



Effects of Dietary Starch and Crude Protein Levels on Milk Production and Composition of Dairy Cows Fed High Concentrate Diet

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ABSTRACT

Effects of two dietary levels of starch and crude protein on performance of dairy cow fed low roughage level (70:30 concentrate to roughage) were investigated. Twenty eight Holstein cows were randomly assigned to one of four dietary treatments in a 2 x 2 factorial arrangement. Factors were two dietary level of starch (14% and 22%) and crude protein (15% and 18%). Wheat straw was used as sole roughage source. The study was continued 6 weeks. Dry matter intake was not affected ($P>0.05$) by the dietary treatments in the study. Milk and protein yield (kg/d) were higher ($P<0.05$) with higher dietary crude protein level at each starch level. Milk urea concentrations were affected ($P<0.01$) by dietary protein levels with a value being higher by high dietary protein level. Nitrogen efficiency (Milk N/N intake) was decreased by increasing dietary crude protein level in the diet ($P<0.01$). In conclusion, the cows fed TMR containing low level of wheat straw responded better when dietary protein increased. But, efficiency of N use decreased and N excretion to the environment increased.

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Introduction

Because of insufficient production of high quality forage sources, cereal straws are the major roughage sources for dairy cows in small dairy farms. Cereal straws have low nutritive value with their lower nitrogen and energy content and digestibility values. Therefore, straws are unable to support high production level of dairy cows. Protein and starch supplementation could stimulate the microbial growth on the fibrous carbohydrates when low-quality roughage are substituted majority of the feed in diet (Souza et al., 2010; Piao et al., 2012; Khandaker et al., 2012). Beside, synchronization of protein and fermentable carbohydrates in rumen could also improve the efficient use of dietary N (Law et al., 2009) and could result in minimized nitrogen excretion (Nadeau et al., 2007). This suggests that feeding a concentrate containing higher level of nitrogen and energy that suggested values can potentially be useful when cereal straws are the major roughage in total mixed ration (TMR) (Chanjula et al., 2004; Wanapat, 2009). In this feeding scheme (low level of roughage), low quality roughage may serve to supply enough fiber to maintain functions of rumen by promoting saliva production as low quality roughage is generally higher effective NDF values (Sarnklong et al., 2010).

Although there have been several studies about effects of different levels of dietary starch and protein on performance of dairy cows, data on TMR containing high

concentrate diets are not sufficient. Therefore, the experiment was conducted to evaluate lactation performance in response to increasing dietary starch and protein levels when TMR is consisted of 70:30 concentrate to wheat straw.

Material and Methods

Animals, Treatments, and Feeding

Twenty eight Holstein cows were used in the study. At the beginning of the study, cows had 526.2 ± 54.3 body weight, 2.83 ± 0.31 body condition score, 41 ± 31.5 days in milk (DIM) and produced 30.4 ± 3.49 kg/d milk.

A completely randomized design with a 2×2 factorial arrangement was used in the study. The treatments were two levels of starch (14% and 22%) and protein (15% and 18%). The study lasted 6 w with 2 w adaptation and 4 w data collection periods.

Cows were housed in individual stalls with free access to water and feed. Ingredients and chemical composition of the diets are presented in Table 1. The proportions (on a dry matter basis) of roughage and concentrate feed in TMR were 30:70. Chopped wheat straw (1.5-2 cm) was used for roughage source. All cows were fed twice daily to receive 5%-10% refusals.

Sampling and Measurements

The refusals were collected, weighted daily before morning feeding. The wheat straw and concentrate samples were milled through a 1 mm screen (ZM-200, Retsch, United Kingdom), dried at 105°C for 4 h to determine dry matter content and ashed at 550°C for 4 h in a muffle furnace (Nabertherm, Bremen, Germany) (AOAC, 2000). The crude protein (CP) content was determined (AOAC, 2000) as N x 6.25 using the Kjeltac 2300 instrument (Tecator, FOSS, Denmark). Ether Extract (EE) content was measured by a standard ether extraction method (AOAC 2000). Neutral detergent fiber (NDF) by using heat stable α-amylase and Na-sulfite and acid detergent fiber (ADF) were determined using an Ankom fiber Analyzer (Ankom® Tech. Corp., Fairport, NY, USA) without correcting for residual ash (Van Soest et al., 1991). Starch analysis was performed according to AOAC (2000).

The body weight (BW) and body condition score (BCS) were measured (Wildman et al., 1982) on two consecutive days at the beginning and end of each trial. Cows were milked twice daily at 0500 h and 1700 h, and milk yield was recorded at each milking for individual cows. Individual milk samples were taken for milk composition (total solids, fat, protein, lactose, casein, and urea-N (MUN) twice weekly from 2 consecutive milking

(a.m. and p.m.). Milk samples from morning and evening analyzed separately using an infrared milk analyzer (Milkoscan FT 120, FOSS Electric, Hillerød, Denmark). The daily N intake was estimated from dry matter intake (DMI) and N content of the diet. Milk N Yield was calculated by multiplying milk yield by proportion of N. Efficiency of conversion of feed intake to milk was computed for each cow over the data collection period by dividing fat corrected milk (FCM) yield by DMI.

Statistical Analysis

All daily data were averaged to weekly means. Descriptive statistical analysis revealed that DMI and fat corrected milk were not normally distributed. Therefore, these parameters were logarithmically transformed prior to analyses. The transformed data were used to calculate P values while least squares means and standard errors in Table are not log-transformed.

Data were analysed as a repeated measures using the MIXED procedure of SAS (2000). The covariance structure was autoregressive order 1 and degrees of freedom were adjusted by the Kenward–Rogers method (Littell et al., 2000). Treatment differences were considered significant if P<0.05 and as a trend for 0.05≤P ≤0.10. All data are reported as least squares means with pooled standard errors (SEM).

Table 1 Ingredient and chemical compositions (DM basis) of the diets

Starch level, %	14		22	
Protein level, %	16	18	16	18
Ingredients, %				
Wheat straw	30.0	30.0	30.0	30.0
Barley grain	11.0	11.0	11.0	11.1
Corn grain	3.5	3.5	3.5	3.5
Wheat middling	1.8	20.7	4.2	21.0
Wheat bran	13.1	0.9	4.9	-
DDGS ^a	21.3	11.4	18.8	5.0
Sunflower meal	12.5	14.1	14.1	10.4
Soybean meal, 44% CP	-	1.7	6.8	12.6
Limestone	2.7	2.4	2.6	2.3
Salt	0.4	0.4	0.4	0.4
Molasses	3.6	3.6	3.6	3.6
Dicalcium phosphate	-	0.2	-	-
Vitamin-mineral premix ^b	0.1	0.1	0.1	0.1
Chemical composition ^c				
DM, %	90.1	89.7	89.7	89.8
CP, %	15.0	17.8	15.1	17.1
RUP, % of CP	38.1	36.5	34.7	33.3
Starch, %	14.4	14.2	21.6	21.5
NDF, %	46.8	44.3	45.0	41.8
ADF, %	25.4	25.4	24.8	24.5
EE, %	4.0	3.8	3.6	3.1
Ash, %	8.7	8.5	8.3	8.3
NEL, Mcal/kg	1.44	1.46	1.42	1.45

^a DDGS= Dried Distillers Grains with Solubles, ^b Provided per kilogram of DM: 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E, ^c DM= Dry Matter, CP= Crude Protein, NDF= Neutral Detergent Fiber, ADF= Acid Detergent Fiber, RUP= Rumen Undegradable Protein, EE= Ether Extract. Rumen undegradable protein, and NEL are calculated as NRC 2001

Results and Discussion

Dietary protein and starch levels in the diets did not affect DMI, 4% FCM, and fat yield (Table 2). Milk yield was not affected by starch level ($P>0.10$). Milk protein yield tended ($P<0.10$) to increase with increasing starch level. Increasing dietary starch level increased milk protein ($P<0.05$) and casein ($P<0.01$) concentrations. Milk urea concentration tended ($P<0.10$) to decrease as dietary starch level increased.

Increasing protein level in the diet allowed cows to consume more N ($P<0.01$). Also, increasing protein level increased milk yield ($P<0.05$), and milk protein yield ($P<0.01$). The concentration of MUN increased ($P<0.01$) by increasing protein level in diet. Interactions between dietary protein and starch level were observed for milk protein ($P<0.01$), and casein ($P<0.01$) levels. Increasing dietary CP level increased milk protein percentage by feeding 14% starch level, but similar effect was not observed by feeding 22% starch level. Similarly, increasing dietary CP level increased milk casein percentage by feeding 14% starch level, but decreased milk casein by feeding 22% starch level. Feed efficiencies (4% FCM/DMI) did not change by treatments. Nitrogen efficiency (milk N / N intake) was lower for high dietary protein ($P<0.01$). As dietary protein level increased, N efficiency decreased from 26% to 23%.

Milk yield increased by dietary protein level, which is in agreement with Wattiaux and Karg (2004) who used early lactation dairy cattle (as in the present study). Supplying additional nitrogenous compounds to animals

fed low-quality forage stimulates the growth of microbes in the rumen (Russell 2002). Increased microbial activity improves the energy status of the animal via increased volatile fatty acid (VFA) production and improves the protein status by increasing microbial N flow to the duodenum (Wickersham et al., 2008). The starch level in the present study was relatively lower than suggested starch level for dairy diets (about 27%) (Staples 2007), therefore increase in protein level may improve microbial growth and supply more nutrient for milk synthesis such as in our case. On the other hand, milk yield in some studies did not change when dietary protein increased from 17 to 19% (Davidson et al., 2003; Broderick, 2003; Groff and Wu, 2005).

Dietary starch level had no effect on intake and yield. The effect of dietary starch level on lactation performance is not consistent in the literature. For example, dietary starch content did not affect milk yield in some trials (Dann et al., 2008; Gencoglu et al., 2010; Dyck et al., 2011) whereas a negative effect of starch on production performance was observed when the concentration of rumen-degradable starch exceed 20% (Weiss et al., 2009). Optimum starch level for dairy diets is not defined, however it is suggested to be 24-30% (Kaiser and Shaver et al., 2006; Staples, 2007). Staples (2007) suggested at least 21% starch may be acceptable for dairy diets based on meta-analysis of 14 trials. This could partly explain why relatively low starch levels (14-22%) in the present study did not produce enough response for milk production.

Table 2 Effects of dietary starch and protein levels on intake, yield, milk composition and efficiency of dairy cows in the study

Starch level, %	14		22		SEM	Effect ^a		
	16	18	16	18		S	P	S x P
Protein level, %								
Intake and yield, kg/d								
DMI ^b	20.4	21.1	20.7	21.4	0.46	0.476	0.156	0.972
N Intake	0.49	0.60	0.50	0.58	0.01	0.811	<0.01	0.284
Milk yield	28.9	29.3	28.4	30.9	0.65	0.448	0.032	0.136
4% FCM ^b	26.3	27.2	25.3	26.9	1.11	0.560	0.272	0.748
Fat yield	0.98	1.03	0.93	0.97	0.06	0.375	0.493	0.972
Protein yield	0.83	0.90	0.87	0.94	0.02	0.081	<0.01	0.960
BW change, kg	-29.7	-27.4	-21.0	-18.0	5.92	0.141	0.657	0.957
Milk composition, %								
Total solids	11.9	12.2	12.0	11.7	0.20	0.440	0.004	0.145
Fat	3.38	3.50	3.24	3.11	0.20	0.185	0.906	0.578
Protein	2.87	3.06	3.09	3.05	0.04	0.014	0.057	<0.01
Lactose	4.67	4.71	4.82	4.68	0.04	0.171	0.249	0.038
Casein	2.30	2.47	2.51	2.44	0.03	<0.01	0.120	<0.01
MUN ^b , mg/dL	24.8	27.5	23.4	27.0	0.54	0.09	<0.01	0.419
Efficiency, yield/intake								
%4 FCM / DMI	1.30	1.30	1.22	1.27	0.06	0.363	0.650	0.702
Milk N / N intake ^c	0.254	0.224	0.261	0.242	0.007	0.134	<0.01	0.528

^a S= Starch level effect, P= Protein level effect, P x S= Interaction effect of starch and protein levels, ^b DMI= Dry Matter Intake, FCM= Fat Corrected Milk, MUN= Milk Urea Nitrogen, ^c Milk N= [(Milk production (kg/d) x milk protein (%)) / 6.38] and N intake= DMI x N content of total mixed ration

Milk urea nitrogen was significantly affected by dietary protein. Positive relationships between dietary rumen degradable protein (RDP) and MUN have been previously reported (Broderick 2003). Schroeder and Titgemeyer (2008) reported that efficiency of protein utilization in the rumen depended on energy supplementation. Increasing dietary starch level usually decreases MUN (Weiss et al., 2009). Simultaneous supplementation with nitrogen and starch promotes higher nitrogen assimilation in the rumen, which decreases MUN level and consequently reduces nitrogen loss in the body fluids (Souza et al., 2010). Also, same approach may be used to explain protein and starch interaction on protein, casein, and lactose concentrations of milk in the present study. Increasing dietary protein in the low starch diet may improve digestibility, microbial growth and supply extra glucogenic nutrient for lactose synthesis and provide higher amino acid to mammary gland (Broderick, 2003).

N efficiency was increased in response to decreased N intake. It was reported that increased N efficiency resulted from a better use of amino acids and/or from a combination with increased energy supply (Charbonneau et al., 2006). The higher efficiency of N utilization showed that the N consumed was better used in the rumen and/or for milk production when dietary protein level was low (Broderick 2003, Cabrita et al., 2007). While maintaining milk production, lowering crude protein level may decrease the excretion of N to the environment and lower ammonia emissions (Chase et al., 2012).

Conclusions

The results showed that the cows fed TMR containing low quality roughage, such as wheat straw, responded better when dietary protein increased 18% (DM basis). Also, dietary protein and starch levels affected milk yield as independently, and MUN level is effected by dietary protein level.

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