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Effects of Different Levels of Effective Fiber in Close-up Cows Diets on Intake and Chewing Activity and Subsequent Lactation Performance in Holstein Dairy Cows

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Abstract: The 18 multiparous close-up Holstein dairy cows averaging BW 791.1 (SD = 44.72) in 23 day (SD = 6) before expected calving date were assigned in a completely randomized design (n = 6) to study the effects of different levels of effective fiber on chewing activity, intake and nutrients digestibility in close-up and performance in the subsequent lactation. The effective fiber was considered as high 30.40, moderate 27.38 and low 24.61% for treatments H, M and L, respectively. All the cows were fed the same diet after parturition until 20 days in milk. Total chewing activity negatively affected by decreasing the effective fiber content in the diet. Total rumination time was 473, 443 and 408 min day^{-1} for treatments H, M and L, respectively ($p<0.03$). Pre-calving DMI was 12.07, 14.29 and 12.89 kg day^{-1}, ($p<0.0007$) and post-calving DMI was 17.41, 19.03 and 18.72 for treatments H, M and L, respectively ($p<0.0001$). Milk yield ($p<0.09$) and milk protein yield ($p<0.07$) were tended to rise with decreasing the effective fiber but there was no effect on milk fat yield among treatments. The results showed that decreasing the effective fiber in close-up diets increased DMI in both pre and post calving. It was concluded that although the strategy of decreasing effective fiber content of the close-up diets increases DMI and improved energy balance in dairy cows, the severe decrease of effective fiber in close-up diets could negatively affect rumination time that possibly could have negative effects on cow health.

Key words: Effective fiber, dry matter intake, transition period, holstein dairy cows, rumination, post-calving

INTRODUCTION

Nutritional management and metabolism of the transition dairy cow have been extensively studied in recent years (Overton and Waldron, 2004; Doepel *et al*., 2009). Dry Matter Intake (DMI) is one of the most important concerning topics in transition cow nutrition program. The DMI is decreased about 30% pre calving and also it will be 20% less after calving rather than the peak of milk production time (Friggens *et al*., 2007). Because of the high demands of nutrients after calving for milk production, lower DMI could not cover the requirements; therefore reserved fats are mobilized to liver to supply the energy and in this situation the cows are susceptible to develop fatty liver (Doepel *et al*., 2009). One of the main goals of the close-up diets is to maximize DMI in the subsequent lactation period to support high energy demand for early lactation (Doepel *et al*. 2009). Moreover, increasing DMI pre parturient could be useful tool for decreasing the metabolic disorders in dairy cows (Overton and Waldron, 2004). The fiber content of the feed is one of the most important factors related to intake in dairy cows (Grummer *et al*., 2004). Feeding the dairy cows with 30, 42 and 54% of NDF, Grummer *et al*. (2004) concluded that DMI of the cows will be 2.03, 1.68 and 1.64% of body weight respectively. Physically effective Neutral Detergent Fiber (peNDF) is a part of NDF which stimulates the chewing activity (Mertens, 1997). From the other hand decreasing the fiber content of the diet caused to make lower ruminal pH which damages the surface of rumen wall causing the ulceration of the epithelium (Krause and Otzel, 2006).

Once the ruminal epithelium is damaged, bacteria enter portal circulation causing the liver abscesses and an inflammatory response (Gozho *et al*., 2005) which could have negative effects in transitional dairy cows (Overton and Waldron, 2004). Although, there are recommendations of Effective Neutral Detergent Fiber (eNDF) and peNDF for high producing dairy cows, the requirements of these parameters have not been considered extensively around calving. In this study the effects of different levels of effective fiber on pre calving

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DMI, blood metabolites, chewing activity, nutrients digestibility and also on post calving blood metabolites and performance of Holstein dairy cows were investigated.

MATERIALS AND METHODS

Cows, management and diets: In the present study 18 multiparous close-up Holstein dairy cows averaging BW 791.1 (SD = 44.72) in 23 days (SD = 6) before expected calving date at the beginning of the study were assigned in a completely randomized design (n = 6). Three isonitrogenous diets differing in effective fiber contents were formulated with the NRC (2001) dairy ration formulation software. The effective fiber was high 30.40, moderate 27.38 and low 24.61% which considered as treatments H, M and L, respectively. Decreasing the effective fiber was gained by replacing the forage sources (alfalfa hay and corn silage) by barely grain. Feed ingredients and composition of three different diets are shown in Table 1. The cows were fed Total Mixed Ration (TMR) in grouping system at 08:00 and 16:00. Orts were collected and weights recorded once daily before morning feeding and the feeding rate were adjusted daily to yield orts of about 5-10% intake. The intake of the individuals was calculated through the total intake of each group divided by the number of the cows in group (6 cows per each group). The diet for all three groups of the cows was similar after calving until 20 days in milk. After calving the cows were fed TMR at 08:00 and 16:00 and calculating the individual DMI was same as the close-up period. Post calving diets also was formulated with NRC (2001) and based on DM% was contained 40.3% NFC, 31.2% NDF, 10.3% RDP, 1.70 Mcal kg^{-1} net energy for lactation (NE_l) and 17.2% CP and was consisting of 453.3 g kg^{-1} forage (DM basis), comprised of 323.3 g kg^{-1} alfalfa hay and 130 g kg^{-1} corn silage. The composition of the concentrate (DM basis) was as follows: 300 g kg^{-1} barley grain, 20.8 g kg^{-1} corn grain, 25 g kg^{-1} cottonseed, 50 g kg^{-1} soybean meal, 18 g kg^{-1} fish meal, 40 g kg^{-1} canola meal, 16 g kg^{-1} tallow, 41.1 g kg^{-1} molasses, 3.9 g kg^{-1} salt, 12.6 g kg^{-1} sodium bicarbonate, 5.6 g kg^{-1} calcium carbonate, 1.1 g kg^{-1} oxide magnesium and 12.6 g kg^{-1} mineral and vitamin mixture. The cows were milked three times daily by 8 h intervals starting from 06:00. The cows had free access to water and salt block.

Experimental procedures and chemical analyses: The DM of the corn silage and alfalfa composites was determined by drying at 60°C for 48 h (AOAC, 1990). Intake of DM was computed based on the 60°C DM determinations for TMR and orts. After drying, ingredients and TMR were ground through a 1 mm screen (Wiley mill, Arthur H. Thomas, Philadelphia, PA) and total composites were prepared by mixing equal DM. Composite samples were analyzed for total nitrogen, DM, ash and organic matter (AOAC, 1990), sequentially for NDF and ADF (Van Soest *et al*., 1991). Milk was sampled daily at three consecutive milking times until 20 days after calving and analyzed for fat, protein, lactose, SNF (Combi-Foss 5000, Foss Electric, Hillerød, Denmark). Grab fecal samples were collected a week before expected calving date and the fecal composite of each cow was oven-dried at 55 for 72 h and then ground through a 1 mm sieve. After analyzing the fecal samples for nutrients, total tract apparent digestibility of nutrients was determined by using acid insoluble ash as an internal marker (Van Keulen and Young, 1977). The BW changes were measured at the 1st day, just after calving and the last day of experiment. At the same days for body weight recording, body condition score was measured based on the Wildman *et al*. (1982). The method of Penn State Particle Separator (PSPS) developed by Penn State University was used for particle size separation and measurement of the distribution of particle size in different sieves. Chewing activity (eating plus rumination) was determined for a period of 48 h with 10 min intervals (Yang and Beauchemin, 2006). Blood samples were collected in a week before expected calving on 3 h after

Table 1: Ingredients and chemical composition of pre calving experimental diets

Items	Treatments[1] H	M	L
Ingredients (DM%)			
Alfalfa hay (Chopped)	32.00	28.00	24.00
Corn silage	32.00	28.00	24.00
Barely (ground)	2.00	10.00	18.00
Corn (ground)	7.00	7.00	7.00
Wheat (ground)	3.00	3.00	3.00
Wheat bran	3.00	3.00	3.00
Cottonseed meal	5.50	5.50	5.50
Soybean meal	11.00	11.00	11.00
Tallow	0.30	0.30	0.30
Glycolan	2.40	2.50	2.50
Vitamin supplement[2]	0.50	0.50	0.50
Mineral supplement[2]	0.51	0.51	0.51
Anionic supplement	0.70	0.70	0.70
Chemical composition			
CP (DM%)	14.50	14.50	14.50
RDP (CP%)	73.10	74.40	75.80
NE_L (Mcal kg^{-1})	1.56	1.61	1.65
NDF (DM%)	37.70	35.50	33.40
Forage NDF (DM%)	30.50	26.70	22.90
Effective NDF (DM%)	30.40	27.38	24.61
ADF (DM%)	25.70	23.60	21.50
NFC (DM%)	40.00	42.40	44.80
Ca (DM%)	0.60	0.60	0.59
P (DM%)	0.40	0.40	0.40

[1]The effective fiber contents of the diets were 30.40, 27.38 and 24.61% for H, M and L treatments, respectively, [2] Composition: 1.6% Mn, 1.8% Zn, 0.85% Fe, 0.40% Cu, 0.03% I, 0.03% Co, 0.01% Se. 5,000,000 IU kg^{-1} of vitamin A, 860,000 IU kg^{-1} of vitamin D, 5,500 IU kg^{-1} of vitamin E

morning feeding and a week after calving at the same time from coccygeal vein of the cows. Blood samples were heparinized and held at 2°C for about 6 h. After being held samples were centrifuged (3,000×g 4°C, 20 min) and the plasma stored at -20°C for later analysis. After thawing, the blood glucose, Nonesterified Fatty Acids (NEFA) and β-Hydroxybutyric Acid (BHBA) measured with commercial kits.

Statistical analysis: Data were analyzed using Proc Mixed in SAS Institute (2000). The following model was fitted the variables:

$$Y_{ij} = \mu + T_i + Z_j + ZT_{ij} + \varepsilon_{ij}$$

Where:

y_{ij} = The dependent variable
μ = The overall mean
T_i = The effect of treatment i (treatments H, M and L)
Z_j = The effect of time j
Zt_{ij} = The interaction between time j and treatment i
ϵ_{ij} = The residual error

Differences between least squares means were considered significant at $p<0.05$ and differences were considered to indicate a trend toward significance at $0.05<p<0.10$.

RESULTS AND DISCUSSION

DMI and nutrients digestibility: Data for pre and post calving DMI and pre calving nutrients digestibility shown in Table 2. The DMI in both pre and post calving were significantly affected with treatments ($p<0.01$). The trend of DMI changes pre and post calving was similar to each other. Mashek and Beede (2001) showed that pre and post calving DMI has a high correlation. Decreasing the effective fiber in treatment M increased DMI in both pre and post calving. Greater decrease in effective fiber in treatment L, decreased DMI compared with treatment Yang and Beauchemin (2006) clarified that increasing the consumption of Physically Effective Neutral Detergent Fiber (peNDF) and Effective Neutral Detergent Fiber (eNDF) decreases the intake of dairy cows. The high ratio of forage in diets cause to rumen fill effect and consequently slow passage rate will decrease DMI in dairy cows (Allen, 2000). From the other hand, treatment L has the lowest forage content which was expected to have the highest DMI among treatments but because of higher consumption of barely grain it has potential to produce more propionate in rumen and therefore more propionate could have negative effect on intake of DM (Allen, 2000). Except than NDF digestibility which tended to be decreased among treatments ($p<0.09$), digestibility of nutrients did not show any effect by

Table 2: Least square means for pre calving DMI and nutrients digestibility and post calving DMI of dairy cows fed different levels of effective fiber content

Items	Treatments[1] H	M	L	SE	p-value
Pre calving					
DMI (kg day^{-1})	12.07[b]	14.29[a]	12.89[b]	0.32	0.0007
Nutrients digestibility (%)					
DM	64.20	63.00	62.90	0.73	0.1500
CP	62.20	63.10	63.60	0.91	0.5000
NDF	48.40	46.00	45.20	1.04	0.0900
Post calving					
DMI (kg day^{-1})	17.41[b]	19.03[a]	18.72[ab]	0.43	0.0001

[a,b,c]Least squares means within the same row without a common superscript differ ($p<0.05$), [1]The effective fiber contents of the diets were 30.40, 27.38 and 24.61% for H, M and L treatments, respectively

different effective fiber consumption. Higher DMI increases passage rate which could decrease digestibility of nutrients (Mertens, 2002). Therefore numerical decrease of NDF digestibility in treatment L compared with treatments H and M probably is related to probable higher passage rate that is caused by higher DMI.

Particle size distribution and chewing activity: Data related to particle size distribution and chewing activity are given in Table 3. As the expectation, by replacing the forage source by barely grain, peNDF was decreased among treatments. Treatment H was contained the highest amount of large particle size (i.e., >8 mm and >19 mm). By replacing the forages by barely physical coefficient of diets was decreased in both treatments M and L compared with treatment H. Total eating time (min day^{-1}) decreased by decreasing the effective fiber content ($p<0.03$).

Moreover total eating time based on kg DMI, kg NDF intake and NFC intake also were decreased by in treatment Phillips (2002) proposed that eating 1 kg of concentrates takes time about 3-4 vs. 30 min needed for 1 kg of forage.

Total rumination time was decreased in treatment L. As Poppi *et al.* (1985) stated that the particles which are longer than 1.18 mm has slower passage rate through rumen and they had to be change to smaller particles via rumination. Based on this, the rumination time was higher in treatment H compared with treatments M and L. Beauchemin (2007) revealed that eating time in a dairy cow is about 2-6 h day^{-1} and for rumination is 3-9 h day^{-1}, therefore total time of chewing (eating plus rumination) will be about 14 h day^{-1}.

The results of the present study show that decreasing the effective fiber content of the diets in close-up diets decreased the chewing time. Probably the severe decrease of this parameter could negatively affect the cow health around calving. It is notable that lower rumination time also could be as a candidate for lower NDF digestibility reasons. Beauchemin (2007) clarified

Table 3: Least square means for particle size distribution based on PSPS system and chewing activity of dairy cows fed different levels of effective fiber content

Items	Treatments H	M	L	SE	p-value
Sieve (mm)					
>19	11.90^{a}	8.30^{b}	3.10^{c}	0.47	0.0001
8-19	42.30^{a}	29.60^{b}	19.20^{c}	1.25	0.0001
1.18-8	34.10^{c}	42.70^{b}	53.10^{a}	1.46	0.0001
<1.18	11.60^{b}	19.30^{ab}	24.60^{a}	2.11	0.0050
Physically effective fiber (%)	33.30^{a}	28.60^{b}	25.10^{c}	0.73	0.0010
Physical effective coefficient	0.88^{a}	0.80^{ab}	0.74^{b}	0.02	0.0400
Eating activity					
min day^{-1}	285.00^{a}	266.60^{b}	226.70^{c}	14.38	0.0300
min kg^{-1} DMI	23.61^{a}	18.97^{ab}	16.31^{b}	1.11	0.0010
min kg^{-1} NDF intake	62.63^{a}	53.43^{ab}	48.82^{b}	3.08	0.0100
min kg^{-1} eNDF intake	78.34	69.27	66.26	3.96	0.0800
min kg^{-1} NFC intake	59.03^{a}	44.73^{b}	36.40^{c}	2.7	0.0001
Rumination activity					
min day^{-1}	473.30^{a}	443.30^{b}	408.40^{c}	1.18	0.0300
min kg^{-1} DMI	39.22^{a}	31.53^{ab}	29.38^{b}	1.18	0.0001
min kg^{-1} NDF intake	104.20^{a}	88.80^{b}	87.95^{c}	3.30	0.0050
min kg^{-1} eNDF intake	130.10^{a}	115.20^{ab}	119.40^{b}	4.29	0.0500
min kg^{-1} NFC intake	21.50^{a}	14.90^{b}	14.10^{b}	0.61	0.0001
Chewing activity					
min day^{-1}	758.30^{a}	710.10^{b}	635.80^{c}	15.71	0.0002
min kg^{-1} DMI	62.80^{a}	50.50^{b}	45.60^{b}	1.22	0.0001
min kg^{-1} NDF intake	166.60^{a}	142.20^{b}	136.70^{c}	3.38	0.0001
min kg^{-1} eNDF intake	208.40^{a}	184.40^{b}	185.60^{b}	4.38	0.0020
min kg^{-1} NFC intake	157.10^{a}	119.10^{b}	101.90^{c}	2.94	0.0001

^{a,b,c} Least squares means within the same row without a common superscript differ ($p<0.05$), [1] the effective fiber contents of the diets were 30.40, 27.38 and 24.61% for H, M and L treatments, respectively

Table 4: Least square means for plasma metabolites of dairy cows fed different levels of effective fiber content

Items	Treatments[1] H	M	L	SE	p-value
Pre calving					
Glucose (mg dL^{-1})	52.33^{b}	62.83^{ab}	68.10^{a}	3.30	0.01
NEFA (mmol L^{-1})	0.56	0.44	0.40	0.08	0.43
BHBA (mmol L^{-1})	0.47	0.43	0.42	0.06	0.86
Post calving					
Glucose (mg dL^{-1})	49.83^{b}	58.33^{b}	58.83^{a}	1.12	0.0001
NEFA (mmol L^{-1})	1.05	0.81	0.71	0.10	0.09
BHBA (mmol L^{-1})	1.14	0.93	0.80	0.11	0.10

^{a,b,c}Least squares means within the same row without a common superscript differ ($p<0.05$), [1]The effective fiber contents of the diets were 30.40, 27.38 and 24.61% for H, M and L treatments, respectively

that lower rumination time could negatively affect NDF digestibility through decreasing the rumen pH because cellulolytic ruminal bacteria have slower growth rate in lower ruminal pH becaused by lower rumination time.

Blood metabolites: Among the blood metabolites only glucose concentrations in both pre and post calving significantly affected by treatments (Table 4). The NEFA concentration in post calving samples tended to rise ($p<0.09$). The treatment with lower effective fiber expected to produce greater propionate in rumen and consequently propionate is a main precursor of glucose in dairy cows (Dewhurst *et al*., 2000). Therefore increase of glucose in treatments M and L compared to treatment H could be a result of higher non fiber carbohydrate consumption. Treatment H has the lowest DMI and it could be concluded that because of l ower DMI, lower energy is supplied in this treatment. Based on this reason, it could be resulted that because of lower energy supplied in treatment H, NEFA which is an indicator of energy balance in early lactating dairy cows had potential to be increased.

Table 5: Least square means for performance of dairy cows fed different levels of effective fiber content

Items	Treatments[1] H	M	L	SE	p-value
Milk yield (kg day^{-1})	28.40	31.10	29.83	0.85	0.09
Efficiency of DMI (DMI/milk yield)	0.61	0.61	0.62	0.01	0.93
4% FCM (kg day^{-1})	26.42	27.58	25.89	1.06	0.48
Milk fat (%)	3.53	3.29	3.13	0.22	0.42
Milk fat (kg day^{-1})	1.00	1.02	0.93	0.06	0.57
Milk protein (%)	2.93	3.13	3.19	0.14	0.43
Milk protein (kg d^{-1})	0.83	0.97	0.95	0.04	0.07
Lactose (%)	4.40	4.50	4.51	0.13	0.83
Lactose (kg day^{-1})	1.25	1.40	1.34	0.06	0.24
Solids non fat (%)	8.38	8.72	8.60	0.18	0.44
Solids non fat kg day^{-1}	2.38^{b}	2.70^{a}	2.56^{ab}	0.07	0.02
Body condition score changes	-0.63	-0.37	-0.41	0.08	0.41
Body weight changes (kg)	-111.60	0133.30	-106.30	21.20	0.17

^{a,b,c}Least squares means within the same row without a common superscript differ ($p<0.05$), [1]The effective fiber contents of the diets were 30.40, 27.38 and 24.61% for H, M and L treatments, respectively

Post calving performance: The data for post calving performance of dairy cows were shown in Table 5. There was a trend to increase for milk production among treatments by decreasing the effective fiber content

($p<0.09$). Not only greater DMI positively affected milk yield in treatments M and L but also higher capacity of absorption with lower forage fiber content could have positive effects on milk yield. As stated in NRC (2001), feeding fibrous diets before calving will decrease the rumen papillae growth and consequently the capacity of nutrients absorption negatively affect in the rumen. Therefore, it is probable that the cows in treatment H which fed high forage fiber content had the lowest capacity of nutrients absorption through rumen wall. Because the cows were fed with similar diets after calving, it is complicated to interpret the results of milk components in this study. Allen (1997) clarified that the milk fat did not respond to dietary changes in post calving time and body reserve mobilization make it complicated to interpret the effects of feed on milk components. In this study milk protein was tended to rise by increasing the effective fiber content in the diet ($p<0.07$). Although protein content of diets was similar, protein intake was higher for treatments N and L because of greater DMI in these treatments compared with the treatment H. Therefore greater protein intake caused to numerical increase of s protein content of milk.

From the other hand Huhtanen and Hristov (2009) recently showed that greater DMI could positively affect milk protein production probably via increasing microbial protein synthesis. Because of increase in milk protein content, the solids non fat affected significantly and increased with lower effective fiber consumption. Body weight changes and also body condition score changes of the cows did not show any significant difference among treatments. It seems that increased DMI caused to increase milk yield numerically and this difference was not effective enough to make a difference in body weights of the cows.

CONCLUSION

The results of the present study showed that decreasing effective fiber contents of dairy cows ration in close-up have positive effects on DMI in both pre and post calving times. Also milk yield was tended to rise in this study which clarifies the transitional effects of lower effective fiber contents of close-up diets on subsequent performance in dairy cows. Although, decreasing the effective fiber to 27.38% increased DMI, greater decrease of effective fiber to 24.61% tended to decrease fiber digestibility and dramatically decreased chewing activity that it is probable to have negative effects on dairy cow health.

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