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Influence of Starch Sources in Prepartum Diet on Colostrum Quality and Blood Immunoglobulin Concentration of Calves

Research Article

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ABSTRACT

The main objective of this study was to evaluate the effect of dietary inclusion of wheat or corn as the main source of starch in prepartum diets on colostrum composition, colostrum IgG_1 and IgG_2 concentrations, serum IgG_1 and IgG_2 concentrations of calves and efficiency of IgG_1, IgG_2 and total Ig absorption. For this purpose, thirty primiparous and twenty multiparous Holstein cows were used in a randomized complete blocks design. Cows were blocked by parity and expected calving dates and assigned to treatments at 27±2.5 d before calving. The dietary treatments contained corn or wheat grain as the main sources of starch. Blood samples of calves were drawn before the first colostrum feeding (0 h) at the birth and 24 h of life. The results indicated that prepartum diets had no effect on daily dry matter intake of cows. Lactose, fat and IgG_2 concentrations in colostrum did not respond to dietary treatment, but protein, total solids, IgG_1 and total IgG concentrations in colostrum were significantly higher for cows fed the wheat containing diet. At 24 h of age, serum IgG_2 concentrations of calves were similar between the two treatments, while serum IgG_1 and total IgG concentrations were significantly higher for calves fed colostrum from cows fed wheat containing diet. Prepartum starch source did not affect apparent efficiencies of IgG_1, IgG_2 and total IgG absorption. Briefly, the results indicated that feeding cows with the wheat containing diet in prepartum period increased colostrum quality and serum IgG_1 concentrations in calves which in turn might have a positive effect on health, survival and growth of newborn calves.

KEY WORDS calf, colostrums, immunoglobulin, prepartum diet, starch source.

INTRODUCTION

Management and feeding of high quality colostrum can reduce calf mortality and morbidity, strengthen immunity, and increase animal life span (Quigley and Drewry, 1998). High levels of immunoglobulins (Ig_s) in colostrum play an important role in establishing passive immunity in young calves. Immunoglobulin intake depends on colostrum intake and its Ig concentration (Jaster, 2005). Volume and Ig concentrations of colostrum are influenced by several factors including preparturient vaccination, nutrition in the preparturient period, lactation number, breed of cow and length of the dry period (Quigley and Drewry, 1998; Godden, 2008). Nutrition and management of dairy cows during the transition period has been the topic of intense research interest for many years. However, little is known about how nutrition during the dry period may affect colostrum composition and provision of Ig_s. Starch is a major source of energy for dairy cows and mainly provided by cereal grains. However, the cereal grains differ greatly in

starch content and its rates and extents of ruminal degradation (Huntington, 1997). Carbohydrate sources that degrade at faster rates may result in higher rates of microbial ammonia capture (Gehman *et al*. 2006; Gozho and Mutsvangwa, 2008), which supplies the majority of absorbable amino acids to the small intestine (NRC, 2001). However, microbial growth is influenced not only by energy supply also by nitrogenous supply, and synchronization of energy and nitrogen. Researches that have been conducted with dairy cows during dry period often have evaluated the effects of nutritional and managerial strategies for dry cows in preparation for lactation. Few data are available on the effects of nutritional and managerial strategies in the dry cow on the health, growth and survival of the calf during the periparturient period. Many of the strategies implemented during the dry period can affect the health and survival of the calf. Because the rate and extent of ruminal starch digestion of wheat is faster than corn (Huntington, 1997), wheat starch may has more ability to support microbial protein synthesis in the rumen. Therefore, the objective of this study was to evaluate the effect of dietary inclusion of wheat or corn as the main sources of starch in prepartum diets on plasma metabolites of cows, colostrum composition, colostrum IgG_1 and IgG_2 concentrations and calves' serum IgG_1 and IgG_2 concentrations.

MATERIALS AND METHODS

The study was conducted during the spring of 2008 (April to May) at Ilam University Dairy Farm (Iran). All procedures involving the use of animals were approved by the Faculty Animal Policy and Welfare Committee at the University of Ilam. Thirty primiparous and twenty multiparous Holstein cows were used in a randomized complete block design to evaluate the effect of starch source in prepartum diet on colostrum quality and serum immunoglobulin concentrations of calves. All animals averaged body weight (BW) of 610±54 kg and an average body condition score (BCS) of 3.5±0.25 (5-point scale). Cows were blocked by parity and expected calving dates and assigned to treatments at 27±2.5 d before calving. The two dietary treatments examined two types of cereal grains (corn and wheat) as the main source of starch in the concentrate portion of prepartum diets.

The ingredient composition and chemical analysis of the experimental diets are shown in Table 1. Diets were formulated to meet requirements of cows for energy, protein, neutral detergent fiber (NDF), minerals and vitamins during prepartum period based on NRC (2001) recommendations and fed twice daily at 08:00 and 15:30 as a total mixed ration (TMR). Cows were fed as a group, *ad libitum* in an amount of 10% orts, till -7 d relative to expected calving. At that time, the cows were moved from group pen to individual pen and their prepartum daily dry matter intakes were measured in last 7 d before calving.

Table 1 Ingredient composition and chemical analysis of experimental diets

TMR ingredients, (%) of DM	Source of starch in the diet	
	Corn	Wheat
Alfalfa hay	64.60	64.60
Ground corn	18.57	-
Ground wheat	-	18.57
Soybean meal	11.29	9.32
Whole cottonseed	1.45	3.46
Fish meal	0.52	0.52
Beet pulp	2.62	2.62
Dicalcium phosphate	0.35	0.52
Mineral and vitamin premix[1]	0.60	0.60
Chemical composition		
NE_L, [2] Mcal/kg	1.55	1.57
CP, (%) of DM	16.50	16.46
MP[2], (%) of DM	6.76	7.62
MP, g/d	748.1	814.8
Bacterial MP, g/d	455.6	523.1
NDF, (%) of DM	34.40	35.00
NFC, [3] (%) of DM	38.00	37.50
Starch, (%) of DM	15.02	14.70
EE, (%) of DM	3.83	3.90
Ca, (%) of DM	0.90	0.87
P, (%) of DM	0.32	0.34
K, (%) of DM	1.75	1.70
Mg, (%) of DM	0.22	0.23
Zn, mg/kg	43.00	45.00
Cu, mg/kg	12.20	12.30
Mn, mg/kg	32.60	32.80
Vit A, IU/kg	5000	5000
Vit D, IU/kg	1500	1500
Vit E, IU/kg	75	75

[1] Mineral and vitamin mix contained vitamin A, 800000 IU; vitamin D, 230000 IU; vitamin E, 12000 IU; Ca, 196 g P, 96 g; Mg, 71 g ; Fe, 3 g; Cu, 0.3 g; Mn, 2 g; Zn, 3 g; Co, 0.1 g; I, 0.1 g; and Se, 0.1 g per kg of DM.
[2] Metabolizable protein, calculated from NRC (2001).
[3] NFC was calculated as: 100-[(NDF-NDFCP)+CP+EE+ash)] (NRC, 2001).

The cows had free access to water at all times. Samles of TMR were collected weekly, stored at -20 °C, and composited for each treatment. At the end of the experiment, pooled samples of TMR were dried at 55 °C in an oven for 48 h, ground through a 1-mm screen mill, and analyzed for dry matter (DM), ether extract (EE), crude protein (CP), Ca, P, Mg, K (AOAC, 2000) and NDF (Van Soest *et al*. 1991).

The starch content of the diets was determined using Karkalas (1985) procedure. Before the morning meal, blood samples were obtained from coccygeal vein at -7 and -1 d relative to expected calving dates. All blood samples were collected in sodium heparinized tubes, immediately placed on ice, and centrifuged at 3000 × g at 4 °C for 15 min for plasma separation. Plasma was stored at -20 °C for later analyses. Plasma samples were analyzed for glucose (kit no. 10-505; ZiestChem Diagnostics Co., Tehran, Iran), total protein (Connell *et al*. 1997), triglyceride (kit no. 10-525;

ZiestChem Diagnostics Co., Tehran, Iran) and nonesterified fatty acids (NEFA) (Johnson and Peters, 1993). Intra- and interassay coefficients of variation for plasma glucose, total protein, triglyceride and NEFA were 8.9%, 12.6%; 6.5%, 11.3%; 10.6%, 5.5%; and 9.6%, 4.2%, respectively. All samples were analyzed in duplicates.

Calving was monitored by farm personals and calves were removed from their dams before colostrum intake. Navels were treated with 7% iodine solution, and calves were weighed, identified with an ear tag, and placed in individual calf hutches. Fresh colostrum from first milking was completely collected from each cow immediately after parturition.

Colostrum samples (100 mL) were collected from each cow and frozen at -20 °C for later analysis. Calves were individually fed from their own mother colostrum at 10% of BW immedeatley after birth and 12 h of life. All calves were fed by esophageal feeder to reduce variation in plasma IgG due to differences in voluntary intake. Blood samples were drawn from the jugular vein of calves just before the first colostrum feeding (0 h) at birth and 24 h later. Serum was separated and frozen at -20 °C. Colostrum samples were analyzed for protein, fat, lactose, and total solids using the infrared spectrophotometer (Milk-O-Scan 133B Foss Electric Denmark). Concentrations of IgG_1 and IgG_2 in colostrum and serum were determined by turbidimetric immunoassay (Etzel *et al*. 1997). Sera, collected at the time of the first colostrum feeding, were also examined for the presence of serum IgG_1 and IgG_2 concentrations prior to colostrum feeding. Efficiencies of IgG_1 and IgG_2 absorptions (AEA) were determined by multiplying the estimated plasma volume of the calf by its 24-h serum IgG_1 and IgG_2 concentrations and dividing this product by the mass of colostral IgG_1 and IgG_2 that was fed. Plasma volume at 24 h was estimated to be 0.08 × BW (Quigley and Drewry, 1998), and birth BW was used to estimate BW at 24 h.

Statistical analysis

The data for dam's plasma metabolites (glucose, total protein, triglyceride and NEFA) concentrations were analyzed using the MIXED procedure for repeated measures by SAS (SAS Institute, 1999). Dry matter intake, colostrum IgG_1 and IgG_2 concentrations and colostrum compositions (protein, fat, lactose, and total solids), calve's serum IgG_1 and IgG_2 concentrations and calculated AEA were analyzed as a randomized complete block experimental design using Proc GLM of SAS (SAS Institute, 1999). Birth BW and sex of calves were evaluated in each model as a covariate but were not statistically significant. Statistical differences were considered significant when $P<0.05$ and trends are discussed when $P<0.10$. Least square means and standard error of the means are reported.

RESULTS AND DISCUSSION

Effects of experimental diets on dry matter intake and concentrations of plasma metabolites are shown in Table 2.

Table 2 Effect of dietary treatments on dry matter intake and concentrations of plasma metabolites of cows

Item	Source of starch in the diet		SEM	P-value
	Corn	Wheat		
DMI, kg/d	11.06	11.69	0.43	0.15
Total protein, g/dL	6.59[b]	7.35[a]	0.13	0.04
Glucose, mg/dL	53.14	57.93	2.30	0.25
NEFA, µEq/L	206	221	25	0.43
Triglyceride, mg/dL	17.69	19.50	2.03	0.37

a, b means within the same row are significantly different ($P<0.05$).

The results show no significant differences for dry matter intake between the two dietary treatments ($P>0.05$). Dann *et al*. (1999) reported that increasing the fermentability of nonfiber carbohydrates (NFC) in prepartum diets (cracked corn replaced with steam flaked corn) tended to increase prepartum dry matter intake (DMI) but replacing sucrose with ground shelled corn in prepartum diet did not affect prepartum DMI (Ordway *et al*. 2002). Effects of ruminaly available carbohydrate on DMI varies considerably and depends on total amount of carbohydrate fermented in the rumen, source of grain, processing method, level of intake and forage source in the basal diet (Huntington, 1997).

Total protein concentration in plasma was higher ($P<0.05$) for cows fed wheat containing diet. Serum contains many different proteins, but the two major protein components are albumin and globulin. Albumin is synthesized in the liver. Many different proteins make up the globulin fraction. A large portion of the globulin fraction consists of immunoglobulins, which are synthesized by lymphoid cells. Many other globulins are synthesized by the liver. Insufficient protein production in the liver can occur in animals with chronic severe hepatic disease or as a result of inadequate protein intake, digestion or absorption (Russell and Roussel, 2007). Since energy intake and carbohydrate availability are the primary factors regulating microbial protein yield in the rumen (NRC, 2001), higher total protein concentrations in plasma for the cows fed wheat containing diet can be related to an increase in ruminal protein synthesis. Cabrieta *et al*. (2006), in a recent literature review concluded that more ruminally degradable starch increased microbial N supply. Microbial protein synthesized in the rumen supplies the majority of absorbable amino acids to the small intestine (NRC, 2001).

Plasma concentrations of glucose did not respond to dietary treatment ($P>0.05$). Under most conditions, intestinal absorption of glucose in dairy cows is limited due to the extensive ruminal fermentation of dietary starch; thus, plasma glucose largely arises from hepatic gluconeogenesis

(Hungtington, 1997). In general, glucose concentrations do not vary greatly due to the nutritional changes of diet.

There were no significant differences in plasma NEFA and triglyceride concentrations between treatments (P>0.05). The NEFA concentrations in plasma reflect the rate of adipose mobilization. The NEFA concentration was inversely related to DMI (Pullen *et al*. 1989). In the present study, the lack of the effect of dietary treatments on NEFA concentration can be related to similar DMI (Table 2). Concentration of TG in blood arises both from dietary fatty acids absorbed and packaged into lipoproteins in the intestine as well as from production of VLDL in the liver. Thus, changes in liver and intestine metabolism of cows affect plasma triglyceride concentration.

Body weight of calves was not different between treatments at birth (mean BW was 40.65 and 39.91 kg for calves born from cows fed corn containing diet or wheat containing diet, respectively). Effect of experimental diets on colostrum composition is shown in Table 3.

Table 3 Effect of dietary treatments on colostrum compositions

	Source of starch in the diet			
Item	Corn	Wheat	SEM	P-value
Fat, (%)	6.93	7.37	0.41	0.52
Protein, (%)	12.99^{b}	13.70^{a}	0.17	0.03
Lactose, (%)	2.87	2.96	0.11	0.61
Total solids, (%)	23.96^{b}	25.20^{a}	0.39	0.04
IgG_1, mg/mL	69.20^{b}	96.57^{a}	5.98	0.02
IgG_2, mg/mL	10.52	9.76	1.05	0.47
Total IgG, mg/mL	79.72^{b}	106.33^{a}	6.14	0.03

a, b means within the same row are significantly different (P<0.05).

Lactose and fat percentages in colostrum did not respond to dietary treatments (P>0.05). These results are supported by the observed similarity of plasma concentrations for glucose and triglyceride between treatments (Table 2). Colostral fat and lactose play a major role in supplying energy to the newborn calves and in establishing glucose homeostasis (Quigley and Drewry, 1998).

Colostrum protein and TS percentages were higher (P<0.05) for cows on wheat containing diet compared with cows on corn containing diet. This response might be related to the higher concentrations of plasma total protein in cows fed the wheat containing diet (Table 2). Colostral proteins are utilized by the neonate for protein synthesis in addition to the absorption of Ig (Quigley and Drewry, 1998).

Feeding the wheat containing diet resulted in greater concentrations of IgG_1 and total IgG in colostrum (P<0.05) which can be explained by the higher plasma concentrations of total protein in the cows (Table 2). Amount of Ig in the colostrum varies according to the dam's disease history, volume of colostrum produced, season of the year, breed, length of the dry period, parity of the dam, prepartum milking and time after calving (Jaster, 2005). However, data summarized by Quigley and Drewry (1998) showed that Ig concentration in colostrum is not markedly affected by prepartum nutrition.

The concentration of IgG_1 and IgG_2 were similar in the serum of new-born calves before the first colostrum feeding (Data not shown). Effect of dietary treatments on serum Ig concentrations and apparent efficiency of Ig absorption are shown in Table 4.

Table 4 Effect of dietary treatments on serum Ig concentrations and apparent efficiency of Ig absorption in calves at 24 h after colostrum feeding

	Source of starch in the diet			
Item	Corn	Wheat	SEM	P-value
IgG_1, mg/mL	18.49^{b}	22.42^{a}	1.22	0.03
IgG_2, mg/mL	6.13	7.00	0.56	0.32
Total IgG, mg/mL	24.62^{b}	29.42^{a}	1.37	0.04
AEA IgG_1, (%)	19.31	19.04	1.21	0.65
AEA IgG_2, (%)	33.20	41.29	3.60	0.47
AEA total IgG, (%)	19.45	19.05	1.26	0.28

a, b means within the same row are significantly different (P<0.05).

At 24 h after colostrum feeding, serum concentrations of IgG_1 and total IgG were higher for calves fed colostrum from wheat-fed cows in prepartum diet (P<0.05). Serum IgG concentration of neonatal calves depends on many factors. The most important of these are the mass of IgG consumed and age at first feeding (Davis and Drackley, 1998). In the current study, this result might be related to higher concentrations of IgG and protein in colostrum of cows fed with the wheat containing diet (Table 3). Colostrum high in Ig resulted in higher Ig concentrations in the serum of calves in previous studies (Jaster, 2005; Morin *et al*. 1997). Colostral proteins are utilized by the neonate for absorption of Ig (Quigley and Drewry, 1998). It is generally accepted that the failure of passive transfer is indicated when a serum Ig concentration is less than 10 mg/mL at 24 to 48 h of age.

Apparent efficiency of the absorption of IgG_1, IgG_2, and total IgG did not vary between treatments (P>0.05). Serum IgG concentrations at 24 to 48 h of age are typically used to assess the success of the passive transfer of immunity to neonatal calves. Mean AEA from maternal colostrum typically averages 20 to 35% (Quigley and Drewry, 1998). The concentration of IgG in the colostrum may influence AEA. Absorption of IgG is related linearly to its concentration in colostrum, although at high intakes the efficiency of absorption is decreased (Quigley *et al*. 2002). Also, Stott *et al*. (1979) suggested that there is a curvilinear relationship between AEA and IgG intake, and that an excessive amount of colostrum may cause inhibition in immunoglobulin absorption because of a limited number of surface receptors responsible for carrying IgG from the intestinal wall to the blood stream. When all the receptors become saturated,

there is no longer a means for IgG to be transported (Jaster, 2005).

CONCLUSION

As a consequence of higher total protein concentrations in plasma, colostrum produced by the cows fed wheat containing diet had higher concentrations of protein and IgG compared to the cows fed corn containing diet, which in turn can be a cause for higher serum concentrations of IgG_1 and total IgG observed in serum of calves which consumed colostrum from cows fed wheat containing diet. Thus, based on the results of this study, the nutritional strategies for cows during the prepartum period have an effect on colostrum quality and most probably on the survival, health and growth of newborn calves. However, further researches are needed to evaluate the effects of prepartum diets on health and viability of calves by passive transfer of immunity through the dam's colostrum.

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