Milk production and dry matter intake of lactating Holstein cows fed low fiber diets in the tropics[1]

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ABSTRACT

Three stargrass silage (SGS)-based diets formulated to contain 20, 26 and 32% neutral detergent fiber (NDF) were compared as to their effect on dry matter intake (DMI) and milk production. Twelve lactating Holstein cows averaging 110 days in milk were arranged in four replications of a 3 × 3 Latin Square design. Treatments did not affect DMI or DMI as percentage of body weight (BW); mean values for these parameters were 15.4 kg/cow/day and 3.06%, respectively. However, cows consuming 32% NDF diet had a tendency toward lower (8.6%) intake of organic matter (OM) as percentage of BW than cows on the 20% NDF diet. Intake of NDF as a percentage of BW increased ($P < 0.01$) linearly (0.62 to 0.93%) as dietary NDF concentration increased. Milk production averaged 21.0 kg/cow/day and was not affected by dietary treatment. Reducing dietary NDF from 32 to 20% resulted in a reduction ($P < 0.01$) in milk fat from 3.09 to 2.66%. This reduction resulted in a 1.3 kg/cow/day increase ($P < 0.05$) in 3.25% fat-corrected milk (3.25% FCM) as the percentage of dietary NDF increased. Gross efficiency of energy (NE_L) use for milk production and 3.25% FCM increased linearly with dietary NDF by 9.7 and 17.3%, respectively. Results point out that for mid-lactation cows at the observed level of production, diets lower than 32% NDF will not result in higher DMI and milk production, and will be less efficient in the use of energy for milk production.

Key words: dairy cows, grass silage, neutral detergent fiber

RESUMEN

Producción de leche y consumo de materia seca de vacas Holstein en lactación consumiendo dietas bajas en fibra en el trópico

Se compararon tres dietas basadas en ensilaje de yerba estrella formuladas para contener 20, 26 y 32% de fibra detergente neutro (FDN) para evaluar su efecto sobre el potencial de consumo de materia seca (MS) y producción de leche de vacas Holstein a media lactancia (110 días). Las vacas se asignaron a tratamientos de acuerdo con un diseño de cuadrados latinos de 3 × 3, replicado cuatro veces. Los tratamientos no tuvieron efecto sobre el consumo de MS y MS a base del porcentaje de peso vivo (PV) de la vaca; los promedios generales fueron 15.4 kg/vaca/día y 3.06% del PV, respectivamente.

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Sin embargo, las vacas que consumieron la dieta con 32% FDN exhibieron una tendencia a un menor (8.6%) consumo de materia orgánica (MO) como porcentaje del PV comparado con la dieta con 20% FDN. El consumo de FDN como un porcentaje del PV aumentó ($P < 0.01$) linealmente de 0.62 a 0.93% según aumentó la concentración de FDN. El promedio de producción de leche fue 21.0 kg/vaca/día y éste no se afectó por los tratamientos. La reducción de 32 a 20% en la concentración de FDN resultó en una reducción ($P < 0.01$) en la concentración de grasa láctea de 3.09 a 2.66%. Como resultado hubo un aumento de 1.3 kg/vaca/día en la producción de leche corregida al 3.25% de grasa, según aumentó el FDN de 20 a 32%. Al aumentar la concentración de FDN de 20 a 32% la eficiencia de la utilización de la energía (NE_L) para la producción de leche y leche corregida al 3.25% de grasa se incrementó en un 9.7% ($P < 0.05$) y 17.3% ($P < 0.01$), respectivamente. Según los resultados de este estudio a los niveles de producción observados, las dietas con menos de 32% de FDN no tendrán un efecto sobre el consumo de MS ni sobre la producción de leche íntegra, aún cuando estas dietas resultan en un mayor consumo de energía. Además, estas dietas son menos eficientes en el uso de energía para la producción de leche.

INTRODUCTION

It can be argued that low dry matter intake (DMI) is the main factor limiting milk production of dairy cows in the tropics (Ugarte et al., 1983). In a tropical environment, high temperatures and humidity combine not only to reduce appetite but also to reduce milk production efficiency in lactating cows (National Academy Press and National Research Council, 1981). Relative to thermoneutrality (18 to 20° C), at 35° C the expected DMI decreases by about 8%, while maintenance requirements are increased by about 20%. These two facts in conjunction are mainly responsible for the large reduction (33%) in milk production observed at the higher temperature.

It follows that feeding management in the tropics should be directed toward maximizing feed consumption if the genetic potential of the lactating Holstein cows is to be fully realized. Mertens (1989) has suggested the possibility of increasing DMI and milk production of dairy cows by manipulating the concentration of neutral detergent fiber (NDF) in the diet. This procedure was demonstrated in a study where Holstein cows were fed Bermuda grass silage-based diets containing 46, 41.2, 36.6 or 31.8% NDF (Bernal, 1992). In this study, DMI was found to increase linearly with a reduction in dietary NDF. In addition, feed intake was 36.7% higher on the diet with the lowest NDF compared to that with the highest NDF concentration. Similarly, the difference in milk production was 17.2% higher in the low NDF diet. Furthermore, Ruiz (1993) indicated that diets with NDF concentrations below 30% result in additional DMI and milk production improvements. The purpose of this study was to investigate the possibility that low fiber diets, below 30% NDF, could influence positively the DMI and milk production of lactating Holstein cows in the tropics.

MATERIALS AND METHODS

The experiment was conducted at the Gurabo Substation dairy farm of the University of Puerto Rico Agricultural Experiment Station, 115 meters above sea level. It lasted 68 days, from 24 June to 31 August 1998. Mean environmental temperature at the site fluctuated from a daily minimum of 20.9° C to a maximum of 33.0° C during the experiment, whereas fluctuations in daily maximum air temperature were from 31.7 to 34.4° C.

A stargrass (*Cynodon nlemfuensis*) plot used for grazing lactating cows was given a standardizing cut and fertilized with approximately 400 kg/ha of a 15-5-10 fertilizer. The grass was harvested in early May at 44 days of regrowth and cut to a stubble height of 15 cm. Mean particle size of the chopped grass was about 5 cm. It was then ensiled in a bag silo (Ag Bag Corp., Astoria, OR)[5] approximately 2.3 m in diameter and remained ensiled for at least 40 days before the silo was opened.

Twelve lactating Holstein cows, between 99 and 136 days-in-milk at the start of the trial, were arranged according to a 3 × 3 Latin Square Design with four replications. Treatment arrangement for each pair of replicate squares was balanced to account for residual effects. One replication consisted of primiparous cows and the other three contained multiparous cows at similar stages of lactation. Each experimental period was 24 days, with 14 days for adaptation to the dietary treatments and 10 days for data collection. However, the last two data collection periods were shortened to eight days because of a projected silage insufficiency.

Cows were housed in an open-sided barn with a concrete floor and fitted with Calan gates (American Calan Inc., Northwood, NH) to allow the measurement of individual feed intake. They remained in the barn throughout the day, except when removed for milking. Experimental cows were milked every day at 04:00 and 15:30 h, and milk yield was recorded in calibrated glass jars at each milking. Samples for milk composition analyses were collected from four consecutive milkings within the last three days of each data collection period. Milk was analyzed for protein and fat contents by the Puerto Rico Dairy Herd Improvement Association Laboratory (Dorado, P.R.). Body weights were recorded at 06:00 h immediately after milking for two consecutive days, two days prior to the start of Period I and during the last two days of each of the

[5]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

three experimental periods. Milk yield was standardized to 3.25% fat, which is considered more relevant than 4% fat for a market where no additional payment is made for butterfat. The formula used for 3.25% fat corrected milk (3.25% FCM) was as follows:

$$(\text{milk fat yield in kg} \times 16.899) + (0.4508 \times \text{milk yield in kg}).$$

Treatment diets were formulated to 20%, 26% and 32% NDF on a dry matter (DM) basis. They consisted of mash concentrate feeds and stargrass silage (SGS), and were formulated to be isonitrogenous. Both SGS and concentrate were weighed on a portable scale and mixed daily by hand prior to feeding. The ration was offered twice daily at 06:30 and 17:00 h in amounts that allowed 10 to 15% orts on an as-fed basis. Total amount consumed and orts were recorded daily for each cow. The proportions of ingredients in the diet were kept constant on a DM basis by monitoring SGS and concentrates for DM twice weekly. Samples of SGS and of the three concentrates were collected weekly and kept frozen until composited for each experimental period. Composite samples were oven dried to a constant weight at 55° C for a minimum of 48 hours. Composite samples were analyzed chemically by the Northeast DHIA Forage Laboratory (Ithaca, NY).

Data were analyzed by least squares ANOVA using the general linear model procedures of SAS (Littell et al., 1992). Differences among treatments were analyzed by the use of contrasts.

RESULTS AND DISCUSSION

The SGS used had a characteristic acid smell typical of well-preserved silage. It exhibited minimal spoilage in the feed bunk and throughout the trial appeared stable under aerobic conditions. However, no chemical or aerobic stability analyses of the silage were conducted. Chemical composition of SGS (Table 1) can be considered typical of a tropical grass of medium maturity. In vitro true digestibility was 54.6%, and was similar to the estimated total digestible nutrient (TDN) content (55.6%) obtained from chemical laboratory analyses. However, crude protein (CP) content was lower than expected for a well fertilized grass and nearly 20% lower than that of the fresh stargrass forage prior to ensiling.

Table 2 presents the ingredients and chemical composition of the diets. The three concentrate mixtures used were based mainly on corn and soybean meal. Use of wheat middlings (high NDF by-product feed) was minimized to maintain NDF concentration of the concentrates below 10%. Experimental diets were formulated to be isonitrogenous; however, lower CP concentration in the 32% NDF diet was mainly due

TABLE 1.—*Average chemical composition, on a dry matter (DM) basis, of stargrass silage used to formulate experimental diets.*

Chemical composition, % of DM	
DM, %	30.8
CP	7.4
NDF	77.4
ADF	56.2
Ca	0.26
P	0.19
K	1.45
Mg	0.13
Na	0.04
In vitro true digestibility, %	56.4

to the lower than expected CP of the SGS and the higher content of silage in this diet.

Actual NDF concentrations (20.2, 26.2, and 31.9%) of the experimental diets were similar to expected values (20, 26, and 32%). Silage contributed 59.3, 72.5, and 78.4% of the total dietary NDF to the 20, 26 and 32% NDF diets, respectively (Table 2). As formulated, the 20 and 26% NDF diets are considered outside current National Research Council (NRC, 1988) recommendations that 75% of dietary NDF should be from the forage portion of the diet. On the other hand, only the 20% diet falls below the recommended dietary minimum of 25% total NDF (NRC, 1988).

Current (1998) NRC guidelines state that diets having greater than 70% concentrate are inadequate for normal ruminal fermentation. Diets with 20 and 26% NDF exceed this maximum recommendation, with forage to concentrate ratios below 30:70 (Table 2). Only the 32% NDF diet was within this recommended limit, with forage to concentrate ratio of 32:68. However, it is not clear whether the NRC's recommendation strictly applies to diets based on tropical forages, which are much higher in fiber than grasses and legumes from temperate zones. In general, forage to concentrate ratios of diets based on tropical grasses are lower than those typically observed for diets based on corn silage and other temperate forages (Bernal, 1992; Ruiz et al., 1995a). Net energy for lactation (NE_L) in the diet was estimated from the ADF analysis using the NRC equation (1988). It decreased from 1.87 to 1.75 Mcal-NE_L/kg DM as dietary NDF concentration increased. This difference can be largely accounted for by the higher concentration of SGS in the total diet as NDF increased.

TABLE 2.—*Ingredients and chemical composition of experimental diet formulated to three neutral detergent fiber (NDF) concentrations.*

	NDF in diet DM		
	20%	26%	32%
Ingredient composition, % DM			
Stargrass silage	15.5	24.6	32.3
Ground corn	62.8	53.5	43.4
Soybean meal	18.0	18.2	17.8
Wheat midds	1.6	1.6	4.3
Mineral mixture	2.1	2.1	2.2
Forage:Concentrate ratio	15:85	25:75	32:68
Chemical composition, % DM			
DM, %	68.5	60.5	55.2
OM	95.5	93.9	94.1
CP	16.7	16.5	15.8
NDF	20.2	26.2	31.9
ADF	11.9	17.3	21.7
Ca	0.79	0.81	0.83
P	0.45	0.47	0.47
Mg	0.40	0.41	0.35
K	0.96	1.04	1.11
Na	0.32	0.38	0.32
Forage NDF as a percentage of diet NDF	59.3	72.5	78.4
Energy density[1] Mcal-NE_L/ kg of DM	1.87	1.81	1.75

[1]NE_L calculated from ADF analysis using the NRC (1988) equation.

Dietary treatment had no effect on DMI or DMI as a percentage of body weight (DMIBW) of cows consuming the experimental diets (Table 3). Mean DMI and DMIBW were 15.4 kg/cow/day and 3.06% of BW, respectively. Organic matter (OM) intake was not different among treatments; however, there was a tendency ($P = 0.106$) for increased intake of OM on a percentage of BW (OMBW) basis as NDF in the diet declined. Cows consumed 8.6% less OMBW on the 32% NDF diet than on the 20% NDF diet. On the other hand, differences in the energy concentration of the diets resulted in a linear ($P < 0.05$) increase in NE_L intake as dietary NDF concentration declined. In all diets, energy intake was sufficient to meet the recommended daily nutritional requirements. Energy intake was 9.7 and 14% higher for the 26 and 20% NDF diets than for the 32% NDF diet.

TABLE 3.—*Least squares means for intakes of DM, OM, CP, ADF, NDF and NE_L by lactating cows fed diets based on stargrass silage and formulated to contain 20, 26 and 32% NDF.*

	NDF in diet DM			
	20%	26%	32%	SE
Intake, % BW				
DM	3.09	3.10	2.89	0.11
OM	3.02	2.97	2.76	0.10
NDF[1]	0.62	0.81	0.93	0.03
Intake, kg/d				
DM	15.7	15.6	14.7	0.61
OM	15.3	14.9	14.0	0.56
CP[2]	2.6	2.6	2.3	0.10
ADF[1]	1.9	2.7	3.2	0.08
NDF[1]	3.2	4.1	4.7	0.14
NE_L, Mcal/day[3]	29.3	28.2	25.7	1.12

[1]Linear increase with increasing concentration of NDF ($P < 0.01$).
[2]Quadratic decrease with increasing concentration of NDF ($P < 0.01$).
[3]Linear decrease with increasing concentration of NDF ($P < 0.05$).

Dry matter intake was far lower than achievable levels (3.5 to 4.0% of BW) by high producing Holstein cows (NRC, 1988). In this trial, cows consumed 31.6 and 20.8% less DMI and DMIBW, respectively, than cows consuming a 31.8% NDF diet based on Bermudagrass silage (Bernal, 1992) under conditions of low humidity and low environmental temperatures. Compared with intake at temperatures around 5° C, at 35° C there should be a reduction of DMIBW of nearly 2% (National Academy Press and National Research Council, 1981). The lower than expected DMI of all cows in this trial might be attributed in part to the high humidity as well as to the high temperatures prevailing. In addition, the high intake of NE_L relative to requirements, particularly for the 20 and 26% NDF diets, could have resulted in metabolic (energy) limitations on DMI and could have prevented higher DM consumption by the cows.

Contrary to energy intake, CP intake was just enough to meet requirements for production. For cows consuming the 32% NDF diet, protein intake appears to have been insufficient, and lower ($P < 0.01$) than for the other two diets. Consumption of CP for these cows was about 8% below the daily requirements necessary to meet production and maintenance needs (NRC, 1988). This reduction was the result of a lower than expected concentration of CP in the diet.

Dietary treatments had their greatest effect on acid detergent fiber (ADF) intake (Table 3). There was a linear increase ($P < 0.01$) with the increase in dietary NDF. Cows on the 20% NDF diet consumed 40.6% less ADF than cows on the 32% NDF diet. As a result, the 20% NDF diet was well below the minimum ADF recommendation of 16% of the total diet (NRC, 1988). This large difference between the high and low NDF diets could be caused by the higher ADF:NDF ratio in SGS compared with that in the concentrate and to the higher percentage of silage in the 32% NDF diet.

As expected, NDF intake increased linearly ($P < 0.01$) with the NDF concentration in the diet. Cows on the 20% NDF diet consumed 31.9% less NDF than cows on the 32% NDF diet. Similarly, NDF intake as percentage of BW increased linearly ($P < 0.01$) from 0.62 to 0.93% as dietary NDF increased from 20 to 32%, even though NDF intake from the 32% NDF diet was lower than that reported by Ruiz et al. (1995a) for cows receiving similar diets. Guidelines for NDF intake from forages compiled by Varga et al. (1998) recommend that minimum forage NDF intake should be 0.85% of BW when 1.1- to 1.2%-units of total diet NDF is provided by grains or starchy ingredients. According to these guidelines, all diets in this trial were below minimum recommended levels. The 32% NDF diet had the highest percentage of NDF from forage (78.4%), yet the mean forage NDF intake was only 0.73% of BW. This might indicate that fill capacity of the cows was never reached or that at the level of milk production and stage of lactation of the cows, energy was controlling intake below the fill capacity of the cows. The most plausible answer, as mentioned before, is that intake was controlled by energy satiation. Particularly in the case of the 20 and 26% NDF diets, estimated energy intake for these can easily exceed requirements for production and maintenance.

The increase in NE_L intake did not result in an increase in milk production when the 20% NDF diet was fed (Table 4). Mean milk production was 21 kg/cow/day across all dietary treatments. Diets did not influence milk protein content, and the overall mean was 3.04%. Mean milk protein concentration appears normal for dairy cows consuming this type of diet (Ruiz et al., 1995b). On the other hand, milk fat percentage increased linearly ($P < 0.01$) as NDF concentration increased from 20 to 32% of DM. Milk fat concentration was 13.9% lower for the 20% NDF diet than for the 32% NDF diet. Perhaps this finding is an indication of a less favorable ruminal environment which could in the long run have negative consequences on the health and productivity of the cows (Ugarte et al., 1983). As a result of the lower fat concentration, production of 3.25% FCM increased ($P < 0.05$) linearly as NDF concentration in the diet increased. Yield of 3.25% FCM was

TABLE 4.—*Least squares means for milk production, 3.25% fat corrected milk (FCM) and milk composition for lactating cows fed diets based on stargrass silage and formulated to 20, 26 and 32% NDF.*

	NDF in diet DM			
	20%	26%	32%	SE
Actual milk, kg/d	21.0	21.0	21.0	0.30
3.25% FCM, kg/d[1]	19.0	19.9	20.3	0.32
Milk fat, %[2]	2.66	2.98	3.09	0.09
Milk protein, %	3.05	3.04	3.01	0.04

[1]Linear increase with increasing concentration of NDF ($P < 0.05$).
[2]Linear increase with increasing concentration of NDF ($P < 0.01$).

6.4% (1.3 kg/cow/d) lower when cows consumed the 20% NDF diet rather than the 32% NDF diet. This decrease occurred despite higher energy and crude protein intake by cows consuming the 20% NDF diet.

There was a tendency ($P = 0.117$) toward increased weight loss as NDF concentration increased from 20 to 32% (Table 5). The 20% NDF diet was the only one that showed weight gain; however, differences were not statistically significant. Mean weight change across all diets was -0.086 kg/cow/day. Cows consuming 20%, 26% and 32% NDF rations produced 1.6, 1.8 and 2.1 kg of actual milk per kilogram of concentrate consumed, respectively. These amounts represent an improvement of 32.5% and 17.7% when cows consumed the 32% NDF diet

TABLE 5.—*Efficiency of concentrate use and gross efficiency of energy[1] use for milk yield (MY) and fat corrected milk (FCM), and least square means for body weight change.*

	NDF in diet DM			
	20%	26%	32%	SE
Mean change in body weight, kg/cow/day	0.12	-0.13	-0.46	0.25
Efficiency of concentrate use[2], kg-milk/kg-concentrate DM	1.64	1.82	2.12	0.06
Gross efficiency of energy for MY[3], kg-milk/Mcal-NE_L intake	0.74	0.76	0.82	0.026
Gross efficiency of energy for FCM[2], kg-3.25% FCM/Mcal-NE_L intake	0.67	0.72	0.81	0.022

[1]NE_L calculated from ADF analysis using the NRC (1988) equation.
[2]Linear increase with increasing concentration of NDF ($P < 0.01$).
[3]Linear increase with increasing concentration of NDF ($P = 0.073$).

rather than the 20 or 26% NDF diet, respectively. On the basis of the reduction in milk fat, lack of a response in milk yield, and current NRC recommendations for minimum NDF concentrations (25 to 28% of DM) in diets of lactating cows, the 20% NDF diet could appear extreme. However, this type of diet is very common among dairy farmers in Puerto Rico. In a recent survey[6] of 205 dairy farms on the island, over 80% had efficiencies of concentrate use for milk production that were lower than 1.6 kg of milk/kg of concentrate DM fed, with a mean of only 1.23.

Similarly, efficiency of DMI for milk production showed a linear decline ($P < 0.05$) from 1.43 to 1.30 to 1.25 kg of 3.25% FCM/kg DMI as NDF concentration declined from 32 to 26 to 20%. Despite the fact that diets low in fiber had higher energy density and cows on these diets consumed more total NE_L, this did not translate into more milk production or higher production efficiency. Gross efficiency of energy utilization for milk production (kg milk/ Mcal NE_L intake) was reduced linearly ($P = 0.07$) by 9.7% as the NDF concentration in the diet declined from 32 to 20%. When milk production was standardized to 3.25% FCM efficiency reduction was more pronounced ($P < 0.01$). Gross efficiency of energy for 3.25% FCM production was 17.3% lower when cows consumed the 20% NDF diet than with the 32% NDF diet.

Determining relative costs (Table 6) can be another means of measuring the efficiency of the diets. Estimated cost of the 20% NDF diet was 2.2 cents/kg DM more than for 32% NDF diet. For all diets, relative cost of concentrate feeds represented an extremely large portion of the total cost of the diet. Cost of concentrate increased from 82 to 87 to 92% of the total cost of the ration as dietary NDF declined from 32 to 26 to 20%. Total ration cost was 55 cents per cow more for the 20% NDF diet than for the diet containing 32% NDF. Feed cost per kg of milk produced was 2.6 cents/kg DM more with the 20% NDF diet than with the 32% NDF diet. For a herd averaging 21 kg milk/cow/day and consuming a diet similar to 20% NDF, this would represent $200.75/cow/year more in feed costs than for a cow consuming a diet similar to a 32% NDF diet. For a 100-cow herd, this is equivalent to $20,075 more in total feed costs in a year without achieving any advantage in milk production.

In spite of being lower in bulk (NDF) and higher in energy concentration than a diet containing 32% NDF, an unbalanced diet low in fiber (20 or 26% NDF) will not result in higher milk production at the level of production achieved in this trial for cows in mid-lactation. It appears that the 20 and 26% NDF diets limited intake through metabolic mechanisms. The low fiber intake was below and the high energy intake above requirements, thus supporting this conclusion.

[6]Ruiz, T. M., M. López-Beníquez and R. Macchiavelli, 1999. Unpublished data.

TABLE 6.—*Relative costs (U.S. dollars) of diet, stargrass silage (SGS) and concentrate, and total daily cost of ration for each of the experimental diets.*

	NDF in diet DM		
	20%	26%	32%
Relative cost of the diet, $/kg[1]	0.232	0.220	0.210
Cost of SGS consumed, $/day	0.29	0.46	0.57
Cost of concentrate consumed, $/day	3.36	2.98	2.53
Cost of the ration, $/day/cow[2]	3.65	3.44	3.10

[1]Assumes cost of concentrate and stargrass silage of 25.3 and 12.1 cents/kg of DM, respectively.

[2]Calculated by multiplying intake of DM by cost/kg.

For cows producing less than 21 kg of milk/day, a diet having 32% NDF or higher is recommended instead of those with lower NDF concentrations. The 32% NDF diet used in this experiment allowed for higher efficiency of production and lower feed costs. The practice among dairy farmers to give their cows diets with a high proportion of concentrates, expecting to improve milk production, is not justified by the results of this trial and will certainly result in increased feeding costs and a reduction in potential earnings for the farmer.

As expected, low fiber diets (20 and 26%) resulted in reductions in milk fat percentage. These reductions could be an indication of a negative effect on rumen fermentation, which can have long-term negative effects on cow health and longevity in the herd. At current production levels, feeding diets with less than 32% NDF is not recommended. At higher milk production levels and for cows in early lactation, the potential of such diets is still unknown and merits further study.

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