Effects of Adding Extra Molasses to a Texturized Calf Starter on Rumen Development, Growth Characteristics, and Blood Parameters in Neonatal Dairy Calves*

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ABSTRACT

A texturized calf starter containing 5 (control) or 12% molasses [on a dry matter (DM) basis] was fed to dairy calves to determine effects on intake, growth, blood parameters, and rumen development. Forty-six Holstein calves (26 male and 20 female) were started at 2 ± 1 d of age and studied for 42 d. Starter DM intake was measured and fecal scoring was conducted daily. Growth and blood parameter measurements were conducted weekly. A subset of 6 male calves (3 per treatment) was euthanized at 4 wk of age, and rumen tissue sampled for rumen epithelial growth measurements. Starter sugar content was significantly increased in the starter containing extra molasses. Postweaning and overall starter DM intake, overall total DM intake, daily heart girth change, and final heart girth were significantly decreased, whereas overall average daily gain tended to decrease when calves received starter containing 12% molasses. However, blood volatile fatty acid concentrations were significantly increased when calves received a starter containing 12% molasses. No significant differences were observed between calves receiving starters containing 5 or 12% molasses for all other variables. The data indicates that adding extra molasses to a texturized calf starter decreases intake and structural growth, possibly causing decreased weight gain, but increases blood volatile fatty acid concentrations and slightly increases ruminal development. However, feed handling and physical prehension problems in addition to the negative influences on calf growth and intake do not support increasing starter molasses content to 12% of the supplement.

(**Key words:** molasses, rumen development, calves)

Abbreviation key: ADG = average daily gain, BVFA = blood VFA, CO = 5% molasses, EM = 12% molasses,

FE = feed efficiency, HEM = blood hematocrit, HG = heart girth, HH = hip height, HW = hip width, PTP = plasma total protein, WH = withers height.

INTRODUCTION

Calf starter rations commonly contain approximately 5 to 12% liquid molasses to increase palatability, minimize particle separation, and decrease dust (Morales et al., 1989). Reported intake, growth, and rumen parameter alterations suggest that additional molasses may affect calf growth and rumen development. Increased DM or OM intake has been reported with dietary molasses inclusion at 10 to 20% in forage-based diets when fed to mature ruminants (Brown et al., 1987; Morales et al., 1989; Brown and Johnson, 1991). Conversely, molasses inclusion in dairy cow rations has depressed intakes with high quality forage diets and high concentrate diets, and when concentrates and forages were fed separately (Lofgreen and Otagaki, 1960; Komkris et al., 1965; Morales et al., 1989). These results suggest that diet quality influences intake alterations, with additional molasses increasing intake to a greater extent with low quality diets than with high quality diets. Because preweaned calf diets are unlike other diets tested, (containing minimal forage and having a high nutrient concentration), the influence of molasses level on calf intake is uncertain. Dietary molasses inclusion has been reported to increase BW gain in growing and mature beef cattle; with increased intake and improved N use indicated as causative effects (Bond and Rumsey, 1973; Brown et al., 1987; Brown and Johnson, 1991). Improved N use, with dietary molasses inclusion, may be a result of synchronized N and energy availability in the rumen. Conversely, decreased gains, similar to those observed with restricted intake, have been reported with molasses inclusion in mature dairy cattle (Bohman et al., 1954; Lofgreen and Otagaki, 1960; Heinemann and Hanks, 1977).

Increased dietary energy via molasses supplementation has improved feed use efficiency in mature ruminants; however, these results with high forage diets may have limited applicability to the feeding of calves

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(Kellogg and Owen, 1969; Brown et al., 1987; Morales et al., 1989). In contrast, molasses inclusion in high-energy dairy cow diets has decreased feed efficiency (**FE**), possibly due to depressed energy digestibility or energy use efficiency (Lofgreen and Otagaki, 1960; Heinemann and Hanks, 1977). Waldo and Schultz (1960) indicated that sucrose moderately increased *in vivo* butyrate production in steers. Other studies have reported increased rumen butyrate production with molasses or sucrose supplementation, with similar effects seen between molasses and sucrose (Owen et al., 1967; Kellogg and Owen, 1969; Bond and Rumsey, 1973). The possibility for increased butyrate production with molasses is of interest in rumen development due to findings that sodium butyrate increases rumen epithelium development to a larger extent than sodium propionate or sodium acetate (Flatt et al., 1958; Sander et al., 1959; Tamate et al., 1962). Possible increases in butyrate production suggest the potential for a molasses influence on calf rumen development. However, this possible influence has not been previously researched. Therefore, this study was conducted to determine the effects of adding extra molasses to a texturized calf starter on rumen development, the physical form of the starter, intake, growth characteristics, blood parameters, and scour occurrences.

MATERIALS AND METHODS

Animals, Housing, and Diet

Treatments consisted of a texturized calf starter containing 5% (**CO**) or 12% (**EM**) molasses, as a percentage of starter DM. Starter containing EM was prepared by hand by mixing 10% (as fed) additional liquid cane molasses (74.0% DM; 4.7% CP, 60.6% sugars as invert, 12.2% ash, all on DM basis) into the CO starter. Forty-six Holstein calves (26 male and 20 female) were separated from their dams shortly after birth, randomly assigned by sex to a treatment, blocked by birthdate (23 blocks/treatment), and placed on study at 2 ± 1 d of age. Calves were cared for and maintained according to guidelines stipulated by The Pennsylvania State University Animal Care and Use Committee. Abrupt weaning occurred at 28 ± 1 d of age, with calves maintained on the study until 42 ± 1 d of age. Calves were housed in a naturally and mechanically ventilated barn from February through July, and kept in 1.2×2.4 m individual pens bedded with wood shavings. Nose to nose contact between calves was minimized by pen arrangement. All calves received 4 L of colostrum within 12 h of birth, followed by 4 feedings of colostrum. Calves received a 20% CP, 20% fat, nonmedicated milk replacer containing all-milk protein (Land O' Lakes Animal Milk Products Co., Arden Hills, MN) from 3 d of age until

weaning. Milk replacer was provided in 2 equal feedings at 10% of birthweight until abrupt weaning. Texturized calf starter was offered *ad libitum* and intake was measured daily, beginning when calves were placed on the study. Water was provided *ad libitum* and changed twice daily.

Starter Nutrient Composition and Particle Size

Starter samples were collected twice weekly, composites made biweekly, and stored at -20°C for further analysis. Samples were then dried at 55°C in a forced air oven and ground (1-mm screen; Wiley mill, Arthur A. Thomas Co., Philadelphia, PA). All feeds were analyzed in duplicate for moisture (AOAC, 1990). Crude protein (AOAC, 2000) was analyzed using a Leco FP-528 Nitrogen Combustion Analyzer (Leco, St. Joseph, MI) with soluble CP determined as described by Krishnamoorthy et al. (1982), where insoluble protein was recovered on 7-cm (diameter) filter paper (Whatman 541, Fisher Scientific, Pittsburgh, PA) and introduced into a Leco FP-528 Nitrogen Combustion Analyzer for determination of CP (AOAC, 2000). Energy values were calculated using the NRC (2001) model. Starter samples were analyzed for NDF (Van Soest et al., 1991), ADF (AOAC, 1990), and crude fat (AOAC, 1990) using a Tecator Soxtec System HT 1043 Extraction unit (Tecator, Foss NA, Eden Prairie, MN). Ash and mineral content were determined (AOAC, 1990) utilizing a Perkin-Elmer 3300 XL ICP (Perkin-Elmer, Shelton, CT). Starch and sugar content were determined according to Holm et al. (1986) and Dubois et al. (1956), respectively. Samples were extracted for 4 h using a 90:10, ethanol:water extract for sugar analysis. Values for non-structural carbohydrates were calculated by addition of starch and sugar content. Particle size distribution was determined using an Analysette 3 PRO Vibratory Sieve Shaker (Fritsch, Oberstein, Germany). Approximately 330 g (DM) of starter was placed on a series of stacked sieves arranged in descending order and shaken for 2 min at an amplitude of 0.7 mm. Following separation, retained particles were weighed to determine the amount and percentage of DM retained on each sieve.

Fecal Scoring and Experimental Measures

Fecal scoring for determination of fecal fluidity, consistency, odor, and days scoured was conducted daily using the procedure of Larson et al. (1977). Scoring was as follows: for fecal fluidity, 1 = normal, 2 = soft, 3 = runny, and 4 = watery; for fecal consistency, 1 = normal, 2 = foamy, 3 = mucousy, 4 = sticky, and 5 = constipated; for fecal odor, 1 = normal, 2 = slightly offensive, or

3 = highly offensive. A scour day was recorded if fecal fluidity = 3 or 4, fecal consistency = 3, and fecal odor = 2 or 3. Weekly measurements of BW, withers height (WH), hip height (HH), hip width (HW), and heart girth (HG) were measured and recorded. Withers height and HH were measured using a vertical standard with a crossbar and level. Hip width was measured with a calipers, and HG was measured using a measuring tape. Blood samples (25 mL) were collected weekly at 4 h after a.m. milk feeding via jugular venipuncture into evacuated tubes containing EDTA for blood hematocrit (HEM), plasma total protein (PTP), plasma urea N, BHBA, and blood VFA (BVFA) determination. Blood samples from wk 4 and 5 were analyzed for acetate, propionate, butyrate, and total BVFA concentration as described by Quigley et al. (1991) using ion exchange cleanup and GLC. Plasma BHBA was determined on samples from wk 3 to 6 using the Stanbio BHBA Liqui-Color kit (Procedure No. 2440, Stanbio Laboratory, Boerne, TX). Blood HEM and PTP were determined according to Naylor and Kronfeld (1977) and McBeath et al. (1971), respectively, for wk 0 to 6. Plasma samples were analyzed for urea N (procedure no. 0580; Stanbio Laboratory, San Antonio, TX).

Rumen Tissue Sampling

A subset of 6 male calves (3/treatment) was euthanized at 4 wk of age using captive bolt stunning and exsanguination. Digestive tracts were harvested, emptied, and rinsed with cold water. Rumen tissue samples were collected for analysis of papillae length, papillae width, and rumen wall thickness according to Lesmeister et al. (2004).

Statistical Analyses

Data for intake, growth, and blood parameters were analyzed as a randomized complete block design with 23 blocks, and the rumen development data were analyzed as a completely randomized design. A repeated measures analysis was conducted using the MIXED procedure of SAS (SAS Institute, 1999), with block and calf used as the random effect for the growth and rumen development analyses, respectively. Differences were noted at $P < 0.05$ and $P < 0.10$ for the growth and rumen development analyses, respectively. The statistical model used for analyses was:

$$y_{mtc} = \mu + \alpha_m + \beta_t + (\alpha\beta)_{mt} + e_{mtc},$$

where y_{mtc} = an observed value for BW, DMI, FE, HH, WH, HW, HG, HEM, PTP, BHBA, BVFA, papillae length, papillae width, or rumen wall thickness taken

from the c th calf receiving the m th level of molasses at the t th time, μ = the overall mean of the population, α_m = the fixed effect of the m th level of molasses where $m = 5$ or 12% molasses, β_t = the effect of the measurement taken at the t th time where $t = 1$ to 42 d for intake analysis, 0 to 6 wk for growth, blood hematocrit, and plasma total protein analyses, 3 to 6 wk for plasma BHBA analysis, and 4 or 5 wk for BVFA analyses, $(\alpha\beta)_{mt}$ = the effect of the interaction between the m th level of molasses and the measurement taken at the t th time, and e_{mtc} = the error associated with the measurement taken from the c th calf receiving the m th level of molasses at the t th time; $e_{mtc} \stackrel{id}{\sim} N(0, \sigma_e^2)$.

Birth weight was included in the model as a covariate for preweaning and overall average daily gain (ADG) analyses; weaning weight was the covariate for postweaning ADG analysis. Initial measurements for HH, WH, HG, and HW were included in the model as covariates for their respective analyses. For the HEM analysis, PTP was included as a covariate. The model for analysis of rumen development parameters did not include a time or treatment $\times$ time interaction effect. Average starter DMI for the feeding period was used as a covariate for all rumen development analyses. A term to evaluate the effect of sex of the calf was included in all models except for rumen development, but was not significant.

RESULTS AND DISCUSSION

Diet Composition

Starter ingredient composition and particle size distribution are presented in Table 1. Starter containing EM was prepared by adding molasses to the CO starter; therefore, remaining ingredients as a percentage of the total ration are slightly reduced for the EM ration. However, the basal calf starter was identical for both treatments. Adding extra molasses increased the percentage of starter particles retained on the larger screens, subsequently reducing the percentage of small or fine particles. Molasses has been used to bind small particle feed ingredients, especially during the pelleting process (Morales et al., 1989). Reduction of fine particles in calf starters aids in the avoidance of ruminal parakeratosis (McGavin and Morrill, 1976; Greenwood et al., 1997; Beharka et al., 1998). However, due to inclusion of pelleted ingredients in the calf starters and particle size determination being conducted on dry samples, differences in particle size distribution in dry starters might not be replicated in the liquid rumen environment. Nutrient composition of the 2 calf starters is presented in Table 2. Adding extra molasses caused a small decrease in CP content and significantly ($P < 0.05$) increased

Table 1. Ingredient composition and particle size distribution of texturized calf starter containing 5 (control; CO) or 12% (EM) molasses.

Ingredients, % of DM	CO	EM
Roasted corn	33.29	30.80
Cane molasses	5.08	12.14
Oats	15.54	14.39
Premix pellet		
Wheat middlings	17.09	15.82
Soybean meal	23.92	22.14
Calcium carbonate	2.35	2.18
Dicalcium phosphate	1.26	1.17
Salt	0.94	0.87
Vitamin A premix ¹	0.02	0.02
Vitamin B ₁₂ ²	0.001	0.001
Deccox ³	0.06	0.06
Vitamin E ⁴	0.009	0.008
Vitamin D ⁵	0.008	0.007
Magnesium oxide	0.09	0.08
Riboflavin ⁶	0.009	0.008
Selenium ⁷	0.11	0.10
Calcium propionate	0.05	0.05
Trace mineral premix	0.016	0.015
Flavor	0.16	0.15
Particle size, % retained		
6.70 mm	21.88	25.96
4.75 mm	13.17	40.60
3.35 mm	39.72	19.56
2.36 mm	18.19	11.81
1.70 mm	4.38	1.43
1.18 mm	1.01	0.31
0.60 mm	0.93	0.19
pan	0.71	0.20

¹812,500,000 IU/kg.²1.362 mg/kg.³Decoquate, Alpharma, Inc., Fort Lee, NJ.⁴500,000 IU/kg.⁵44,000,000 IU/kg.⁶165 mg/kg.⁷0.06%.

dietary sugar and K content. Increased sugar and K content were expected due to a high content of these nutrients in sugarcane molasses (NRC, 2001). Dietary K level of both starters was higher than that recommended by NRC (2001). However, findings by Weil et al. (1988) indicate no effect of increased dietary K level on calf growth or DMI at levels up to 1.32% of the diet. Potassium level of EM starter was slightly higher than the 1.32% level in the Weil et al. (1988) study; however, Neathery et al. (1980) indicated that K levels up to 2% of the diet had no adverse effects on intake or growth of dairy calves.

Intake and Weight Gain

Table 3 presents least square means for initial, weaning, and final BW, ADG, FE (feed:gain), and milk replacer, starter, and total DMI. Values for ADG, DMI, and FE are presented for preweaning (wk 1 to 4), post-

Table 2. Nutrient composition of texturized calf starter containing 5 (control; CO) or 12% (EM) molasses.¹

Nutrients	Diet		SEM
	CO	EM	
DM, %	90.05	88.05	. . .
CP, %	20.05	19.23	0.31
Soluble CP, % of CP	16.51	20.07	0.72
Total digestible N, ² %	75.62	75.66	0.13
NE _M , ² Mcal/kg	2.25	2.26	0.02
NE _G , ² Mcal/kg	1.71	1.72	0.01
ADF, %	7.98	7.50	0.27
NDF, %	18.48 ^a	17.05 ^b	0.42
Ash, %	10.05	10.48	0.45
Starch, %	31.00	29.93	1.05
Sugar, %	6.65 ^b	8.98 ^a	0.35
Nonstructural carbohydrates, %	37.65	38.90	0.76
Ca, %	1.69	1.57	0.11
P, %	0.92	0.92	0.03
Mg, %	0.34	0.35	0.01
K, %	1.21 ^b	1.45 ^a	0.04
Na, %	0.407	0.442	0.035
Fe, ppm	313	298	13.27
Mn, ppm	93	86	11.01
Zn, ppm	112	114	9.54
Cu, ppm	18	17	1.73

^{a,b}Means within a row without common superscripts are different at $P < 0.05$.

¹All values reported on DM basis.

²Net energy for maintenance (NE_M) and growth (NE_G) were calculated using NRC (2001).

weaned (wk 5 and 6), and overall (wk 1 to 6) periods. Initial BW, and therefore, milk replacer DMI were not different between treatments. No treatment differences were observed for ADG, starter DMI, or FE during the preweaning period. However, total DMI tended ($P = 0.13$) to be greater for calves receiving CO than EM starter during the preweaning period. Similar initial BW and ADG during the preweaning period resulted in no difference for weaning BW between treatments. Starter DMI was significantly ($P < 0.04$) greater for CO than EM calves, postweaning. However, higher dietary intake during this period did not result in treatment differences for ADG or FE. Overall, starter ($P < 0.03$) and total DMI ($P < 0.04$) were significantly greater for calves receiving CO than EM starter. In addition, overall ADG tended ($P = 0.10$) to be greater for CO than EM calves. However, final BW and overall FE were not significantly different between treatments.

Molasses inclusion in high quality diets, when dietary concentrates and forages were fed separately, or at inclusion rates greater than 20% has been reported to depress intake in lactating dairy cows (Lofgreen and Otagaki, 1960; Komkris et al., 1965; Morales et al., 1989). In addition, decreased DM or OM and fiber digestibility have been reported with molasses inclusion rates greater than 10% (Mould et al., 1983; Brown et al., 1987; Brown and Johnson, 1991), possibly due to

Table 3. Least square means for intake and BW of Holstein calves receiving 5 (control; CO) or 12% (EM) molasses in a texturized calf starter.

	n	Treatment		SEM
		CO	EM	
BW, kg				
Initial	46	43.08	43.27	1.11
Weaning	46	53.30	51.80	1.43
Final	40	62.83	59.52	1.70
Daily gain, g/d				
wk 1 to 4	46	357	327	29
wk 5 and 6	40	628	512	58
wk 1 to 6	46	449 ^y	389 ^z	27
Predicted daily gain, ¹ g/d				
wk 1 to 4	...	370	350	...
wk 5 and 6	...	300	190	...
wk 1 to 6	...	360	290	...
DMI, g/d				
Milk replacer				
wk 1 to 4	46	536	539	14
Starter				
wk 1 to 4	46	139	107	19
wk 5 and 6	40	1130 ^a	960 ^b	57
wk 1 to 6	46	509 ^a	396 ^b	35
Total				
wk 1 to 4	46	677 ^y	645 ^z	19
wk 1 to 6	46	853 ^a	742 ^b	36
FE ²				
wk 1 to 4	46	2.20	2.30	0.32
wk 5 and 6	40	2.07	2.23	0.26
wk 1 to 6	46	2.02	2.16	0.12

^{ab}Means within a row without common superscripts are different at $P < 0.05$.

^{yz}Denotes trends at $P < 0.15$ but > 0.05 .

¹Predicted using NRC (2001).

²FE = Feed efficiency; expressed as ratio of kilogram of feed to kilogram of gain.

microbial substrate substitution of fiber with highly soluble carbohydrates (Burroughs et al., 1949; Mould et al., 1983; Hoover, 1986). Therefore, decreased diet digestibility may have decreased passage rate, subsequently limiting the intake of calves fed EM starter in the current study. However, all concentrate diets having a high nutrient concentration and relatively low fiber component content were used in the current study. This might support a negative-associative effect between molasses and high quality concentrate diets on intake, but may not support substrate substitution as a causative effect. Alternatively, an increase in the starter sugar content because of increasing the molasses level may explain the treatment differences observed for starter DMI. Dietary sugar intake from starter during the postweaning period was 76 and 86 g for calves receiving CO and EM starter, respectively. Likewise, starter sugar intake on an overall basis was 34 and 36 g for calves receiving CO and EM starter, respectively. Therefore, the energy requirements for calves receiving EM starter may have been met more

rapidly due to a higher dietary sugar content, and equivalent starter DMI was not necessary for these calves. Conversely, the EM starter had a thick and sticky consistency, which tended to cause caking when placed in feed buckets (visual observation), possibly decreasing the calf's ability to prehend starter, and subsequently decreasing starter DMI for calves receiving EM starter.

Observed ADG from the current study was compared against predicted values for ADG calculated using NRC (2001). However, differences between actual and predicted values must be interpreted carefully, especially for postweaned ruminant calves weighing less than 100 kg, due to age, diet, and BW differences between calves in the current study and calves contained within the NRC (2001) data. The NRC (2001) indicated a void in the literature for calorimetric and comparative slaughter research conducted with weaned, ruminant calves weighing less than 100 kg. In addition, Blaxter (1967) indicated efficiencies of energy and protein for growth decreased as calves aged, BW and fat deposition increased, and as the diet changed. Therefore, comparisons of observed and predicted ADG are likely only valid for preweaned calves from the current study. However, due to the current popularity of alternative calf feeding programs (i.e., accelerated growth, early weaning) and the concomitant possibility for altered weaning age and diet with these new programs, results for predicted ADG during the postweaning and overall period are included in an effort to stimulate future research (Table 3).

Actual prewean ADG was lower than predicted by the NRC (2001) model. During the postweaning period, ADG predicted by the NRC (2001) model was lower than observed ADG for the experiment, suggesting improved nutrient supply or efficiency of use than are assumed by the NRC (2001) model. In addition, actual overall ADG was higher than predicted by the NRC (2001) model. However, as stated earlier, comparisons between actual and predicted ADG for the postweaning and overall periods must be interpreted carefully and may not be valid due to weaning age, BW, and dietary differences between the current study data and NRC (2001) data.

Structural Growth

Least square means for initial, final, and average daily change of HH, WH, HW, and HG are presented in Table 4. There were no significant differences between treatments for initial structural growth measurements, final HW, and daily WH and HW changes. Daily HH change tended ($P = 0.09$) to be greater for calves receiving CO than EM starter, but did not result in a differ-

Table 4. Least square means for structural growth measurements of Holstein calves receiving 5 (control; CO) or 12% (EM) molasses in a texturized calf starter.

	n	Treatment		SEM
		CO	EM	
Hip height				
Initial, cm	40	80.43	80.55	0.57
Final, cm	40	86.77	86.01	0.57
Change, cm/d	40	0.15 ^y	0.13 ^z	0.01
Withers height				
Initial, cm	40	77.22	76.94	0.36
Final, cm	40	83.50 ^a	82.65 ^b	0.40
Change, cm/d	40	0.15	0.14	0.01
Hip width				
Initial, cm	40	18.24	17.99	0.22
Final, cm	40	20.65	20.18	0.24
Change, cm/d	40	0.06	0.05	<0.01
Heart girth				
Initial, cm	40	78.20	78.43	0.64
Final, cm	40	88.29 ^a	85.88 ^b	0.76
Change, cm/d	40	0.24 ^a	0.18 ^b	0.01

^{ab}Means within a row without common superscripts are different at $P < 0.05$.

^{yz}Denotes trends at $P < 0.15$ but > 0.05 .

ence for final HH. Final WH was significantly ($P < 0.01$) greater for CO than EM calves. Daily HG change was ($P < 0.01$) greater and resulted in a ($P < 0.04$) greater final HG for calves receiving CO than EM starter. Differences in HG, a measure of body capacity, may have resulted from decreased intake or may have caused intake depression (Van Soest, 1994; Forbes, 1995).

Blood Parameters and Days Scoured

There were no treatment effects for blood parameters measured over time; therefore, Table 5 presents overall least square means for HEM, PTP, plasma urea N,

Table 5. Least square means for blood parameter measurements and days scoured of Holstein calves receiving 5 (control; CO) or 12% (EM) molasses in a texturized calf starter.

	n	Treatment		SEM
		CO	EM	
Hematocrit ¹	40	34.44	34.29	0.88
Plasma total protein, g/dL	40	5.43	5.40	0.08
BHBA, mmol/L	40	0.193	0.190	0.011
Plasma urea N, mg/dL	40	8.76	8.43	0.73
Blood VFA, mmol/L				
Total VFA	20	0.412 ^b	0.675 ^a	0.055
Acetate	20	0.381 ^b	0.629 ^a	0.051
Propionate	20	0.007 ^b	0.010 ^a	0.001
Butyrate	20	0.024 ^b	0.037 ^a	0.003
Days scoured	40	3.35 ^y	5.00 ^z	0.98

^{ab}Means within a row without common superscripts are different at $P < 0.05$.

^{yz}Denotes trends at $P < 0.15$ but > 0.05 .

¹Blood hematocrit volume = percentage of whole blood.

Table 6. Least square means for rumen development measurements of Holstein calves¹ receiving 5 (control; CO) or 12% (EM) molasses in a texturized calf starter.

	n	Treatment		SEM
		CO	EM	
Papillae length, cm	6	0.65 ^z	0.86 ^y	0.08
Papillae width, cm	6	0.43 ^z	0.53 ^y	0.04
Rumen wall thickness, cm	6	1.11	1.15	0.02

^{yz}Denotes trends at $P < 0.20$ but > 0.10 .

¹At 4 wk of age.

plasma BHBA, BVFA concentrations, and days scoured. There were no significant differences between treatments for HEM, PTP, plasma urea N, and plasma BHBA. The change in soluble protein was not large enough to alter plasma urea N levels, likely due to the relatively small DMI of the calves. Murphy (1999) reported a linear increase in plasma BHBA concentrations with 0.14, 0.25, and 0.35% (DM) molasses inclusion in mature ruminant rations, but similar results were not observed in the current study. However, the increase between the 0.25 and 0.35% level was minimal and may have indicated an inflection point leading to a lesser increase in BHBA concentrations at higher molasses levels (Murphy, 1999).

Blood concentrations of total VFA, acetate, propionate, and butyrate were all significantly ($P < 0.01$) higher in EM calves than CO calves. Higher BVFA concentrations for EM calves possibly indicates increased rumen epithelial metabolic activity or increased rumen VFA production. However, the relationship between peripheral blood VFA concentration and rumen VFA production has not been conclusively determined. Days scoured tended ($P = 0.11$) to be less for CO than EM calves, but was not significantly different.

Rumen Development

Least square means for papillae length, papillae width, and rumen wall thickness from the subset of calves used to determine the influence of molasses level on rumen development parameters are presented in Table 6. A slight tendency for increased papillae length ($P = 0.18$) and papillae width ($P = 0.17$) was observed for calves receiving EM starter, but differences were not statistically significant. Numerically higher, but nonsignificant, values for EM than CO calves may have become increasingly different with higher intakes of EM starter. In addition, Lesmeister et al. (2004) reported a rapid rate of rumen development between wk 4 and 5 in dairy calves. Rumen development measurements were obtained from calves at 4 wk of age in the current trial, possibly preceding indication of treatment

effects on rumen development. Furthermore, plasma BHBA of calves receiving EM starter was numerically lower after 3 wk of age (data not shown), possibly indicating greater rumen epithelial metabolism for EM calves after 3 wk of age (Sutton et al., 1963). In addition, a tendency for increased rumen absorptive area coupled with increased BVFA concentrations seen in calves receiving EM starter, suggests that increased butyrate production reported in other studies may have occurred in the current study (Owen et al., 1967; Kellogg and Owen, 1969; Bond and Rumsey, 1973). However, rumen VFA production was not determined and starter DMI was depressed in EM calves; therefore, these possible occurrences cannot be confirmed.

CONCLUSION

Adding extra molasses negatively influenced total and starter DMI and daily HG change. However, dietary sugar and likely energy intake were similar between treatments, even with depressed starter DMI for calves receiving EM starter, resulting in only a slight decrease in overall ADG for EM calves. Conversely, significantly increased BVFA concentrations and a tendency for increased rumen absorptive area in neonatal calves may indicate a possible advantage to increasing starter molasses level. However, mixing, handling, feeding, prehension, and possible palatability problems may occur in starters containing the level of molasses used for EM starter in the current study. Therefore, increasing the molasses content of calf starters to 12% is not suggested, but additional research should be conducted to determine the starter molasses level that optimizes intake with calf growth and rumen development while meeting feed industry requirements for handling.

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