Iranian Journal of Applied Animal Science

Performance of Holstein Calves, Heifers and First-Lactating Cows Fed Starter Diets with Different Protein Levels and Types of Soybean Meal

Research Article

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Received on: 2 Jan 2018
Revised on: 11 May 2018
Accepted on: 15 May 2018
Online Published on: Mar 2020

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Online version is available on: www.ijas.ir

ABSTRACT

Holstein calves were fed pelleted starter diets with crude protein (CP) concentrations of 18%, 22% and 24% per dry matter (DM) containing soybean meal (SBM) (SBM18, SBM20 and SBM24), respectively, for 10 weeks from 14 days of age. Another diet with a CP concentration of 18% per DM was tested using commercial xylose-soybean meal (XSB; Yasminomax) instead of SBM. Each diet was fed to 24 calves and the feed consumption, nutrient intake, body weight (BW) gain, skeletal growth and selected blood metabolites were determined. Weaned animals were kept under observation for economic characteristics such as post-weaning (days 84 to 196) weight gain, withers height, weight at first heat, number of services per pregnancy and milk yield during first lactation. The average daily starter consumption was highest in calves fed SBM20. The average BW gain and total DM intake were highest in calves fed SBM20. Feed efficiency was highest in calves fed SBM24, but protein efficiency was highest in calves fed SBM20. A decreased blood glucose and increased blood insulin concentrations were observed in calves fed SBM18. Blood urea N and blood glucose were highest in calves fed SBM24. The service rate, age at first parturition and milk yield varied according to diet (P<0.001).

KEY WORDS growth, milk, protein, starter diet.

INTRODUCTION

The aim of calving management is to produce good-quality replacement heifers with high milk production in good health. The performance of dairy calves depends on adequate dry matter (DM) intake, which is necessary for rumen development (Baldwin *et al.* 2004; Miller-Cushon *et al.* 2014) because early transition from simple gastric digestion to functional ruminal digestion is essential to their health and growth (Khan *et al.* 2007a). These changes and the ruminal development in weaned calves are essentially affected by the intake and composition of dry matter (Baldwin *et al.* 2004). It has been reported that the feed intake and growth of calves are affected by the level of protein in the starter.

Increasing the protein will increase feed intake and average daily body weight gain (Bartlett *et al.* 2006; Diaz *et al.* 2001). There is a synergistic relationship between starter dry matter intake and improvements in milk, fat and protein production and a positive correlation between first-lactation and pre-weaning average daily body weight (BW) gain (Gelsinger *et al.* 2016). The functioning of the rumen is almost complete at 3 to 6 weeks of age when all microbial activity in the rumen has matured and can compete with that of adult animals (Bascom *et al.* 2007). Ruminal parameters such as pH, rumen development, nutrient digestibility and nitrogen utilization in Holstein calves fed different starch and protein sources has been evaluated. It has been demonstrated that soybean meal is a primary source of protein in all animal feeds, especially in calf starters.

Slower rates of digestion increase the amount of protein bypassing the rumen to be digested in the small intestine, which produces more because of the more efficient use of digestive end-products (amino acids) (Chesworth *et al.* 1998). Therefore, the site of protein digestion along the gastrointestinal tract effects the performance and feed efficiency in cattle (Stamey *et al.* 2012; Swan *et al.* 2006). This can affect the DM consumption and the quantity and proportion of amino acids in the rumen and, thus, the development and performance of the animal during weaning and early post-weaning periods (Stamey *et al.* 2012; Swan *et al.* 2006). Studies have investigated the effects of the physical forms of calf starters (Abdelgadir and Morrill, 1995; Beharka *et al.* 1998), the source and level of protein (Miller-Cushon *et al.* 2014; Suarez *et al.* 2007), feed processing (Lesmeister *et al.* 2004) and feed types (Miller-Cushon *et al.* 2014) on feed consumption, growth performance and ruminal development of dairy calves. Scientific research to evaluate effects of the nature of the protein source in calf starter on DM consumption, nutrient intake, body weight gain and metabolic response is limited (Miller-Cushon *et al.* 2014). This study was conducted to compare the effect and nature of the protein source with low rumen digestibility (xylose-protected soybean meal; XSB); Yasminomax) versus a high rumen digestible soybean meal (SBM) using starters with different levels of CP on feed consumption, body weight gain, skeletal growth and blood metabolites in Holstein calves during weaning (14 to 84 days) and compensatory growth during post-weaning (84 to 196 days), service, first calving age and milk yield at first calving.

MATERIALS AND METHODS

Animals and diets

A total of 96 Holstein calves were used in the study. Parturition was from 23 Oct 23 2013 to 20 Jan 2014. The calves were separated from their mothers within 1 h of birth, weighed and moved into individual calve pens (1.25×2.25 m) where they were fed colostrum totaling 10% of their BW for the first 8 h after birth. The individual pens were interspersed evenly throughout the calf barn. All calves were fed whole milk using mobile plastic bottles (2 l capacity) fitted with soft rubber nipples according to a step-down procedure (Khan *et al.* 2007a; Khan *et al.* 2007b). A steel bottle stand was attached to an iron rod at the front side of each pen at 70 cm above the floor. Milk was provided at a rate of 10% of calf BW to 28 days of age. This rate was gradually reduced by diluting the milk with water (10% of volume at each feeding) until a milk feeding rate of 8% of BW was achieved. The animals were fed at this rate for the remaining 50 days of the 84 day period.

Three starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively). An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM. All diet ingredients including concentrate (80%) and forage (alfalfa, 20%) were ground and passed through a 3 mm screen, then mixed and pelleted (20 mm in length and 5 mm in diameter; Table 1).

The pelletizer conditions were dry steam with 3 bar of pressure at 180-220 ˚C. The starters were randomly allocated to the calves in each treatment (12 male and 12 female). Animals had free access to water from a bowl drinker in each pen. Three times daily, the calves were fed milk (07:00, 15:00, 23:00). Before 30 days of age, the calves were fed only concentrate. From day 30, this was mixed with alfalfa at a 80:20 ratio. Feed consumption was recorded daily. Once a week at two hours after the consumption of milk in the morning, the body weight, pin and withers height, body length and heart girth were measured and blood samples were taken from the jugular vein. At weaning at 84 days, a total of 45 female calves and 46 male calves remained (2 male and 3 female calves had died). The weaned calves were kept in individual boxes for a week and then were divided into groups of 40 mixed calves and kept for 3 months.

The diet was changed to 30% alfalfa and 70% concentrate *ad libitum*. During compensatory growth to 196 days, the skeletal growth factors were measured. After that, the 45 remaining heifers were transitioned into groups with 60 heifers until the age of 13 months. Their diet was changed to 60% forage and 40% concentrate (Table 2). The male calves were removed from the study. The first heat of the heifers was recorded.

The heifers were inseminated on the first heat after 13 months of age and were tested for pregnancy at 45-60 days after the last insemination. Pregnant heifers were separated from their groups and transitioned to pregnant heifer groups. The service period, pregnancy age and parturition age were recorded in 41 pregnant heifers and the milk yield was recorded in 39 surviving cows.

Sampling and analysis

Dry matter intake and milk consumed were recorded daily throughout the experiment. Polythene sheets were attached to each feeding bucket to account for wastage of calf starter. Samples of each calf starter (n=4) were collected weekly, then analyzed to determine their chemical compositions. All samples were ground (1 mm), then dried using forced-air oven drier (60 ˚C; 48 h). The samples were ground using a Wiley mill and passed through a 1-mm screen and stored at −20 ˚C until analysis.

Table 1 Ingredient composition and chemical composition of calf starter diets[1]

Feedstuffs, % DM	Starter diets[1]*			
	SBM 18	SBM 20	SBM 24	XSM 18
Alfalfa	18.3	18.3	18.3	18.3
Barley grain	25.8	22.8	22.8	26.0
Corn grain	18.8	18.9	13.9	18.8
Wheat bran	10.4	8.4	8.4	10.4
Yasmino	-	-	-	11.2
Soybean meal	11.4	11.6	17.4	-
Cotton seed meal	1.5	3.3	3.3	1.5
Canola meal	3.3	5.8	5.8	3.3
Molasses	4.3	4.3	2.4	4.3
Sugar beet pulp	3.9	3.9	3.9	3.9
Salt	0.2	0.2	0.2	0.2
Di calcium phosphate	0.3	0.3	0.3	0.3
Calcium carbonate	0.6	0.6	0.6	0.6
Vitamin and mineral premix	1.2	1.2	1.2	1.2
Dry matter	89.6±1.2	90.4±1.4	90.2±2.1	89.2±1.5
Crud protein	17.9±0.2	19.9±0.3	24.6±0.5	18.3±0.5
Ash	7.0±0.0	7.3±0.9	6.6±0.1	6.4±0.1
NE_g Mcal/kg of DM	1.35±0.1	1.34±0.2	1.32±0.3	1.35±0.2

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
*Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively). An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.

Table 2 Ingredient composition and chemical composition of weaned calf (84-196) and heifer (until 13 month) diets

Feedstuffs, % DM	Weaned calf	Heifer
Alfalfa	30	30
Barley grain	22.9	9.9
Corn grain	12.0	4.0
Wheat bran	12.7	16.0
Silage	0	30
Soybean meal	11.9	2.8
Cotton seed meal	1.5	1.3
Canola meal	2.3	1.0
Molasses	2.5	1.0
Sugar beet pulp	1.4	1.9
Salt	0.5	0.3
Di calcium phosphate	0.5	0.4
Calcium carbonate	0.6	0.4
Vitamin and mineral premix	1.2	1.0
Dry matter	87.6±1.4	80.5±1.9
Crud protein	18.6±0.2	14.2±0.3
Ash	7.2±0.1	8.3±1.1
Net energy for gain (NE_G, Mcal/kg of DM)	1.3±0.2	1.2±0.3

This was done for CP using $CuSO_4/TiO_2$ mixed catalyst and the Kjeldahl procedure (AOAC, 2000) and for neutral detergent fiber (NDF) (Van Soest *et al*. 1991) using α-amylase (A3306; Sigma Chemical; USA). The sodium sulfite and corrected ash concentration was adapted for the Ankom 200 Fiber Analyzer (USA) and the acid detergent fiber (ADF) (AOAC, 2000), ether extract (AOAC, 2000) and ash (AOAC, 2000) were analyzed. The starch content of the feeds was determined according to the procedure recommended by some studies. Samples of calf starter were analyzed for DM and CP using the methods described above.

The chemical compositions of the diets are presented in Tables 1 and 2.

Blood samples were centrifuged at 3200 rpm for 15 min and the serum was partitioned into aliquots and stored at −20 ˚C until analysis for glucose (ELISA), total protein (ELISA), urea N (ELISA) and insulin (Auto Analyzer; Technicon). The auto analyzer uses continuous flow analysis, which separates a continuously flowing stream with air bubbles (Richard, 2006). The Elisa is a solid-phase enzyme immunoassay that detects the presence of a substance, usually an antigen, in a liquid sample or wet sample (Lequin, 2005).

Digestibility trails

The samples were powdered to 2 mL in size and then dried (105 ˚C; 24 h). The crude protein (Kjeldahl method), crude fat (Soxhlet method) and ash (electric furnace at 550 ˚C; 6 h) were measured according to AOAC (2000) standards. The method recommended by Van Soest *et al*. (1991) was used to measure the cell wall (NDF) and cell wall free cell wall (ADF). Determination of the degradability coefficients was done using nylon bags (*in situ* method) as follows: 5 g of 2 mm milled grinding sample was poured into synthetic silk fiber bags 50 µm in pore size with dimensions of 12 - 19 cm (4 bags per sample were released at 4, 8, 16, 24, 48, and 72 h) in the rumen of two calves with incubated rumen fistula. For zero time, the unboxed bags in the rumen were washed with cold running water from a laboratory tube until the water ran clear (Danesh-Mesgaran, 2002). The onset of incubation for all specimens was 08:00. After leaving the rumen, the bags were flushed with running water until the water ran clear. The bags were dried in a vacuum oven at 56 ˚C (48 h). After weighing, the nitrogen levels were measured using the Kjeldahl method.

Determination of the ratio of rumen and intestinal disappearance (three-step enzymatic method) proceeds as follows: Samples that have been digested are removed after 12 h of incubation in the pancreas. After weighing, they were placed into polypropylene centrifuge tubes (each containing 15 mg nitrogen). Next, 10 mL of pepsin-acid chloride solution (4 g of pepsin (M-7185) in a normal 1/2 chloride lithraxide) previously heated to 37 ˚C was added to each tube. The tubes were placed in a shaker incubator for 1 h at 38 ˚C and 0.5 mL of sodium hydroxide solution (0.1 normal) was added to each tube. A 13.5 µL pancreatin and phosphate buffer (12 g of pancreatin M-7130 in a 0.5 mol solution (pH=7.8) of potassium dihydrogenphosphate) was added to each well. The tubes were once again placed in a shaker incubator for 24 h at 38 ˚C. After incubation, 3 mL of trichloroacetic acid solution (100 g of trichloroacetic acid per 100 mL of distilled water) was added to each tube and the contents of the tubes were well mixed. After 15 min, the tubes were centrifuged for 15 min (15000 rpm). The top of the solution of each tube was collected (5 mL) and its nitrogen concentration was determined by the Kjeldahl method.

Statistical analysis

Body weight, BW gain, skeletal growth, feed consumption, milk consumption, nutrient intake, compensatory growth, withers height, weight at first heat, milk yield at first calving and feed efficiency data were summarized and measured at each week of the experiment. Analysis was done in a randomized complete block design using SAS (SAS, 2008).

The differences in treatment means were tested using Duncan's multiple range test. To examine the effect of time and treatment difference, the blood metabolite data was evaluated using the random and repeated methods in the mixed SAS (SAS, 2008). Treatment (calf starter diets) and time were the fixed effects and the individual calves were the random effects. For analysis of differences in time patterns among groups, the interaction (treatment×time) was included in the model. Regression between treatment and age at first heat, service rate and milk yield at first calving were evaluated. The results were considered statistically significant at $P < 0.05$ unless otherwise noted.

RESULTS AND DISCUSSION

Feed intake, performance and blood metabolites

Average daily milk consumption, starter and nutrient intakes are presented in Table 3. Daily milk intake was similar in the calves fed calf starter diets. Starter consumption increased as the calf age increased. A rapid increase in the consumption of both starters was observed in calves after 28 days of age. A pronounced surge in DM consumption was observed in calves during weaning. During weaning, the calves fed SBM24 consumed higher amounts of calf starter than the other groups. During this period, starter intake was the highest ($P<0.05$) in calves fed SBM24, (Tables 4 and 5). The average daily milk yield (DMY), service rate (SR), age at first parturition (AFP), and milk yield (MY) at 305 days of age are presented in Table 6. The production traits in the heifers before and after parturition differed according to the starter diets. Service rate, DMY and AFP differed significantly according to the source and levels of protein ($P<0.001$). The SBM24 diet performed highest and differed from the SBM18, SBM20 and XSB18 diets. The SR was similar for SBM24 and SBM20, but was significantly different from the other diets ($P<0.001$). The mean serum glucose, BUN, total protein and insulin concentrations are presented in Table 7. The serum glucose increased in all calves as they increased in age, but this was not significant between weeks. The serum glucose concentration was higher ($P<0.01$) in calves fed SBM24 than in those fed SBM20, SBM18 and XSB18. Although blood urea N increased as the age increased, it was not significant. The highest BUN ($P<0.01$) and blood glucose concentration was observed in calves fed SBM24, followed by a high daily milk yield (DMY). Insulin levels were good in calves fed SBM18 and SBM24 ($P<0.01$). Up to 5 weeks of age, the increase in insulin was significantly different between diets. After this point, the difference was not significant between diets. The treatment × time interaction for serum glucose, BUN, insulin and total protein in calves during the experimental period were not significant.

Table 3 Average daily intake of milk, starter, and nutrients by Holstein calves (d 14 to 84)

Intake	Starter diets[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Milk, kg/d	4.50	4.45	4.48	4.50	0.20
Starter, g/d	839.21	847.54	940.63	905.65	20.4
Dry matter, g/d	751.93	766.18	848.45	807.84	15.24
Crud Protein, g/d	134.59	152.78	208.72	147.83	4.23

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
[*] Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively). An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.
[$] When the difference between means is greater than two times the standard error of the means (SEM), it is considered as significant (P<0.05).

Table 4 Average body weight and body measurements from birth to weaning and 196d and month13 in Holstein calves

Parameter	Starter diet[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Body weight, kg					
At birth	37.8	38.2	36.2	37.1	1.9
Initial	40.5	40.3	38.4	38.1	1.6
At weaning (d 84)	71.4	84.6	81.3	74.3	2.5
At 196 d	125.5	126.8	127.0	124.8	2.5
At month 13	383.5	386.5	387.0	379.5	2.8
Body length, cm					
Initial	59.0	59.0	57.2	57.3	1.9
At weaning (d 84)	78.4	76.7	76.7	73.6	1.3
At 196 d	106.2	107.8	108.3	105.4	2.6
At month 13	150.4	152.2	156.5	155.0	2.8
Heart girth, cm					
Initial	79.0	78.8	77.8	77.3	3.2
At weaning (d 84)	98.9	103.7	102.4	99.4	3.8
At 196 d	113	113.6	113.2	112.6	1.2
At month 13	169	169	169	169	0
Wither height, cm					
Initial	74.3	72.4	72.3	72.4	2.2
At weaning (d 84)	88.1	89.1	87.9	88.1	3.7
At 196 d	103	103.5	104.5	104.5	1.4
At month 13	129.5	131.2	133.1	130.1	2.4
Pin height, cm					
Initial	72.1	72.2	70.5	69.5	1.9
At weaning (d 84)	90.2	88.4	87.8	87.2	2.8
At 196 d	101	99.5	104	98.5	2.0
At month 13	127	128.5	131.5	130.5	3.2

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
[*] Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively). An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.
[$] When the difference between means is greater than two times the standard error of the means (SEM), it is considered as significant (P<0.05).

Table 5 Average overall body weight gain (BWG), total dry matter intake (DMI), feed efficiency in Holstein calves

Parameter	Starter diet[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Body weight gain (kg)	31.8	45.1	42.8	37.5	3.1
Total dry matter intake (kg)[2]	33.5	32.5	39.5	35.7	1.67
Feed efficiency[3]	1.05	0.72	0.92	0.95	0.03

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
[2] Total DMI= starter and hay DMI.
[3] Feed efficiency= kg of BWG/kg of total DMI.
[*] Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively). An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.
[$] When the difference between means is greater than two times the standard error of the means (SEM), it is considered as significant (P<0.05).

The serum glucose, blood urea nitrogen (BUN) and total protein concentration were similar in calves fed SBM18, SBM20 and XSB18. The serum total protein concentration increased as the age of the calves increased. Increased concentrations of insulin (P<0.01) were observed in calves fed SBM2 over those fed SBM18, SBM20 and XSB18. The concentrations of total serum protein were similar for all diets.

Digestibility traits

The digestibility of DM and crude protein are presented in Tables 8 and 9, respectively. The digestibility of DM and CP differed between diets in the rumen and intestines (P<0.05). The gastrointestinal digestibility of DM and CP was the same between diets (P<0.05).

All calves in this experiment safely consumed equal amounts of milk that are generally provided to dairy calves under a conventional restricted milk feeding system. All calves in the study started rumination at 10 to 12 days of age except for the 5 calves on XSB18, for which regurgitation movement was observed at 16 days of age. Delay in the initiation of rumination in XSB18-fed calves can be attributed to lower starter intake during the first 2 weeks prior to the experiment because of its palatability or unknown organoleptic factors (Miller-Cushon *et al.* 2014). A slow increase in solid feed consumption with age during the weaning period also has been demonstrated by other researchers (Khan *et al.* 2007a; Khan *et al.* 2007b). The rapid increase in starter intake for a few days after 28 days of age in all experimental calves can be attributed to a hyperphagic response to the reduced milk and nutrient supply. Khan *et al.* (2007a) reported a rapid surge in solid feed consumption and reduced blood glucose levels in Holstein calves when the milk supply was reduced.

The lower consumption of starter during the weaning periods of calves fed SBM20, SBM18 and XSB18 than in those fed SBM24 could be related to low ruminal pH (Owens *et al.* 1998; Khan *et al.* 2006; Lee *et al.* 2008). The higher intake of DM, CP and NDF in calves fed SBM2 than in those fed SBM, SBM and XSB during the weaning periods may result from the difference in ruminal development and its metabolic and structural capacity to accommodate and digest solid food.

Significantly increased nutrient intake in calves fed SBM24 than in those fed the other experimental diets may be related to structurally and metabolically to development of the rumen in the former. Calves fed SBM showed a linear increase in ADG, GF, BL, HG, WH and pH (Blome *et al.* 2003; Bartlett *et al.* 2006). Greater protein intake during weaning periods in calves fed SBM24 than in those fed SBM20, SBM18, and XSB18 was a function of increased starter consumption.

The significantly greater intake of NDF in calves fed SBM24 can be ascribed to increased starter consumption. Conversely, decreased NDF consumption in calves fed SBM18, SBM20 and XSB18 can be attributed to decreased CP intake. Several investigators (Stobo *et al.* 1966; Coverdale *et al.* 2004) have reported a positive relationship between starter and CP consumption during weaning; however, others have found a negative correlation between intake of starter and NDF in the rations (Leibholz, 1975). This controversy could possibly be attributed to the nature of CP and its fermentation pattern, composition and the physical form of the starter and the type of CP used in these studies.

Increased serum glucose and BUN levels can be attributed to improved ruminal function in calves fed SBM24 than in those fed SBM18, SBM20 and XSB18. Blood urea nitrogen showed a positive linear relationship with dietary CP intake, its ruminal degradability and the resultant ruminal ammonia concentration in cattle (Broderick and Clayton, 1997; Lohakare *et al.* 2006). Increased protein intake caused by increased solid feed consumption and its ruminal degradation have probably resulted in increased concentrations of ruminal ammonia and BUN in calves fed SBM24.

Increased concentrations of BUN is also an index of renal dysfunction (Khan *et al.* 2007b). A rapid drop in serum glucose concentration at weaning was observed in all calves, in contrast to results reported by other studies (Quigley *et al.* 1994; Klotz and Heitmann, 2006). This can be attributed to differences in the milk feeding methods used in the present study and previous studies. In the present study, early initiation of solid feed intake and the onset of ruminal fermentation in calves fed milk through a step-down procedure probably resulted in a decreased serum glucose concentration.

Khan *et al.* (2007a) and Khan *et al.* (2007b) reported decreased serum glucose concentration at weaning and for several weeks post-weaning in calves fed milk through a step-down procedure than in those fed restricted or *ad libitum* amounts of milk. The increased concentrations of total serum protein in older calves and differences among calves fed SBM18, SBM20, SBM24 and XSB18 can be ascribed to variations in CP consumption. Similar milk consumption levels during weaning in calves fed SBM18, SBM20, SBM24 and XSB18 resulted in similar BL, HG, WH and pH values at weaning. Differences in growth parameters among calves fed protein from different sources were apparent during the weaning period. The process of transitioning calves from their neonatal reliance on nutrients supplied from milk to nutrients supplied from feed is of significance for their growth (Tahmasbi *et al.* 2014; Baldwin *et al.* 2004; Khan *et al.* 2007a).

Table 6 Production traits: service rate (SR), age of first parturition (AFP), average daily milk yield (DMY), age of first parturition (AFP) and milk yield (MY) (305d) in Holstein calves

Parameter	Starter diet[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Daily milk yield (kg)	32	33	36	32	0.8
Milk yield, (305 d)	8572	8633	9483	8521	200
Age of first parturition (d)	742	725	717	770	30
Service rate	1.7	1.3	1.3	2.4	0.2

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
[*] Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM2), respectively. An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.
[$] When the difference between means is greater than two times the standard error of the means (SEM), it is considered as significant (P<0.05).

Table 7 Mean (±SE) blood glucose, urea nitrogen (BUN), total protein, and insulin in Holstein calves

Parameter	Starter diet[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Glucose (g/dL)	25.7	27.2	30.6	27.0	8.4
BUN (mg/dL)	21.2	19.2	25.2	20.3	8.4
Total protein (g/dL)	44.8	46.7	46.6	45.8	21.2
Insulin (g/dL)	3.2	2.5	3.1	2.5	1.8

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
[*] Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively. An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.
[$] When the difference between means is greater than two times the standard error of the means (SEM), it is considered as significant (P<0.05).

Table 8 Digestibility of dry matter in rumen, intestine and total digestive tract

Digestibility (%)	Starter diet[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Ruminal	50.47	57.82	51.88	57.39	3.26
Intestinal	70.96	60.17	68.15	67.81	1.87
Total digestive tract	85.63	81.02	77.83	86.85	2.94

[1] Pelleted (20 mm in length and 5 mm in diameter) starter diets were formulated to contain equal amount of neutral detergent fiber (NDF) (27±0.5%).
[*] Starter diets were provided based on soybean meal (SBM) at protein levels of 18%, 20% and 24% per DM (SBM18, SBM20 and SBM24, respectively. An additional starter containing 18% CP per DM included xylose prosed soybean meal (XSB18) instead of SBM.
[$] When the difference between means is greater than two times the standard error of the means (SEM), it is considered as significant (P<0.05).

Table 9 Digestibility of crud protein in rumen, intestine and tract

Digestibility (%)	Starter diet[1*$]				SEM
	SBM18	SBM20	SBM24	XSB18	
Ruminal	36.65	39.06	35.44	30.63	2.71
Intestinal	94.28	86.25	91.56	92.38	1.62
Total digestive tract	94.85	91.45	94.35	95.26	1.15

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Increased BW, BL, HG, WH, and pH in calves fed a diet with a high protein content than those fed low protein diets can be attributed to increased solid feed intake. This is metabolically and physically better for the stomach and, thus, increase the supply of nutrients from ruminal fermentation. Blood urea nitrogen concentrations along with the increased serum glucose concentrations in calves fed SBM2 than in those fed other experimental diets indicate a metabolically functional rumen in the former. This suggests that a physically and metabolically developed rumen results in greater solid feed consumption and supplies more nutrients to support the increased BW gain in calves fed SBM24 over those fed SBM18, SBM20 and XSB18.

Increased solid feed intake, which increases the supply of nutrients resulted in better feed conversion efficiency in SBM24- and SBM20-fed calves.

CONCLUSION

The increase in solid feed and nutrient consumption in calves fed SBM24 than in those fed SBM18, SBM20 and XSB18 during weaning can be ascribed to differences in ruminal development and metabolic and structural capacity, which accommodates and digests solid feed. Increased BW gain and skeletal measurements in calves fed SBM24 can be ascribed to the increased supply of nutrients, especially because the increase in DM and nutrient intake. This could be one reason for the increase in milk yield and productive traits in the heifers.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the technical and financial support of Ferdowsi University of Mashhad and Movahed Gostaran Jovain Animal Husbandry Co.

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