Effects of Roughage Neutral Detergent Fiber on Dairy Performance under Tropical Conditions**

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ABSTRACT : Holstein × indigenous multiparous dairy cows were offered diets with increasing roughage neutral detergent fiber (NDF) contents to determine the effects on intake, milk yield and compositions. Roughage NDF contents were 15, 18, 21 and 24% dry matter (DM), and concentrate NDF content was 10% DM. Experimental treatments were isonitrogenous and isocaloric diets. Maximum and minimum temperature humidity index during the experimental period were 85.9 and 76, respectively. Intakes of DM, crude protein and net energy, 4% fat corrected milk, milk protein and average daily gain decreased with increasing roughage NDF contents ($p<0.05$). Intakes of ether extract ($p<0.01$) and dietary NDF ($p>0.05$) and milk fat ($p<0.01$) increased with increasing roughage NDF contents. The results support the conclusion that higher DM intake, optimal milk yield and compositions can be maintained with lower roughage NDF diets for dairy cows under tropical conditions. *(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 10 : 1400-1404)*

Key Words : Roughage, Neutral Detergent Fiber, Dairy, Performance, Tropical Conditions

INTRODUCTION

Reduction in feed intake is one of the major problems related to decreased productivity of dairy cows under tropical conditions. (Fuquay, 1981; Beede and Collier, 1986). Cows exposed to a 32.2°C environment used digestible energy with 35.4% less efficiency than those in an 18°C environment (McDowell et al., 1969). The ability to provide adequate energy to dairy cows under tropical conditions depends on moderate the balance between starch and NDF in the diets. Rate of digestion of starch is the major factor controlling the energy available for growth of rumen microbes (Hoover and Strokes, 1991) while providing precursors for milk synthesis. Too much coarse NDF in a diet reduces energy density, intake and productivity of dairy cows, whereas too little coarse NDF in a diet can alter rumen fermentation resulting in severe acidosis (Mertens, 1997).

Majority of roughage in tropical conditions is low in digestibility and nutrient contents (Leng and Brumby, 1986). A common practice in the dairy industry in Thailand is to reduce roughage contents in the diets in order to increase nutrient density while reducing fiber contents. A minimum of dietary NDF and proportion of roughage NDF are 25% DM and 75% dietary NDF, respectively, recommended by NRC (1988). Grant (1997) reported that the roughage NDF of 60% still provided sufficient effective fiber for production of fat corrected milk. However, the minimum dietary NDF of 25% and roughage NDF of 60% have not been reported in literature in dairy cows under tropical conditions.

MATERIALS AND METHODS

Eight Holstein × indigenous (93.75×6.25) multiparous dairy cows averaging 60±10 days in milk were randomly allocated to dietary treatments according to a double 4×4 Latin square design with 28-d periods.

Experimental treatments consisted of 15, 18, 21 and 24% DM as roughage neutral detergent fiber (NDF) and 10% DM as concentrate NDF, so that levels of dietary NDF were 25, 28, 31, and 34% DM. Total mixed rations (TMR) were isonitrogenous and isocaloric diets as shown in table 1. Paragrass hay was made from perennial paragrass. The paragrass was cut, chopped into 2-3 cm length and sun dried for TMR.

Experimental diets were offered ad-libitum at 06:00, 9:00, 13:00, 16:00 and 19:00 h and were sampled weekly and bulked for later analysis of chemical composition. Within the 28-d experimental periods, the first 4-d was regarded as a transitional period, following 10-d for an adaptation period and within the last 14-d, milk sampling was undertaken. Over the last 14-d, feed intake and milk yield were daily measured. Milk samples of 50 ml were collected at 3-d intervals at consecutive a.m. and p.m. milking in bottles containing 2-Bromo-2-nitro-1,3-propadiol and stored at 5°C for composition analysis. Cows were weighed once each week immediately following the a.m. milking prior to accessing feed and water. The trial was conducted during summer months from the end of February to the end of June. Ambient temperature and

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Table 1. Feed ingredients and chemical compositions of TMR containing different levels of roughage NDF

Item	Roughage NDF, %			
	15	18	21	24
Ingredients, %				
Soy bean meal	7.6	7.6	7.6	7.6
Cotton seed meal	16.0	14.5	14.3	14.3
Whole cotton seed	-	3.0	4.0	5.2
Tallow	-	0.8	1.8	3.0
Cassava chips	42.5	36.7	31.9	25.7
Molasses	5.6	4.2	2.9	2.0
Urea	1.2	1.1	1.0	0.9
Minerals + vitamins	2.7	2.7	2.7	2.7
$NaHCO_3$	0.8	0.8	0.8	0.8
Paragrass hay	23.6	28.3	33.0	37.8
Total	100	100	100	100
Chemical compositions				
Crude protein, %	16.09	15.97	16.00	16.14
Rumen undegradable protein, % CP*	27.40	29.40	28.30	28.90
Total NDF, %	24.90	27.77	30.56	33.81
Total non-fiber carbohydrates, %	48.99	45.20	41.47	37.79
Ether extract, %	1.58	2.69	4.06	5.46
Total digestible nutrients, %*	67.31	67.13	67.23	67.32
Net energy for lactation**, Mcal/kgDM	1.53	1.52	1.53	1.53

* Calculated RUP and TDN.

** NEL (Mcal/kgDM) =0.0245×TDN-0.12.

relative humidity were recorded before morning feeding with thermograph and hygrograph (Classella, London) located within the housing barn. The temperature humidity index (THI) was calculated following the equation; THI = td - (0.55-0.55 RH) (td-58), where td is the dry bulb temperature (°F) and RH is the relative humidity expressed as a decimal (NOAA, 1976).

Crude protein (CP), ether extract (EE), ash and DM contents of the experimental diets were determined according to the AOAC (1980). Neutral detergent fiber (NDF) and neutral detergent insoluble nitrogen (NDIN) were measured following the method of Van Soest and colleague (1991). Total non-fiber carbohydrates (TNFC) is calculated following the equation; TNFC = 100 - CP - EE - (NDF - NDIN) - ash. Milk compositions were measured with MilkoScan (Foss Electric, Denmark). Statistical analysis was carried out by SAS (1989) and the difference between treatments means was measured by Least Squared Means.

RESULTS

The nutrient composition of experimental diets is shown in table 1. With increasing roughage NDF contents, dietary NDF and EE contents increased whereas dietary TNFC content decreased. However, values of analyzed CP, calculated RUP and calculated net energy of the experimental diets were similar.

Means for environmental conditions during the experimental periods are shown in table 2. Daytime temperature was much higher than the nighttime averaging 36.8°C and 24.8°C, while daytime relative humidity was much lower than the nighttime averaging 44.2% and 93.7%. The combination of high environmental temperature and relative humidity led to extremely high THI averaging 85.9 during the daytime and 76.0 during the nighttime.

The live weight change and nutrient intake of dairy cows fed TMR containing different roughage NDF contents are shown in table 3. As roughage NDF contents in the diets increased, average daily gain ($p<0.05$), and intakes of DM ($p<0.05$), net energy ($p<0.05$), CP ($p<0.05$) and TNFC ($p<0.01$) decreased. However, intake of EE increased ($p<0.01$) with increasing roughage NDF contents in the diets and intake of dietary NDF tended to increase ($p>0.05$).

Milk yield and compositions and conversion of DMI to milk of dairy cows fed TMR containing different roughage NDF contents are shown in table 4. Milk protein, solids-not-fat, milk yield and 4% fat corrected milk decreased with increasing roughage NDF contents in the diet ($p<0.05$). Milk fat increased with increasing roughage NDF contents in the diet ($p<0.05$). However, conversions of DMI to milk and 4% fat corrected milk were similar for all cows ($p>0.05$).

DISCUSSION

Formulation of diets to meet fiber and energy requirements for dairy cows needs to moderate the balance between starch and NDF contents in order to maximizing microbial yields while minimizing the incidence of ruminal acidosis (Varga et al., 1998). In this study, Roughage NDF contents were from 15 to 24% DM and concentrate NDF content was 10% DM, so that dietary NDF were from 25 to 34% DM. The lowest content of dietary NDF was similar to the NRC (1988) recommendation but the proportion of roughage NDF was 60% of dietary NDF which is well below the NRC (1988) recommendation of 75%. The lower

Table 2. Means for environmental conditions during the experimental period

Item	Value
Maximum temperature, °C	36.8±2.5
Minimum temperature, °C	24.8±1.7
Maximum relative humidity, %	93.7±1.9
Minimum relative humidity, %	44.2±5.8
Maximum temperature humidity index	85.9±1.0
Minimum temperature humidity index	76.0±1.2

Table 3. Liveweight change and nutrient intake in dairy cows fed TMR containing different levels of roughage NDF

Item	Roughage NDF,%				S.E.
	15	18	21	24	
Nutrient intake					
Dry matter, kg/d	15.9[a]	14.5[a,b]	13.6[b]	13.0[b]	1.03
Dry matter, %BW	3.42[a]	3.24[a,b]	3.08[b]	2.91[b]	0.19
Crude protein, kg/d	2.56[a]	2.32[a,b]	2.12[b]	2.10[b]	0.16
Ether extract, kg/d	0.25[4]	0.39[3]	0.55[2]	0.71[1]	0.27
Dietary neutral detergent fiber, kg/d	3.96	4.03	4.16	4.40	0.60
Non-structural carbohydrate, kg/d	7.79[1]	6.55[2]	5.64[3]	4.91[4]	0.30
Total digestible nutrient, kg/d	10.70[a]	9.73[a,b]	9.14[b]	8.75[b]	0.69
Net energy for lactation, Mcal/d	24.33[a]	22.04[a,b]	20.81[b]	19.89[b]	3.21
Live weight change					
Beginning weight, kg	455.5	452.3	441.8	451.0	21.6
Finishing weight, kg	476.0	442.3	440.0	441.3	8.0
Average daily gain, g	244[a]	171[a]	-86[b]	-263[c]	147.3

[a b] and [1,2] Mean within a row without a common superscript letter and number differ ($p<0.05$) and ($p<0.01$).

proportion of roughage NDF is confirmed to have sufficient effective fiber for production of fat corrected milk (Grant, 1997). The highest content of dietary NDF in this study was 34% DM which is slightly below the level having negative effect on DMI and NDF digestibility (Firkins, 1997). However, an increase in contents of roughage NDF in a diet will decrease nutrients density (Merten, 1997). Energy contents in this study were adjusted by increasing contents of whole cotton seed and tallow with increasing roughage NDF contents, while CP contents were adjusted using urea following soluble fractions of TNFC (Kanjanapruthipong et al., 2001). Therefore dietary treatments were isonitrogenous and isocaloric diets.

Johnson (1987) reported various temperature and humidity combinations that have equal effect on Holstein productivity. The minimum THI of 76 reported in the presented study exceeded the upper critical point of 72 for optimal productivity while the maximum THI of 85.9 exceeded the lower range of danger zone for survival of the animal. These environmental conditions indicate the extremely stressful conditions to dairy cows under this experimental condition.

In general, heat stress reduces feed intake (Fuquay, 1981; Beede and Collier, 1986), particularly reducing intake of roughage before concentrate (Coppock and West, 1986). As contents of crude fiber (Breidenstein et al., 1960), ADF (Cummins, 1992) and NDF (West et al., 1999) are increased, DMI of dairy cows in heat stress conditions decreases. A similar result was also observed as shown in table 3. This behavior is considered an adaptive response of dairy cows to reduce heat production (Moose et al., 1969; McDowell at al., 1976).

An increasing dietary NDF content generally decreases nutrient density and DMI as mentioned above. However, effects of fiber contents on milk yield during hot weather reported in literature were not consistent. Milk yield of dairy cows during hot weather increases with decreasing dietary crude fiber (Breidenstein et al., 1960) and dietary ADF (Cummins, 1992). With increasing roughage NDF contents in this study, a similar result was also observed. West et al. (1999) reported that milk yield improved as roughage NDF contents in the diet increased. The explanation is that a slight acidosis was corrected with increasing fiber contents in the diet while improving ruminal efficiency and digestion. This correction, perhaps, partly improved by increasing substitution rates of hay for silage. However, higher fiber diets have a higher heat increment (Moose et al., 1969; McDowell et al., 1976). Although the magnitude of the heat increment is not large (Baldwin et al., 1985), the heat increment can seriously impair the efficiency of utilization of higher fiber diets as compared to lower fiber diets. This claim is supported by the finding that there was an increasing weight loss with increasing roughage NDF contents in the diets (West et al., 1999). A similar finding was reported in this study as shown in table 3.

Milk fat percentage is well correlated with contents of coarse NDF in the diets (Merten, 1997). Higher fiber diets produce higher ratios of acetate to propionate in the rumen (Schwartz and Gilchrist, 1975). However, the partial efficiencies for acetate and dietary fat conversions to milk fat are 70 to 75% and 94 to 97%, respectively (Baldwin and Smith, 1979). An increase in milk fat contents reported in this study was likely derived from higher intakes of NDF and EE as shown in table 4.

It is likely that decreased mammary blood flow (Lough et al., 1990) and concentrations of blood nutrients (McGuire et al., 1989) may be due to the reduction in feed intake as well as thermal stress *per se*. The amount of feed intake influences the rate of microbial cell synthesis in the rumen

Table 4. Effects of increasing roughage NDF contents on milk yield and compositions and conversion of feed to milk

Item	Roughage NDF				S.E
	15	18	21	24	
Milk fat					
- %	3.71 [b]	3.90 [a,b]	4.05 [a]	4.10 [a]	0.05
- kg/d	0.640	0.651	0.640	0.626	0.00
Milk protein					
- %	3.27 [a]	3.14 [a,b]	3.12 [a,b]	3.07 [b]	0.11
- kg/d	0.564 [1]	0.524 [1,2]	0.494 [2,3]	0.469 [3]	0.01
Lactose					
- %	4.95	4.94	4.81	4.85	0.22
- kg/d	0.853 [a]	0.824 [a]	0.761 [b]	0.740 [b]	0.01
Minerals					
- %	0.73	0.73	0.73	0.71	0.09
- kg/d	0.126	0.122	0.115	0.108	0.01
Solids not fat					
- %	8.88 [1]	8.84 [1]	8.65 [2]	8.63 [2]	0.06
- kg/d	1.531 [1]	1.474 [1]	1.368 [2]	1.318 [2]	0.02
Total solid					
- %	12.64	12.73	12.70	12.73	0.26
- kg/d	2.179 [a]	2.124 [a,b]	2.008 [b,c]	1.943 [c]	0.07
Milk yield, kg/d	17.24 [a]	16.68 [a,b]	15.81 [b,c]	15.27 [c]	0.48
4% fat corrected milk, kg/d	16.49 [a]	16.43 [a]	15.93 [a,b]	15.50 [b]	0.51
Milk/DMI, kg/kg	1.08	1.15	1.16	1.16	1.17
4% FCM/DMI, kg/kg	1.04	1.13	1.17	1.17	1.19

[a,b] and [1,2] Means within a row without a common superscript letter and number differ ($p<0.05$) and ($p<0.01$)

(Chen et al., 1992) and of blood flow from the digestive tract (Huntington et al., 1981). In addition, net flux of α-amino N was reduced 35% by thermal stress compared with thermal comfort (McGuire et al., 1989). Decreased milk protein as well as milk yield with increasing roughage NDF contents as a result of decreased DMI reported in this study were likely due to lower nutrients available for mammary secretion.

Conversions of DMI to 4% fat corrected milk tended to improve with increasing roughage NDF contents while increasing weight losses (West et al., 1999). A similar result was observed in the study as shown in table 3. These results suggest that energy contents of the diets high in roughage NDF are not adequate and thus, dairy cows on high roughage NDF diets under tropical conditions can be in a severe negative energy balance.

Increasing roughage NDF contents decreased DMI, 4% corrected milk, milk protein, but increased weight losses. Optimal DMI, milk yield and compositions can be maintained with lower roughage NDF diets for dairy cows under tropical conditions, and thus low roughage NDF diets are recommended.

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