J. BIOL. ENVIRON. SCI.,
2010, 4(10), 9-14

The Effect of Starch Sources with Different Degradability Rates on Milk Production and Composition in Lactating Cows

Bulent Haluk Gulmez[1], Hidir Gencoglu[1], Hakan Biricik[1], Gulay Deniz[1], Çağdaş Kara[1], Faruk Balci[2], Ibrahim Ismet Turkmen[1*]

[1]Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, University of Uludag, Bursa, 16059, TURKEY
[2]Department of Animal Science, Faculty of Veterinary Medicine, University of Uludag, Bursa, 16059, TURKEY

ABSTRACT

The purpose of this study was to investigate the effect of starch sources with different degradability rates on chewing activities, milk production and composition of lactating dairy cows. Twelve lactating Holstein cows were used in a 4 x 4 Latin square design and fed with diets containing different rates of corn and wheat. The diets were: 1) 26.20% corn based diet (CBD); 2) 16.10% corn and 7.09% wheat based diet (CWBD); 3) 16.51% wheat and 7.26% corn based diet (WCBD); or 4) 25.88% wheat based diet (WBD). The eating, ruminating and total chewing time were not affected by the treatments and time spent total chewing time ranged from 761 to 801 min/d. Cows fed with CBD higher milk production, fat, protein and lactose yield than did cows fed with WCBD and WBD (P<0.05). The fat, protein, and lactose yield were greater for cows fed CBD than for cows fed WBD due to cows fed CBD produce more milk yield compared with cows fed WBD (P<0.05). The milk fat percentages ranged from 3.89 to 4.18%, protein percentages ranged from 3.38 to 3.52%, and lactose percentages ranged from 4.86 to 4.93%, and were not affected by dietary treatments. These results showed that milk production and milk yield compositions were increased by replacing wheat with ground corn.

Key Words: Chewing activity, Milk production and composition, Starch sources.

INTRODUCTION

Cereal grains are the most common sources of readily available energy for livestock and comprise up to 60% of the total diet for high yielding dairy cows (Herrera-Saldana et al. 1990). According to Fulton et al. (1979) wheat is more rapidly and extensively fermented than other cereal grains. Moreover, Nocek and Tamminga (1991) reported that the starch in similarly processed wheat, oats, and barley is generally more degradable than is the starch in corn. Therefore, wheat is more prone to lead to acidosis because of faster fermentation in the rumen. Thus, it can lead to a variety of metabolic disorders, including subclinical ruminal acidosis, reduced fiber digestion, milk fat depression, displaced abomasum, lameness, and fat cow syndrome National Research Council (NRC) 2001. The effect of different grain sources on milk production is conflicted. Several studies (Grings et al. 1992, Khorasani et al. 1994) reported that substitution of barley with corn did not influence milk yield, whereas other studies (McCarthy et al. 1989, Casper et al. 1999) reported higher milk yields for cows fed corn based diets than for those fed barley based diets. On the other hand, the effect of the usage of wheat grain rather than corn grain in dairy cattle rations on milk production and composition is limited. Consequently, the objectives of this study were to investigate the effect of starch sources with different degradability rates on chewing activities, milk production and composition of lactating dairy cows.

MATERIALS AND METHODS

Twelve lactating Holstein cows averaging 170±10 d in milk and weighing 580±45 kg were randomly assigned in a 4x4 Latin square design. Cows were housed in individual tie stalls and all diets were formulated for a 600 kg cow producing 20 kg/d of milk with 3.6% fat and 3.0% true protein by using the NRC 2001 guidelines. Throughout the experiment, cows were fed a total mixed ration (TMR) twice daily (09:00 and 21:00 h) at 110% of expected intake. Each period consisted of 14 d of adaptation to diets and 7 d of experimental measurements.

Four diets were formulated with 50% concentrate and 50% forage (Table 1). Different ratio of corn and wheat were used in the concentrate components as starch sources according to the results of a study by Herrera-Saldana et al. (1990). The concentrate components were formulated to contain 1) 52.40% corn based concentrate (CBD); 2) 32.20% corn and 14.18% wheat based concentrate (CWBD); 3) 33.02% wheat

[*] Corresponding author: turkmen@uludag.edu.tr

and 14.52% corn based concentrate (WCBD); or 4) 51.76% wheat based diets (WBD). The corn and wheat were ground through a 3-mm diameter screen using a hammer mill (Tosun Tarim, Izmir, Turkey). Corn silage was obtained from Uludag University, Faculty of Veterinary Medicine Farm. Whole plant corn (hybrid C955 Pioneer Hi-Bred International, Des Moines, IA, USA) was harvested at about 26.5% DM using a self-propelled forage harvester (without a kernel processing unit; Tosun Tarim) set to obtain a 19.0 mm theoretical cut length. The chopped forage was placed in a horizontal silo (300 ton capacity), covered with nylon plastic, and ensiled for approximately 2 months. Wheat straw was chopped using a miller rotary hay mill equipped with a 5 cm screen (Tosun Tarim).

Eating and ruminating behaviours were monitored visually for a 24-h period in twelve cows. Eating and ruminating activities were noted every 5 min, and each activity was assumed to persist for the entire 5-min. To estimate the time spent eating, ruminating and total chewing per kilogram of dry matter intake (DMI) and neutral detergent fiber (NDF) the actual intake for that day was used. A period of rumination was defined as at least 5 min of rumination occurring after at least 5 min without rumination activity. Total chewing time was determined as the sum of total eating and ruminating times.

Milk samples were collected from each cow at each milking on the last 7 d of each period. Experimental cows were milked twice daily at 06:00 and 18:00 h, and milk weights were recorded (Milko Scope MK II, De Laval, Sweden). Milk samples were analyzed for fat, protein and lactose using Gerber, Kjeldahl (N×6.38) and polarimetric methods, respectively as described by AOAC (2002). Production of 4% fat corrected milk (FCM) was calculated from unadjusted milk production (UMP) and milk fat percentage (F) by the equation of Gaines (1928): $FCM = UMP (0.4 + (0.15 \times F))$. Production of solids corrected milk (SCM) was calculated from UMP, F, protein (P), and lactose (L) percentages from the equation of Tyrell and Reid (1965): $SCM = UMP \times ((0.1224 \times F) + (0.0710 \times P) + (0.0635 \times L) - 0.0345)$.

Chemical Analyses

The dietary samples were dried in forced-air oven at 60°C for 48 h for measurement of DM content and then ground through a 1-mm diameter screen using a laboratory 3303 Mill (Hundenge, Sweden). The CP was determined by the Kjeldahl method (AOAC 2002). Ash was determined by combustion at 550°C for 6 h. The NDF, Acid Detergent Fiber (ADF) and lignin contents were determined using the methods described by Van Soest et al. (1991) with heat-stable amylase (Sigma No: A-3306, Sigma Chemical Co., St Louis, MO, USA) and sodium sulfite used in the NDF procedure. Starch was measured on composited samples as described by Bal et al. (2000).

Statistical Analyses

Chewing activities, milk yield and composition parameters were analyzed as a 4x4 Latin square. Data were analyzed by ANOVA using the general linear model procedure of SPSS to examine the effect of cow, period, and starch sources, followed by the Tukey test procedure.

RESULTS AND DISCUSSION

Ingredients and chemical composition of the total mixed diets were shown in Table 1. The diets were chemically similar but varied in the starch sources. The results of the chewing activities data are given in Table 2. The chewing activities data did not differ between experiments and time spent total chewing time ranged from 761 to 801 min/d. It is assumed that the reason for the similar eating, ruminating and total chewing time were the same forage sources and ratio of forages (Table 1), thus all diets contained the same particle size.

Milk yield and composition data are presented in Table 3. Cows fed WBD and WCBD produced less milk yield, 4%FCM, and SCM compared with cows fed CBD ($P<0.05$). This decrease in yield can be probably explained by negative effects of ground wheat on ruminal digestion (i.e., low pH and reduced cellulolytic activity). Likewise, Stone (1999) reported that milk yield decrease 2.7 kg/d in a commercial dairy herd which are suffering from subacute rumen acidosis (SARA). On the other hand, Robinson and Kennelly (1989) already reported that diets with similar digestibilities resulted in higher milk yields when cows were fed less ruminally degradable starch. McCarthy et al. (1989) and Casper et al. (1999) showed that milk production was greater for cows fed corn than for cows fed barley, whereas Khorasani et al. (1994) and Grings et al. (1992) showed no difference in milk production between cows fed diets based on corn or barley. In this connection, Casper et al. (1999) stated that the slightly greater starch content of the corn diets may have contributed to the greater milk production for cows fed corn than cows fed the barley-based diets. On the other hand, Petit and Santos (1996) reported that cows fed high moisture wheat tended to yield more milk than cows fed high moisture corn because of in vitro DM digestibility was higher for high moisture wheat than for high moisture corn.

Table 1. Ingredients and chemical composition of the total mixed diets

Item	CBD[1]	CWBD[2]	WCBD[3]	WBD[4]
Ingredients, %				
Corn silage[5]	35.00	35.00	35.00	35.00
Wheat straw[6]	15.00	15.00	15.00	15.00
Ground corn	26.20	16.10	7.26	-
Ground wheat	-	7.09	16.51	25.88
Soybean meal ground, 44% CP	9.55	8.88	10.70	9.97
Sunflower meal ground	13.04	16.72	14.31	12.94
Calcium carbonate	1.04	1.04	1.04	1.04
Vitamin-mineral premix[7]	0.01	0.01	0.01	0.01
Salt (NaCl)	0.16	0.16	0.17	0.16
Total, %	100.00	100.00	100.00	100.00
Chemical composition				
Dry matter (DM), %	68.15	67.71	67.21	66.95
Crude protein (CP), % of DM	14.98	15.21	15.51	15.85
Ether extract (EE), % of DM	3.10	3.06	2.98	2.54
Neutral detergent fiber (NDF), % of DM	38.92	39.44	38.19	39.15
NDF from forage, % of DM	30.19	30.48	29.74	30.33
NDF from concentrate, % of DM	9.04	9.92	9.51	9.47
Acid detergent fiber, % of DM	21.35	23.67	21.46	23.42
NFC[8], % of DM	36.71	36.44	36.85	36.02
NFC from concentrate, % of DM	26.47	25.62	25.88	25.50
Starch, % of DM	22.98	20.03	19.22	19.93
Starch from concentrate, % of DM	19.44	16.89	16.06	16.89
Ash	6.29	5.85	6.47	6.44
NE_L[9], Mcal/kg of DM	1.59	1.58	1.61	1.58

[1]**CBD=** 26.20% corn based diet, [2]**CWBD=** 16.10% corn and 7.09% wheat based diet, [3]**WCBD=** 16.51% wheat and 7.26% corn based diet, [4]**WBD=**25.88% wheat based diet. [5]Corn silage analysis (DM basis): NDF, 55.64%, [6]wheat straw analysis (DM basis): NDF, 77.22%. [7]Supplied per kilogram of premix (Kavimix VM, Kartal Kimya A.S., Turkey): Vitamin A 12000000 IU, Vitamin D_3 3000000 IU, Vitamin E 30 g, Mn 50 g, Fe 50 g, Zn 50 g, Cu 10 g, I 0.8 g, Co 0.1 g, Se 0.15 g, Antioxidant 10 g. [8]NFC: Nonfiber carbohydrate, %; calculated as: 100 - (NDF, % + CP, % + EE, % + ash, %). [9]Estimated according to NRC 2001.

Table 2. Effect of starch source on chewing activities

Dependent variable	CBD[1]	CWBD[2]	WCBD[3]	WBD[4]	SE	P
Eating						
Min/d	299	312	295	282	18.89	NS
Min/kg of DM	18.98	20.20	19.06	17.99	1.11	NS
Min/kg of NDF	48.75	51.22	49.91	45.95	2.84	NS
Ruminating						
Min/d	503	449	475	499	23.56	NS
Min/kg of DM	31.99	29.14	30.72	31.75	1.63	NS
Min/kg of NDF	82.19	73.88	80.44	81.11	4.19	NS
Total chewing						
Min/d	802	761	770	781	25.16	NS
Min/kg of DM	50.98	49.34	49.78	49.74	1.94	NS
Min/kg of NDF	131	1250	130	1276	4.97	NS

[1]**CBD=** 26.20% corn based diet, [2]**CWBD=** 16.10% corn and 7.09% wheat based diet, [3]**WCBD=** 16.51% wheat and 7.26% corn based diet, [4]**WBD=**25.88% wheat based diet. NS: P>0.05

Table 3. The effect of starch sources on milk yield and milk composition

Item	CBD[1]	CWBD[2]	WCBD[3]	WBD[4]	SE	P
DMI[5],						
kg/d	15.72	15.47	15.51	15.71	0.23	NS
Yield						
Milk, kg/d	22.94[a]	21.67 [ab]	20.60[b]	19.57 [b]	0.63	*
4% FCM[6], kg/d	23.58[a]	21.28[ab]	20.90[b]	20.05[b]	0.89	*
SCM[7], kg/d	23.62[a]	21.74 [ab]	21.13[b]	20.33[b]	0.91	*
Fat, g/d	961[a]	844[ab]	841[ab]	815[b]	52.66	*
Protein, g/d	775[a]	764[a]	712[ab]	666[b]	31.45	*
Lactose, g/d	1120[a]	1054[ab]	990[ab]	950[b]	61.98	*
Composition, %						
Fat	4.18	3.89	4.12	4.16	0.25	NS
Protein	3.38	3.52	3.46	3.41	0.13	NS
Lactose	4.93	4.91	4.86	4.89	0.17	NS
SCM/DMI	1.49[a]	1.41[ab]	1.36[b]	1.29[b]	0.05	*

[1]**CBD=** 26.20% corn based diet, [2]**CWBD=** 16.10% corn and 7.09% wheat based diet, [3]**WCBD=** 16.51% wheat and 7.26% corn based diet, [4]**WBD=**25.88% wheat based diet. [5]DMI = Dry matter intake, [6]FCM = Fat corrected milk, [7]SCM = Solids corrected milk. *P<0.05, NS: P>0.05

a-b: Means in the same row with different superscripts differ according to P value indicated.

The fat, protein, and lactose yields were greater for cows fed CBD than for cows fed WBD due to cows fed CBD produce more milk yield compared with cows fed WBD (P<0.05). Milk fat yield was significantly lower when cows fed WBD (0.82 kg/d) compared with cows fed CBD diet (0.96 kg/d). This result is related to, the lower milk production of WBD.

Because of higher SCM of diets containing 26.20% corn grain and similar DMI in all the diets, efficiency of milk production, expressed as SCM production per unit of DMI, increased from 1.29 to 1.49 when corn replaced wheat grain (P<0.05). We cannot explain the difference in SCM/DMI observed for corn versus wheat based diet or greater energy utilization for the corn than wheat based diet due to improve rumen pH status. (refer to Gulmez and Turkmen, 2007). On the other hand, an increase in SCM/DMI was found by Krause et al. (2002) when high moisture corn replaced dry corn. Krause et al. (2002) stated that greater ruminal fermentation is associated with higher energetic efficiency, which could explain the higher efficiency of milk production for the high moisture corn diets compared to the dry corn diets.

The milk fat percentage ranged from 3.89 to 4.18% and was not affected by the treatments. The effects of fiber amount and source on milk fat production have been known for a long time. In the present study, it can also be concluded that all four diets provided adequate amounts of forage sources and NDF level of diets. These results are consisted with Mertens (1983) who reported that FCM yield was the greatest for cow fed diets based on alfalfa hay, corn silage, or bermudagrass hay when dietary NDF content was 35% for each diet. However, milk fat percentages are higher than expected for cows fed WBD and WCBD because of wheat grain has highly degradable starch. Why the milk fat percentages are higher than expected in this study is not known, but the results could be related high forage NDF, NDF content of diets and some other factor (day in milk). On the other hand, Mertens (1997) reported that to maintain milk fat at 3.6% would require 744 min of chewing/d or 36.1 min/kg of DM. The requirements are more than the 30 min of chewing time per kilogram of DM that was recommended by Nørgaard (1980). In this study, the chewing per kilogram of DM in all diets was high and this greater chewing per kilogram of DM contributed to the higher milk fat percentage. Gentile et al. (1986) studied the effect of nutritionally induced acidosis on milk composition. At 15, 45, and 90 d postpartum, acidotic cows had less milk fat (2.73 vs 3.88%). The reduction in milk lipids was related to ruminal inversion of the molar ratio of acetate to propionate. Yang and Beauchemin (2003) stated that low milk fat content was consistent with low mean rumen pH (5.50) and low ratio of acetate to propionate (range of 1.7 to 2.0). Allen (1997) did find a positive relationship between milk fat percentage and ruminal pH ($P<0.0001$; $r^2 = 0.39$). Although ruminal pH was decreased significantly in the current study, daily means ranged from 5.83 to 6.45 and from 3.31 to 4.21 for rumen pH and acetate/propionate for WBD, CBD diets, respectively (Gulmez and Turkmen 2007); we did not observe a decrease in milk fat percentage (Table 3). As mentioned previously, this can be probably explained the results could be related particle size and quality of forage, NFC content of the ration, buffer feeding, NDF content of diets or some other factor (days in milk). On the other hand, diets with less than 25 percent total NDF and less than about 16 percent NDF from forage depressed milk fat percentages (Clark and Armentano 1993).

The milk protein percentage ranged from 3.38 to 3.52% and was similar among diets. The CBD had the lowest contents of dietary crude protein among the groups, but the difference between it and the three treatments were small. The NRC (2001) reported that dietary crude protein was not correlated ($P>0.25$) with milk protein percent, but was correlated weakly ($r = 0.14$; $P<0.01$) with milk protein yield. Microbial protein synthesis is related to the amount of carbohydrate fermented in the rumen and the yield of microbial protein per kilogram of fermented carbohydrate (Hoover and Stokes 1991). The dietary ratios of degradable crude protein would indicate a similar yield of microbial protein per kilogram of fermented carbohydrate for all treatments. Corn distillers grains have been found by Owen and Larson (1991) to depress milk protein concentration. O'mara et al. (1997) stated that ground corn was a significant source of rumen undegradable protein, and its low lysine content could affect milk protein synthesis. Grieve et al. (1986) reported that similar milk protein content across treatments probably resulted from similar energy content of diets and organic matter digestibility in the total tract because milk protein is positively correlated with dietary energy. In this study, the cows had similar DMI (Table 3) and daily fermentable energy intake (Table 1); therefore, there are several possible explanations for the similar milk protein concentration for all dietary treatments. The milk lactose percentages ranged from 4.86 to 4.93% and were not affected by dietary treatments.

CONCLUSIONS

According to the results of our study, we conclude that the productive parameters of animals fed a 26% mixture of corn is better than that of animals fed 16% and 26% mixture of wheat. The data also indicate that the wheat had unfavorable effects on the productive parameters when the diets consist of 26% wheat in dairy cow ration. Finally, the data indicate that not only dietary starch amount but also the starch source is important in dairy cattle nutrition.

Acknowledgements

This experiment was financially supported by the Research Funds of University of Uludag (Grant no. 2004-3).

REFERENCES

Allen MS (1997). Relationship between fermentation acid production in the rumen and the requirement for physically effective fiber. J Dairy Sci 80: 1447-1462.

AOAC (2002). Official Methods of Analysis. 17 th rev. ed. AOAC International, Gaithersburg, Maryland, USA.

Bal MA, Shaver RD, Jirovec AG, Shinners KJ, and Coors JG (2000). Crop processing and chop length of corn silage: Effects on intake, digestion, and milk production by dairy cows. J Dairy Sci 83: 1264-1273.

Casper DP, Maiga HA, Brouk MJ, and Schingoethe DJ (1999). Synchronization of carbohydrate and protein sources on fermentation and passage rate in dairy cows. J Dairy Sci 82: 1779-1790.

Clark PW, and Armentano LE (1993). Effectiveness of neutral detergent fiber in whole cottonseed and dried distillers grain compared with alfalfa haylage. J Dairy Sci 76: 2644-2650.

Fulton WR, Klopfenstein TJ, and Bitton RA (1979). Adaptation to high concentrate diets by beef cattle. 1. Adaptation to corn and wheat diets. J Anim Sci 49: 775-784.

Gaines WL (1928). The energy basis of measuring milk yield in dairy cows. Illinois Agric. Exp. Stn., Urbana, pp 308..

Gentile G, Cinotti S, Ferri G, and Famigli-Bergamini P (1986). Nutritional acidosis and technological characteristics of milk in high producing dairy cows. Proccessing 14th World Congress. Diseases of Cattle. (Eds.: P.J. Harigan and M.L. Monaghan). Dublin, pp. 823.

Grieve DG, Korver S, Rijpkema YS, and Hof G (1986). Relationship between milk composition and some nutritional parameters in early lactation. Livest Prod Sci 14: 239-254.

Grings EE, Roffler ER, and Deitelhoff DP (1992). Evaluation of corn and barley as energy sources for cows in early lactation fed alfalfa-based diets. J Dairy Sci 75: 193-200.

Gulmez BH and Turkmen II (2007). The effect of starch sources with different degradability rates on ruminal fermentation of lactating dairy cows. Revue Méd Vét 158: 92-99.

Herrera-Saldana RE, Huber JT, and Poore M (1990). Dry matter, crude protein, and starch degradability of five cereal grains. J Dairy Sci 73: 2386-2393.

Hoover WH and Stokes SR (1991). Balancing carbohydrates and proteins for optimum rumen microbial yield. J Dairy Sci 74: 3630-3644.

Khorasani GR, De Boer G, Robinson B, and Kennelly JJ (1994). Influence of dietary protein and starch on production and metabolic responses of dairy cows. J Dairy Sci 77: 813-824.

Krause KM, Combs DK, and Beauchemin KA (2002). Effects of forage particle size and grain fermentability in midlactaion cows: I. Milk production and diet digestibility. J Dairy Sci 85: 1936-1946.

McCarthy JRD, Klusmeyer TH, Vicini JL, Clark JH, and Nelson DR (1989). Effects of source of protein and carbohydrate on ruminal fermentation and passage of nutrients to the small intestine of lactating cows. J Dairy Sci 72: 2002-2016.

Mertens DR (1983). Using neutral detergent fiber to formulate dairy rations and estimate the net energy content of forages. Proceedings of Cornell Nutrition Conference, Syracuse, Cornell Univ., Ithaca, pp. 60.

Mertens DR (1997). Creating a system for meeting the fiber requirements of dairy cows. J Dairy Sci 80: 1463-1481.

National Research Council (2001). Nutrients requirements of dairy cattle. 7th rev. ed. National Academy Press. Washington, DC, USA.

Nocek JE and Tamminga S (1991). Site of digestion of starch in the gastrointestinal tract of dairy cows and its effect on milk yield and composition. J Dairy Sci 74: 3598-3629.

Norgaard P (1980). Physical structure of feeds for dairy cows. New developments and future perspectives in research on rumen function. (Eds.: A. Neimann-Sorensen), European Community, Luxembourg, pp. 85.

O'mara FP, Murphy JJ, and Rath M (1997). The effect of replacing dietary beet pulp with wheat treated with sodium hydroxide, ground wheat, or ground corn in lactating cows. J Dairy Sci 80: 530-540.

Owen FG and Larson LL (1991). Corn distillers dried grains versus soybean meal in lactation diets. J Dairy Sci 74: 972-979.

Petit HV and Santos GTD (1996). Milk Yield and Composition of Dairy Cows Fed Concentrate Based on High Moisture Wheat or High Moisture Corn. J. Dairy Sci. 79:2292-2296.

Robinson PH and Kennelly JJ (1989). Influence of ammoniation of high-moisture barley on digestibility, kinetics of rumen ingesta turnover, and milk production in dairy cows. Can J Anim Sci 69: 195-203.

Stone WC (1999). The effect of subclinical rumen acidosis on milk components. Proceedings of Cornell Nutrition Conference. Feed Manufacturer, Syracuse, Cornell Univ., Ithaca, pp 40-46.

Tyrell HF and Reid JT (1965). Prediction of the energy value of cow's milk. J Dairy Sci 48: 1215-1223.

Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 74: 3583-3597.

Yang WZ, and Beauchemin KA (2003). Effects of physically effective NDF on rumen fermentation and nutrient digestion of dairy cows fed diets based on barley or corn silages. J Anim Sci 81 (Suppl. 1)/J Dairy Sci 86 (Suppl. 1) 1: 340.