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Interaction between particle sizes of alfalfa hay and corn grain on milk yield, milk composition, chewing activity, and ruminal pH of dairy cows

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Abstract: The objective of this study was to determine the interactions between alfalfa hay and corn grain particle sizes on nutrient intake, milk yield, milk composition, chewing activity, and ruminal pH of dairy cows. Alfalfa hay was chopped either at 4 cm (long; L) or 1 cm (short; S) theoretical length of cut. Particle size of corn grain was obtained by grinding either at 1 mm (coarse; C) or less than 1 mm (fine; F) mean particle size. Four lactating multiparous Holstein cows were assigned in a 4×4 Latin Square design in a 2×2 factorial arrangement of treatments with 21-day periods. Intakes of DM (DMI) and NDF (NDFI) were not different among treatments averaging 23.6 and 10.6 kg/d. Similarly, yields of milk and milk protein were not different among treatments averaging 22.8 and 0.75 kg/d, respectively. However milk fat yield tended to be higher for C (0.82 kg/d) than F (0.73 kg/d) corn grain. An interaction trend was observed between particle sizes of alfalfa hay and corn grain for milk protein percentage where it tended to be higher for SC (3.31%) compared to SF (3.23%). Chewing activity was not affected by any treatment. Ruminal pH was higher at 9 h of post-feeding for both SF (6.50) and SC (6.36) compared to LF (6.06) and LC (6.17). The data indicate that particle size of alfalfa hay had no effect on milk yield and any milk composition but diets containing C corn grain resulted in a higher milk fat yield.

Key words: Particle size, alfalfa hay, milk yield, chewing activity, ruminal pH

Yonca otu ve dane mısır partikül büyüklüklerinin süt ineklerinde süt verimi ve bileşenleri, çiğneme aktivitesi ve rumen pH'sı üzerine etkileri

Özet: Bu çalışmada yonca otu ve dane mısır partikül büyüklüklerinin süt ineklerinde yem tüketimi, süt verimi, süt kompozisyonu, çiğneme aktivitesi ve rumen pH'sı üzerine olan etkileri araştırılmıştır. Yonca otu 4 cm (uzun; U) veya 1 cm (kısa; K) teorik kesim uzunluğunda doğranmıştır. Dane mısırın partikül büyüklüğü ise 1 mm (iri; İ) veya 1mm' den daha küçük (ufak; U) partikül büyüklüğünde öğütülmeyle sağlanmıştır. Dört tane 2 veya üstü laktasyondaki Holstein inek 4×4 Latin Kare deseninde ve 2×2 faktör düzenlemesindeki muamelelere 21 günlük dönemde tahsis edilmiştir. Muameleler arasında kuru madde (KM) ve NDF tüketimleri yönünden bir fark gözlenmemiş ve ortalama 23,6 ve 10,6 kg/gün bulunmuştur. Muameleler arasında süt ve süt protein verimi yönünden de bir fark bulunmamış, sırasıyla ortalama 22,8

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ve 0,75 kg/gün bulunmuştur. Ancak süt yağı verimi İ dane mısırda (0,82 kg/gün) U'ya (0,73 kg/gün) göre daha yüksek olma eğiliminde bulunmuştur. Yonca otu ve dane mısır partikül büyüklükleri arasındaki etkileşim yönünden, süt protein yüzdesi Kİ rasyonunda (% 3,31) KU rasyonuna (% 3,23) göre daha yüksek olma eğiliminde bulunmuştur. Çiğneme aktivitesi yönünden muameleler arasında bir fark gözlemlenmemiştir. Yemlemeden 9 saat sonrasındaki rumen pH'sı, KU (6,50) ve Kİ (6,36)'de UU (6,06) ve Uİ (6,17)'ye göre daha yüksek şekillenmiştir. Bu araştırmadaki veriler, yonca otu partikül büyüklüğünün süt verimi ve süt kompozisyonu üzerine bir etkisinin olmadığını gösterirken, İ dane mısır içeren rasyonlarda süt yağı verimi yüksek şekillenmiştir.

Anahtar sözcükler: Partikül büyüklüğü, yonca otu, süt verimi, çiğneme aktivitesi, ruminal pH

Introduction

Physical characteristics of dairy rations are very critical for obtaining proper ruminal fermentation as well as for animal production. In this regard, physical forms of both forages and concentrates should be in an appropriate particle size to avoid metabolic disorders (acidosis, displaced abomasum) and milk composition changes (1). Research indicated that finer particle size of alfalfa hay caused reductions in both rumination time and milk fat in lactating dairy cattle (2,3). Recently the terms, physical effectiveness factor (pef) and physically effective NDF (peNDF), have been used to clarify either forage or total mixed ration (TMR) particle size, causing chewing activity along with obtaining proper milk fat concentration (1). Shaver et al. (4) found a significant reduction in both milk fat (3.11% vs. 3.62%) and chewing activity (3.2 vs. 9.5 h/day) of dairy cows when alfalfa hay was provided in ground and pellet form compared to the unchopped form. In addition, they found a lower averaged ruminal pH (5.7 vs. 6.3) of dairy cows when alfalfa hay was provided in a ground compared to the unchopped form. It is generally believed that coarsely ground concentrates may result in incomplete nutrient digestion. Callison et al. (5) indicated that there were no DM intake (18.5 kg/day), yields of milk (25.1 kg/day), protein (3.18%), and fat (3.54%) differences of dairy cows received particle sizes of 1.2, 2.6, and 4.8 mm of dry corn in a concentrate mix. Some other studies (6,7) also indicated that finely ground corn grain (1.11 and 0.70 mm) compared to coarsely (3.28 and 1.70 mm) ground corn grain in TMRs resulted in a higher percentage and yield of milk protein.

The objectives of this study were to determine the interactions between alfalfa hay and corn grain particle sizes on intake, milk yield, milk composition, chewing activity, and ruminal pH of dairy cows.

Materials and methods

Fourth cut baled alfalfa hay was chopped either at 4 cm (L) or 1 cm (S) theoretical length of cut using a commercial hay harvester mounted with 10 or 58 mm screens. The particle size of corn grain was obtained by grinding the material with a hammer mill either at 1 mm (C) or less than 1 mm (F) mean particle sizes. Particle size analysis of treatment alfalfa hays, TMRs, and orts was performed by PennState Particle Separator (8). Calculation of particle size distribution and geometric mean particle size (GMPS) of alfalfa hays and corn grain were performed according to ASAE standards (9,10).

Four multiparous lactating Holstein cows averaging 70 days in milk at the trial initiation were assigned to each experimental diet in a 4×4 Latin Square design with 2×2 factorial arrangements of treatments for 21-day periods. The first 14 days of each period were for diet adaptation, and sampling occurred during days 15 to 21 of each period. Treatment diets were; long alfalfa hay + coarse corn grain (LC), long alfalfa hay + fine corn grain (LF), short alfalfa hay + coarse corn grain (SC), and short alfalfa hay + fine corn grain (SF). Diets were fed as TMR with 50:50 forage to concentrate ratio (DM basis), which contained 33.5% alfalfa hay and 16.5% corn silage (Table 1). The amounts of TMR offered and refused were recorded daily. Cows were fed ad libitum, and orts were maintained at approximately 10%. The treatment forages (alfalfa hay and corn silage) and corn grain were sampled on days 15 and 21 of each period and each was composited by period for nutrient analysis. Orts were collected on days 19 to 21 of each period and composited by cow within the period. Each individual feed, TMR, and orts were analyzed for DM, OM, CP (11), ADF, and NDF (12). Cows were milked at AM and PM milkings and milk compositions were measured during last 3 days of each period.

Table 1. Ingredient and nutrient composition of diets.

Ingredient	% of DM	Ingredient	% of DM
Alfalfa hay	33.5	Molasses	1.5
Corn silage	16.5	Limestone	1.2
Corn grain	22.5	Urea	0.5
Cottonseed meal	7.0	Sodium bicarbonate	0.4
Soybean meal	6.0	Salt	0.3
Corn gluten feed	4.0	Dicalcium phosphate	0.1
Wheat bran	3.8	Lysine+Methionine	0.1
Sunflower meal	2.5	Trace-mineral and vitamin premix	0.1

	Diet[1]			
Nutrient, % of DM	LC	LF	SC	SF
DM	66.3	66.4	67.4	66.0
OM	92.4	92.3	92.1	92.0
CP	16.1	16.5	15.9	16.3
NDF	44.8	45.1	44.8	45.1
ADF	32.2	32.5	32.0	32.3
Ash	7.6	7.7	7.9	8.0
NE_L (Mcal/kg)	1.45	1.45	1.45	1.45

[1]LC: long alfalfa hay+coarse corn grain, LF: long alfalfa hay+fine corn grain, SC: short alfalfa hay+coarse corn grain, SF: short alfalfa hay+fine corn grain

Times spent for eating and ruminating were recorded within 24 h at the last day of each period by recording the chewing action (eating + ruminating) of each cow visually every 5 min. Ruminal pH was measured during the last 2 days of each period using a special filter mounted to the stomach tube at 0, 3, 6, 9, and 12 h of post-feeding using a hand held pH meter (HI-8314N, Hanna Instruments, UK).

Production and chewing activity data were analyzed by PROC GLM; ruminal pH data were analyzed by PROC MIXED procedure for repeated measures of SAS (13). For ruminal pH, period and hour were used as repeated measurements.

Results

Particle size distribution of alfalfa hays, diets, and orts is presented in Table 2. Both pef and peNDF were higher for L than S alfalfa hays ($P < 0.01$). As hypothesized, a higher GMPS was resulted for L (4.9 mm) compared to S (3.1 mm) alfalfa hay. The pef of both treatment diets (averaging 0.75 vs. 0.69) and orts (averaging 0.89 vs. 0.75) was higher with L compared to S containing alfalfa hay. The percentage of particles retained on top 4 screens (4.75, 3.35, 2.36, and 1.70 mm) was higher for C (1.5, 4.2, 11.4, and 14.1%) compared to F corn grain (0.2, 1.0, 4.4, and 9.4%; $P < 0.05$). A significantly higher GMPS was also observed for C (0.82 mm) compared to F (0.53 mm) corn grain.

Treatment effects on nutrient intakes, milk yield, and milk composition are presented in Table 3. Neither alfalfa hay particle length nor corn grain particle size had an effect on DMI, NDFI, and peNDF intake (peNDFI) averaging 23.6, 10.6, and 3.44 kg/d, respectively. Milk and milk protein yields were not different across the diets, averaging 22.8 and 0.75 kg/days, respectively. However milk fat yield tended to be higher ($P = 0.07$) for C compared to F corn grain in both diets containing L and S alfalfa hays. Similarly, there was a trend for milk fat percentage being higher for C (3.53%) compared to diets containing F (3.28%) corn grain ($P = 0.11$). There was an interaction trend

Table 2. Particle size distribution and mean particle size of alfalfa hays, diets, and orts by PennState Particle Separator.

% as fed DM retained	Alfalfa hay[1]			Diet[2]					Ort[2]				
	L	S	SEM[3]	LC	LF	SC	SF	SEM	LC	LF	SC	SF	SEM
>19 mm	16^{a}	0^{b}	3	11^{A}	12^{A}	1^{B}	0^{B}	2	31^{X}	33^{X}	3^{Y}	0^{Y}	5
19-8 mm	21^{a}	17^{a}	1	17^{A}	16^{A}	15^{A}	14^{A}	1	23^{XY}	27^{X}	24^{XY}	17^{Y}	2
8-1.18 mm	42^{b}	56^{a}	3	49^{B}	45^{C}	57^{A}	52^{B}	1	34^{Y}	30^{Y}	54^{X}	52^{X}	4
<1.18 mm	21^{b}	27^{a}	2	23^{B}	27^{B}	27^{B}	34^{A}	1	12^{Y}	10^{Y}	19^{Y}	31^{X}	3
pef[4]	0.79^{a}	0.73^{b}	0.01	0.77^{A}	0.73^{A}	0.73^{A}	0.66^{B}	0.01	0.88^{X}	0.90^{X}	0.81^{X}	0.69^{Y}	0.03
$peNDF^{5}_{>1.18}$	44.5^{a}	41.5^{b}	0.9	34.5^{A}	32.8^{A}	32.7^{A}	29.8^{B}	0.6	-	-	-	-	-
GMPS[6], mm	4.9^{a}	3.1^{b}	0.4	4.0^{A}	3.8^{A}	3.0^{B}	2.6^{B}	0.2	8.5^{X}	9.4^{X}	4.0^{Y}	3.1^{Y}	1.1

^{a,b}means (for alfalfa hays) within the same row with different superscripts differ (P < 0.01)
^{A,B,C}means (between the diets) within the same row with different superscripts differ (P < 0.01)
^{X,Y}means (between the orts) within the same row with different superscripts differ (P < 0.01)
[1]L: long, S: short
[2]LC: long alfalfa hay+coarse corn grain, LF: long alfalfa hay+fine corn grain, SC: short alfalfa hay+coarse corn grain, SF: short alfalfa hay+fine corn grain
[3]standard error of mean
[4]physical effectiveness factor determined as the proportion of particles retained by top 3 sieves
[5]physically effective NDF, measured as the NDF content of treatment multiplied by the pef
[6]geometric mean particle size

(P = 0.10) between particle sizes of alfalfa hay and corn grain for milk protein percentage where it tended to be higher for SC (3.31%) compared to SF (3.23%).

Time spent for eating was longer for LF (371 min/d; 25.8%) and SC (356 min/d; 24.7%) than for LC (325 min/day; 22.6%) and SF (333 min/day; 23.1%) diets (P < 0.05). Time spent for ruminating and chewing were not affected by particle sizes of alfalfa hay and corn grain averaging 423 (29.4%) and 769 (53.4%) min/day, respectively. Similarly times spent for eating, ruminating, and chewing corrected DMI were not different across the diets averaging 15, 18.2, and 33.1 min/kg, respectively (data not presented).

Treatment effects on post-feeding ruminal pH are presented in the Figure. Ruminal pH was higher for SF (6.50) and SC (6.36) compared to LC (6.17) and LF (6.06) diets at 9 h post-feeding (P < 0.05). In addition, based on the repeated measures of analysis, there were significant interaction effects of time by alfalfa hay particle length and time by particle sizes of alfalfa hay and corn grain on ruminal pH (P < 0.05).

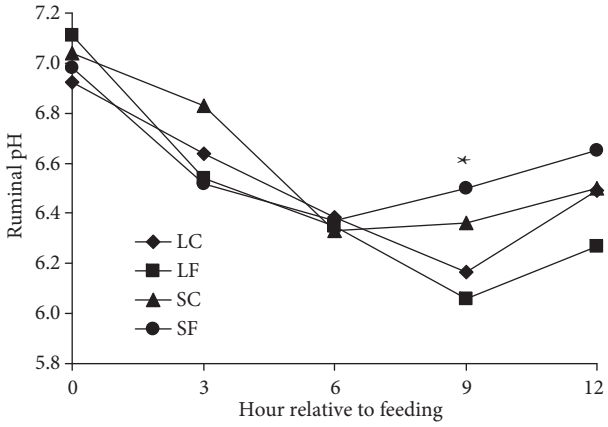

Figure. Effects of alfalfa hay and corn grain particle size on post-feeding ruminal pH of dairy cows.
LC: long alfalfa hay+coarse corn grain, LF: long alfalfa hay+fine corn grain, SC: short alfalfa hay+coarse corn grain, SF: short alfalfa hay+fine corn grain
*Alfalfa hay particle size effect; P < 0.05

Discussion

Based on the NRC (14) recommendations, the GMPS of both L and S alfalfa hays was higher than 3 mm. This recommendation is related to optimal

ruminal pH, chewing activity, and milk fat concentration of dairy cows. Based on a previous work (8), in diets containing alfalfa hay, proportions of particles >19 mm, 19-8 mm, and <8 mm should be between 5% to 10%, 30% to 35%, and 53% to 65%, respectively. Due to the lowest and the highest particles being retained >19 mm (0%) and <1.18 mm (31%), respectively, a significantly lowest pef for SF containing ort resulted. As peNDF is a stimulatory fiber source for an indication of proper rumination along with salivary secretion, particle size of forages >1.18 mm is a sign of optimal milk fat content and ruminal pH in dairy cows (15). Based on this hypothesis, peNDF values of 19.7% and 22.3% are needed for 3.4% milk fat content and 6.0 of ruminal pH, respectively. In the present study, peNDF values of all diets are well above this recommendation level and only diets containing F corn grain had milk fat contents slightly less than 3.4% (refer to Table 3). However in all experimental diets, ruminal pH was reflecting the optimal peNDF value. A higher GMPS for LC and LF compared to SC and SF orts could be due to greater feed selection through longer particles (>19 mm).

Similar to the present study, a previous work (16) also found no DMI difference for cows consumed diets containing S (2.22 mm) and L (5.67 mm) alfalfa hay. It was also indicated that DMI is tended to be higher when animals are consumed shorter forage particles (17). In addition, dietary forage to concentrate ratio would be another reason for greater DMI of shorter particles of alfalfa hay where this is the only feed source in diets (17). In our study, the ratio of forage to concentrate was 50:50 and as a result alfalfa hay particle size might not have an effect on DMI, NDFI, and peNDFI.

Lack of milk yield response to alfalfa hay varying in different particle sizes (1.1, 2.2, 4.0, 5.7, 7.8 mm) was also found in previous studies (16,18). Although it is believed that long particle size of forages tend to increase milk fat content, closest particle lengths (4.9 vs. 3.1 mm) of alfalfa hay in our study might preclude this response. Reduction in milk fat content by smaller corn grain particles in the present study could be explained by a greater starch degradability in the rumen wherein lowered ruminal pH resulted (19).

Although times spent for eating, ruminating, and chewing were within the normal range (20), no

Table 3. Effects of alfalfa hay and corn grain particle size on nutrient intake, milk yield, and milk composition of dairy cows.

	Diet[1]					Effect (P-value)[2]		
Parameter	LC	LF	SC	SF	SEM[3]	HPS	CPS	HPS×CPS
DMI, kg/d	22.9	23.6	24.7	23.2	0.7	0.58	0.77	0.40
NDFI, kg/d	10.2	10.6	11.1	10.5	0.3	0.55	0.88	0.43
peNDFI[4], kg/d	3.53	3.48	3.63	3.13	0.11	0.59	0.27	0.34
Milk, kg/d	22.9	22.9	23.1	22.3	1.0	0.73	0.55	0.50
Fat, kg/d	0.83	0.76	0.81	0.71	0.04	0.40	0.07	0.79
Protein, kg/d	0.75	0.74	0.77	0.72	0.03	0.96	0.23	0.39
Fat, %	3.59	3.34	3.47	3.21	0.10	0.38	0.11	0.95
Protein, %	3.24	3.26	3.31	3.23	0.04	0.45	0.26	0.10

[1]LC: long alfalfa hay+coarse corn grain, LF: long alfalfa hay+fine corn grain, SC: short alfalfa hay+coarse corn grain, SF: short alfalfa hay+fine corn grain

[2]HPS: alfalfa hay particle size, CPS: corn grain particle size

[3]standard error of mean

[4]physically effective NDF intake; estimated by multiplying NDF intake by percentage peNDF of total NDF

significant difference was observed for respective parameters on treatment diets. A previous research study (21) recommended that chewing corrected for DMI could be a criterion for physical effectiveness of forages where the values equal to or more than 30 min/kg of DMI is suitable for limiting the risk of digestive upsets. In our study, all diets resulted in a higher value of chewing corrected for DMI (averaging 33.1 min/kg) as recommended.

In general ruminal pH values did not change abruptly with any treatment. However, diets containing S alfalfa hay had a greater post-feeding (9 and 12 h) ruminal pH. This could be related to greater cellulolytic degradation potential of those alfalfa hays. As opposed to our findings, others (22,23) found no ruminal pH difference with varying GMPS of alfalfa silage (4.1 vs. 6.8 mm) and hay (2.7 vs. 5.3 mm). Lack of ruminal pH response to different corn particle sizes could be due to greater buffering capacity of alfalfa hay (5).

In conclusion, the studied GMPS of alfalfa hays had no effect on milk yield and any milk composition. However diets containing C corn grain compared to F corn grain tended to increase milk fat yield. Although there was no adverse effects of any dietary treatment on ruminal pH, diets containing S alfalfa hay caused a significant increase on ruminal pH regardless of corn grain particle size. Based on the results from this study, lactating dairy cows can be fed the rations containing S alfalfa hay (>3 mm GMPS) within the range of proper peNDF without causing a negative effect on milk yield, milk composition, and ruminal pH.

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