16 h) during the adaptation and experimental period, 15 and 62 days, respectively. The experimental design was completely randomized blocks, consisting of 3 blocks and 4 treatments. The heifers were weighed and their thoracic perimeter; withers and hip height, and body score were determined at the beginning and at the end of the experimental period, at every 21 days. There was no diet effect ($P > 0.05$) on ponderal development and body score. The heifers had an average growth of 0.05 cm/day withers height and 0.04 cm/day hip height and 0.17 cm/day of heart girth during the experimental period.

Table 1. Means of crossbred dairy heifers ponderal development

Item	Diet CP level (%)				CV	P-value ¹	
	13	15	19	22		LE	QE
Weight (kg)	279.1	275.6	268.9	277.1	13.3	ns	ns
Withers height (cm)	120.1	121.1	119.3	119.6	4.2	ns	ns
Hip height (cm)	124.0	124.9	123.6	123.0	3.9	ns	ns
Thoracic perimeter (cm)	158.1	155.7	155.8	156.3	5.0	ns	ns
Initial BCS ²	2.5	2.6	2.6	2.6	8.2	ns	ns
Final BCS ²	2.8	2.8	3.0	2.8	9.0	ns	ns

¹LE = linear effect; QE = quadratic effect.

²Scale 1 to 5.

Key Words: body score, feedlot, heifer rearing

M303 Pre- and postweaning performance and health of dairy calves when sodium butyrate is fed in milk replacer and/or calf starter during the summer months. H. Chester-Jones^{*1}, S. Moreland², D. Ziegler¹, M. Raeth-Knight³, and J. van Eys², ¹University of Minnesota Southern Research and Outreach Center, Waseca, ²Nutriad Inc., Elgin, IL, ³University of Minnesota, St. Paul.

One-hundred eight (2–4 d old) individually fed Holstein heifer calves (39.3 ± 0.64 kg) were randomly assigned to 1 of 4 treatments to evaluate pre- (d 1–42) and post weaning (d 43–56) calf performance and health when fed sodium butyrate in milk replacer and/or calf starter. All calves were fed a non-medicated 20% fat:20% protein milk replacer (MR) at 0.284 kg in 1.99 L water (12.5% solids) 2X daily for the first 35 d and 1X daily from d 36 to weaning at 42 d. Calf starter (CS; 18% CP) and water were fed free choice d 1 to 56. Day 1 to 14, 1:1 neomycin:oxytetracycline was added to the MR solution to provide 22 mg/kg BW/d. Treatments (Trt) were 1), Control MR and CS with rumensin (R; 33 mg/kg); 2), MR with 0.3% sodium butyrate (NaB; Adimix-Pro) and CS with R; 3), Control MR and CS with 0.33% NaB (Adimix-30C); and 4), MR with 0.3% NaB and CS with 0.33% NaB. Ambient temperatures averaged a high of 27.2°C (range 18.9 to 38.3°C) and a low of 16.9°C (range 10.6 to 26.1°C) during the study (June, July, August, 2011). Calves fed MR with NaB (Trt 2,4) had greater pre-weaning ADG ($P = 0.02$) and gain/feed ($P = 0.001$) than those fed MR without NaB (Trt 1,3). Similar trends ($P = 0.09$) were observed for d 1–56 ADG. Calves fed Trt 1 had reduced gain/feed and tended to have lower pre-weaning and overall ADG ($P = 0.07$) vs. Trt 2, 3, and 4. The addition of NaB or R to starter did not affect starter intake pre- or post-weaning. There were also no differences in total DMI between treatments averaging 0.78 kg/d

and 1.76 kg/d during the pre- and post-weaning periods, respectively. There were no pre- or post weaning scouring days and treatment cost differences due to treatments. Under the conditions of this study there were benefits to calf performance of adding NaB to non-medicated MR during the summer months. Using NaB in CS appeared to be an acceptable alternative to R.

Key Words: Holstein calves, performance, sodium butyrate

M304 Limiting amino acids for pregnant heifers fed corn silage-based diet. D. Wang, J. Q. Wang,* S. C. Li, D. P. Bu, Y. D. Zhang, P. Sun, and L. Y. Zhou, *Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing, China.*

Two experiments were conducted to determine limiting amino acids (AA) for pregnant heifers fed corn silage-based diet. In experiment 1, four 21-mo-old Holstein Heifers (BW = 450 ± 20kg) fitted with ruminal, proximal duodenal and terminal ileal cannula were used to determine flows of AA into the duodenum and apparent intestinal AA digestibilities. These data were used to calculate amounts of total essential amino acids (TEAA) that should be infused into the duodenum to match the requirements of AA of growing and pregnant heifers according to calculations, which suggested that 8, 15, 20, 5, 15, 15, 20, 5, 10 and 5 g/d of methionine, histine, lysine, arginine, threonine, valine, leucine, isoleucine, phenylalanine and tryptophane were required, respectively, to be supplemented to the duodenum. In experiment 2, three 23-mo-old Holstein Heifer (BW = 470 ± 25kg) fitted with ruminal, proximal duodenal and terminal ileal cannula were used in a duplicate 3 × 3 Latin square design experiment, and the 3 treatments were continuously duodenal infusion of a mixture of methionine, Histine, lysine, arginine, threonine, valine, leucine, isoleucine, phenylalanine and tryptophane at 8, 15, 20, 5, 15, 15, 20, 5, 10 and 5 g/d, respectively (TEAA, from experiment 1), or replacement of histine (–15 g histine) or lysine (–20 g lysine) respectively from the TEAA mixture. Data were analyzed using MIXED procedures. When cows were fed corn silage diet, there was no significant effect ($P > 0.05$) of amino acids infusion on nitrogen retention plasma amino acid and plasma urea nitrogen. Replacement of lysine reduced lysine concentrations in plasma ($P < 0.01$). Replacement of histine reduced histine concentrations in plasma ($P = 0.07$). Replacement of lysine increased phenylalanine and valine concentrations in plasma ($P < 0.05$). Collectively, these data suggest that for pregnant heifers fed corn silage-based diet, lysine was likely the first limiting amino acid, followed by histine.

Key Words: limiting amino acid, lysine, plasma amino acids