Formulating Diets on an Equal Forage Neutral Detergent Fiber from Various Sources of Silage for Dairy Cows in the Tropics

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ABSTRACT : An attempt was made to evaluate the effects of total mixed rations (TMR) containing 17.5% forage neutral detergent fiber (NDF) from paragrass, paragrass+cassava chips and corn silages on the performance of dairy cows in the tropics. Experimental dietary treatments contained a similar content of total NDF, total non-fiber carbohydrates, crude protein and energy. Maximum and minimum temperature humidity index during the experimental period were 79.1-80.6 and 66.8-68.6, respectively. Among silage sources, there were no differences ($p>0.05$) in concentrations of acetic and propionic acids and butyric acid was undetectable. Concentration of lactic acid was higher ($p<0.01$) in corn silage but its pH was lower ($p<0.01$) than in paragrass and paragrass+cassava silages. Dairy cows on TMR containing corn silage not only gained more weight (161 and 46 vs. -189 g/d) but also consumed more feed (18.47, 15.84 and 14.49 kg/d), and produced more milk (23.89, 22.03 and 20.83 kg/d), 4% fat corrected milk (25.47, 24.05 and 22.02 kg/d), solids-not-fat (1.99, 18.3 and 1.73 kg/d) and total solid (3.10, 2.85 and 2.64 kg/d) compared with those on TMR containing paragrass+cassava and paragrass silages, respectively ($p<0.01$). Dairy cows on TMR containing paragrass+cassava silage were better in these respects ($p<0.01$). These results suggest that in formulating diets on an equal NDF basis for different forage qualities, diets higher in forage quality can stimulate higher DMI for dairy cows in the tropics and thus improve productivity. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 5 : 660-664)***

Key Words : Forage NDF, Silage Source, Dairy Cows, Tropics

INTRODUCTION

The major limitation supporting performance of dairy cows in the tropical region is often daily intake (Fuquay, 1981; Beede and Collier, 1986). Higher dry matter intake (DMI), optimal milk yield and compositions can be maintained when lower forage NDF diets are formulated for dairy cows in the tropics (Kanjanapruthipong et al., 2001). However, there are relationships between forage NDF concentrations and characteristics of diets that limit intake, such as source of forage, ruminal fill, digestibility, rate and extent of NDF degradation, time spent on eating and ruminating, passage rate of digesta and forage to concentrate ratios (Smith et al., 1972; Varga et al., 1984; Teller et al., 1990; Poore et al., 1991; Wattiaux et al., 1991; Poor et al., 1993).

When low quality (high NDF and low digestibility) forages are substituted on an equal weight basis for high quality forages in diets for dairy cows, forage NDF can be excessive and result in reduced DMI (Shaver et al., 1988). When the substitution is on an equal NDF basis, lower quality forage diets usually have a lower ratio of forage to concentrate and that can adversely affect ruminal environment (Nocek and Russell, 1988). Better understanding of formulating diets on an equal NDF basis should enable more predictable utilization of forage in diets for dairy cows in the tropics, since the majority of forage in the tropical region is low in digestibility and nutrient contents (Leng and Brumby, 1986). The study reported here was conducted to evaluate the effects of diets formulated to contain similar contents of forage NDF from silage made of paragrass, paragrass+cassava chips and whole corn, on dairy performance in the tropics.

MATERIALS AND METHODS

Six Holstein×Indigenous (93.75×6.25%) multiparous dairy cows, 60±6 days in milk, were randomly allocated to dietary treatments according to a double 3×3 Latin square design with 28 d periods.

The experimental silages were made from perennial paragrass and whole corn at milky stage. Plants were harvested and chopped into 2-3 cm length. Ensiling was directly after chopping. For paragrass+cassava silage (PS), paragrass was mixed with cassava chips at the ratio of 84 : 16 as fresh basis so that total non-fiber carbohydrates (TNFC) and neutral detergent fiber (NDF) were close to the values of corn silage (Table 1). About 30kg of the forage was packed tightly in double layer plastic bags. Before tying the bags, air was removed by a vacuum pump. The experimental silages were sampled weekly for chemical analysis.

Total mixed rations (TMR) were formulated to contain 17.5% forage NDF and 28% total NDF. Similar levels of crude protein and energy were maintained as shown in Table 1. Total mixed rations were offered *ad libitum* in equal portions at 7.30 h and 17.30 h. The experimental diets

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Table 1. Chemical composition, organic acids and pH of silage

Item	Silage			S.E.
	PS*	PCS*	CS*	
Chemical composition, %				
Moisture	69.14	62.68	77.01	-
Crude protein	7.19	5.06	6.33	-
Ether extract	1.79	2.02	1.96	-
Total non-fiber carbohydrates	12.59	30.40	29.98	-
Neutral detergent fiber	65.86	55.83	55.79	-
Acid detergent fiber	40.82	29.40	34.42	-
Acid detergent lignin	7.01	4.14	3.65	-
Ash	14.17	6.89	5.94	-
Organic acids, g/100 g DM				
Lactic acid	3.21[1]	3.85[1]	9.77[2]	0.04
Acetic acid	2.50	2.70	1.58	0.21
Propionic acid	3.11	2.25	1.94	0.26
Butyric acid	nil	nil	nil	-
pH	4.53[1]	4.39[1]	3.93[2]	0.43

* PS-Paragrass silage; PCS-Paragrass+cassava silage; CS-Corn silage

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

were sampled weekly and bulked for later chemical analysis. Within the 28 d experimental periods, the first 4 d was regarded as a transitional period, the following 10 d as 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

Table 2. Ingredients and chemical compositions of total mixed rations (TMR)

Item	TMR containing		
	PS*	PCS*	CS*
Ingredients, % on a DM basis			
Whole cotton seed	7.5	6.2	6.2
Cotton seed meal	12	15.6	16.3
Full fat soy bean	14.8	11.7	8.5
Cassava chips	32.7	28	30.5
Molasses	3	2.6	2.6
Urea	0.9	0.8	0.8
Paragrass silage	26	-	-
Paragrass+cassava silage	-	32	-
Corn silage	-	-	32
Sodium bicarbonate	0.45	0.45	0.45
Minerals+vitamins	2.65	2.65	2.65
Chemical compositions on a DM basis			
Crude protein, %	16.3	16.3	16.1
Rumen undegradable protein, %CP**	37.6	37.4	35.7
Ether extract, %	5.6	4.9	4.3
Total neutral detergent fiber, %	28.3	27.8	28.1
Total non-fiber carbohydrates, %	40.8	41.9	41.7
Total digestible nutrients, %**	69.6	69.6	70.5
Net energy for lactation, Mcal/kgDM***	1.59	1.59	1.61

* PC-Paragrass silage; PCS-Paragrass+cassava silage; CS-Corn silage

** Calculated RUP and TDN

*** NEL (Mcal/kgDM)=(0.0245×TDN)-0.12

Table 3. Means for environmental conditions during the experimental period

Item	Months		
	Nov	Dec	Jan
Maximum temperature, °C	30.1±3.1	30.8±3.0	31.6±2.3
Minimum temperature, °C	20.5±3.6	20.2±4.4	19.4±3.5
Maximum relative humidity, %	95±3.0	95±3.0	98±2.0
Minimum relative humidity, %	54±9.0	53±7.0	51±9.9
Maximum THI*	79.1±3.7	79.8±1.2	80.6±8.5
Minimum THI*	68.6±3.5	68.1±9.9	66.8±5.3

* THI-Temperature humidity index

collected at 3-d intervals at consecutive a.m. and p.m. milkings in bottles containing 2-bromo-2-nitro-1, 3-propadiol and stored at 5°C for analysis. Cows were weighed once each week immediately following the a.m. milking prior to accessing feed and water. The trial was conducted during cool months from the beginning of November to the end of January. Ambient temperature and relative humidity were recorded before morning feeding with thermograph and hygrograph (Cassella, London). The temperature humidity index (THI) was calculated following the equation: THI=td-(0.55-0.55RH) (td-58), where td is the dry bulb temperature (°F) and RH is the relative humidity expressed as a decimal (NOAA, 1976).

Organic acids of silage were measured by HPLC (Nitisinprasert et al., 2000). 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 et al. (1991). Total non-fiber carbohydrates (TNFC) was calculated following the equation:

$$TNFC=100-CP-EE-(NDF-NDIN)-ash.$$

Milk composition was 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 on a DM basis for paragrass and whole corn were as follows: CP, 7.47 and 7.16%; EE, 2.86 and 3.01%; NDF, 63.36 and 55.60%; ADF, 38.68 and 31.47%; ADL, 6.61 and 2.86% and DM, 30.69 and 25.37%

Chemical composition, organic acids and pH of the experimental silage are shown in table 1. Compared with paragrass+cassava and corn silages, paragrass silage contained higher contents of NDF, ADF, ADL, ash and CP, and lower content of TNFC.

Paragass+cassava and corn silages contained a similar level of nutrients. The concentration of lactic acid was

Table 4. Nutrient intake and live weight change in dairy cows fed total mixed rations (TMR) containing various sources of silage

Item	TMR containing			S.E.
	PS*	PCS*	CS*	
Nutrient intake				
Dry matter, kg/d	14.49[a]	15.84[b]	18.47[c]	0.84
Dry matter, %BW	3.12[a]	3.39[b]	3.84[c]	0.20
Crude protein, kg/d	2.37[a]	2.57[b]	2.95[c]	0.14
Ether extract, kg/d	0.81	0.77	0.80	0.04
Neutral detergent fiber, kg/d	4.10[a]	4.40[b]	5.19[c]	0.24
Total non-fiber carbohydrates, kg/d	5.92[1]	6.64[2]	7.70[3]	0.34
Total digestible nutrient; kg/d	10.09[1]	11.03[2]	13.03[3]	0.59
Net energy for lactation, Mcal/d	23.04[1]	25.19[2]	29.75[3]	1.40
Live weight change				
Beginning weight, kg	467.0	467.0	478.6	11.55
Finishing weight, kg	461.7	468.3	483.1	15.67
Average daily gain, g	-189[1]	46[2]	161[3]	51.10

* PS-Paragrass silage; PCS-Paragrass+cassava silage; CS-Corn silage
[a,b and 1,2] Means within a row without a common superscript letter and number differ (p<0.05) and (p<0.01), respectively.

higher (p<0.01) in corn silage and its pH was lower (p<0.01) than in paragrass and paragrass+cassava silages.

The nutrient composition of experimental diets is shown in Table 2. Analysed and calculated density of nutrients for the dietary treatments were similar.

Table 5. Composition and yield of milk in dairy cows fed total mixed ration (TMR) containing various sources of silage

Item	TMR containing			
	PS*	PCS*	CS*	S.E
Butter fat				
%	4.38	4.61	4.44	0.08
kg/d	0.91[1]	1.02[2]	1.06[2]	<0.01
Milk protein				
%	2.84	2.85	2.87	<0.01
kg/d	0.59	0.63	0.69	<0.01
Lactose				
%	4.79	4.77	4.74	<0.01
kg/d	0.98	1.03	1.13	<0.01
Minerals				
%	0.68	0.70	0.76	0.02
kg/d	0.14	0.15	0.18	<0.01
Solids-not-fat				
%	8.31	8.32	8.37	0.10
kg/d	1.73[a]	1.83[b]	1.99[c]	0.02
Total solid				
%	12.69[a]	12.93[b]	12.96[b]	0.04
kg/d	2.64[1]	2.85[2]	3.10[3]	0.02
Milk yield, kg/d	20.83[1]	22.03[2]	23.89[3]	1.28
Fat corrected milk (4%), kg/d	22.02[1]	24.05[2]	25.47[3]	1.11

* PS-Paragrass silage; PCS-Paragrass+cassava silage; CS-Corn silage
[a,b and 1,2] Means within a row without a common superscript letter and number differ (p<0.05) and (p<0.01), respectively.

Means for environmental conditions during experimental periods are shown in Table 3. The average maximum and minimum temperatures were 30.8 and 20.0°C, while the average maximum and minimum humidities were 96.0 and 52.7%. The combination of fairly mild temperature and moderately high humidity led to mild temperature and humidity index.

Dietary treatment effects on nutrient intakes and live weight change are presented in Table 4. Intakes of CP, NDF, and DM (p<0.05) as well as TNFC, TDN and NE_L (p<0.01) but not were significantly different. Average daily gain was affected by dietary treatments (p<0.01).

Dietary treatment effects on milk composition, yield and 4% fat corrected milk are demonstrated in Table 5. Of milk compositions, only total solid for dairy cows fed TMR containing paragrass silage was lower than those fed TMR containing paragrass+cassava and corn silages (p<0.05) and yield of fat was also lower (p<0.01). Yield of solids-not-fat, total solid, milk and 4% fat corrected milk was lower for dairy cows fed TMR containing paragrass and paragrass+cassava silages than those fed TMR containing corn silage (p<0.01). However, these values were substantially improved for dairy cows fed TMR containing paragrass+cassava silage, compared to those fed TMR containing paragrass (p<0.01).

DISCUSSION

Potential intake and digestibility are major components for evaluation of forage quality. Content of forage NDF is negatively correlated to intake (Van Soest, 1965; Khorasani et al., 1993). Physical factors that limit intake of forage NDF are bulk density, ruminal fill, rate and extent of digestion, passage rate, rumination and total chewing time (Welch and Smith, 1970; Sudweeks et al., 1981). Cross-linking of lignin to polysaccharides by ferulate bridges is one of several chemical and structural features of cell wall constituents that reduce forage NDF digestibility (Jung and Allen, 1995). Content of NDF and lignin of paragrass in this study was higher than that of whole corn, presumably having more adverse affects on intake and digestibility in ruminants.

Quickly creating an anaerobic environment in the container or silo is a critical mechanism for limiting plant respiration and proteolytic activity, clostridial activity and growth of aerobic microbes (Muck, 1988). Defective preservation that results in high concentrations of ammonia-nitrogen and butyric acid and high pH reduces quality of silage (Flynn, 1988). Although concentration of ammonia in silage was not measured in this study, butyric acid was undetected for all silages, indicating good quality of preservation. The concentration of lactic acid and the pH value of corn silage presented in this study were in a general range reported by others (Thomas and Thomas, 1988; Teller et al., 1990). As indicated by concentrations of higher lactic acid and lower pH, silage from whole corn appeared to have higher quality than that from paragrass. Cassava chips added to increase starch contents in paragrass, reported in this study, tended to slightly increase concentration of lactic acid and pH and thus improve quality of preservation.

When low digestibility forages are substituted on an equal DM basis for higher quality forage, forage NDF can be excessive and result in reduced nutrient density in a diet (Mertens, 1997). In this study, substitution of paragrass silage on an equal NDF basis for paragrass+cassava and corn silage in TMR resulted in a lower ratio of forage to concentrate. However, dietary treatments were isocaloric and isonitrogenous and contained a similar content of NDF and TNFC.

During cooler months in the tropics, environmental temperature is lower by 3-5°C and 5-9°C than in rainy and summer months, respectively while relative humidity is 2-5% lower than rainy months but 2-9% higher than summer months. The combination of fairly mild ambient temperature and moderately high humidity during cool months contributes to moderate THI which is much lower than the THI during rainy months (Kanjanapruthipong and Buatong, 2002) and summer months (Kanjanapruthipong et al., 2001). The maximum THI of 80 reported in this study still exceeded the lower range of danger zone of 78 for survival of Holstein cows (Johnson, 1987) and the minimum THI of 67 was within the range of maximum productivity (Johnson, 1987). These environment conditions suggest maximum productivity can be obtained for dairy cows under cooler months in the tropics.

Although attempts to relate low voluntary intake to pH or contents of specific fermentation end-products in silage have given variable results (Thomas and Thomas, 1988), the depression in intake has often been noted with poorly preserved silage (Clancy at al., 1977). All silages in the present study were well preserved as discussed earlier. The differences among silages in pH and lactic acid cannot explain the differences in DMI, suggesting that other factors besides silage quality affect DMI.

A number of studies reported that DMI were not influenced by source of forage fiber in diets formulated to have the same forage NDF content and similar physical form (Kaiser and Combs, 1989; Poore et al., 1991; Poore et al., 1993). However, Briceno et al. (1987) suggested that formulating diets on NDF may not be applicable across a wide range of fiber sources due mainly to differences in bulk density along with differences in rate and extent of NDF degradability and forage to concentrate ratio. Cows fed high-fill forage tended to have lower rates of solids and liquid turnover and higher total dry matter in the rumen compared with cows fed low-fill forage (Varga et al., 1984). Rate of NDF degradation of corn silage was higher than that of hay crop silage, orchardgrass and timothy (Varga et al., 1983). Rate of intake depression increased as proportion of starch in the diet increased when low quality forage was the only forage and the effect of starch on rate of intake depression was less pronounced for diets based on corn silage (Tyrell and Moe, 1975). Starch from corn shows slower degradation in the rumen than that from cassava (Tamminga et al., 1990). The depression in intake for cows fed TMR containing paragrass silage reported in this study was possibly involved with the increased time lag for functional density of feed particles as affected by higher bulk density and slower rate of NDF degradation (Teller et al., 1990). The reason for the higher intake for dairy cows fed TMR containing paragrass+cassava silage, compared to intake for dairy cows fed TMR containing paragrass silage is not known. An adverse affect of higher proportion of degradable starch on the lower intake for dairy cows fed TMR containing paragrass+cassava silage than those fed TMR containing corn silage might be an explanation. Increased intake of degradable starch in dairy cows fed TMR containing paragrass+cassava silage might reduce pH and resulted in a decrease in NDF digestibility in the rumen (Bhat et al., 1990). This reduction might increase retention time in the rumen and result in more distension and lower DMI (Allen, 2000).

Productivity of dairy cows in the tropics is influenced by DMI (Fuquay, 1981; Beede and Collier, 1986). The amount of DMI influences the rate of microbial cell synthesis in the rumen (Chen et al., 1992). Consequently, there is an increase in nutrients available for mammary secretion. Dietary treatments reported in this study contained similar contents of forage NDF, total NDF, CP and energy. An increased yield of milk, 4% fat corrected milk, solids-not-fat and total solid for dairy cows fed TMR containing corn silage and paragrass+cassava silage reported in this study can be explained by the higher nutrient intake.

Yields of milk, 4% fat corrected milk, solids-not-fat and total solid were influenced by DMI, which in turn was influenced by source of forage in diets formulated to have the same contents of forage and total NDF and similar physical form. Substitution of forage with low NDF and high digestibility for forage with high NDF and low digestibility on an equal NDF basis can actually improve performance of dairy cows in the tropic.

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