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EFFECT OF REPLACEMENT OF ALFALFA HAY WITH STRAW IN ISO-FIBROUS DIETS WITH DIFFERENT LEVELS OF CATION-ANION BALANCE ON DAIRY COWS PERFORMANCE

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ABSTRACT

Effect of replacing alfalfa hay with wheat straw in iso-fibrous (35% NDF) diets with different levels of dietary cation-anion balance (DCAB) was studied by using eight mid-lactation Holstein cows blocked according to parity and milk yield in a 4×4 replicated Latin Square design. The treatments were 1) alfalfa hay (AH) with +35 meq, 2) wheat straw (WS) with +35 meq, 3) WS with +45 meq, and 4) WS with +55 meq (Na^+ + K^+)–Cl^-/100 g diet dry matter (DM). Treatment periods were 15 d with the first 10 d serving as an adaptation period. Forage to concentrate ratio decreased from 43:57 to 26:74 when WS was substituted for AH. Apparent digestibility of DM, organic matter (OM), and nitrogen (N), and DM disappearance rate at 24 h post-feeding decreased significantly in WS containing rations ($P<0.01$), but was not increased with increasing dietary cation-anion balance (DCAB) in WS rations. No significant differences were observed in DM intake. Actual milk yield and 4% fat-corrected milk (FCM) were not affected by the treatment. Milk fat percentage was significantly ($P<0.05$) higher in cows fed WS +55 compared to cows fed the other diets and lactose percentage was significantly ($P<0.05$) lower in cows fed WS +55

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compared to cows fed the WS+45. In conclusion, the WS diet with DCAB +55 meq/100g DM maintained actual milk yield and 4% FCM and resulted in higher milk fat percentage as compared with AH diet.

Key words: Cation-anion balance , Cows, Lactation, NDF, Wheat straw.

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تاثیر جایگزینی کامل یونجه با کاه گندم در جیره های دارای فیبر برابر و سطوح مختلف تعادل کاتیون- آنیون بر عملکرد گاوهای شیرده

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به ترتیب، دانشجوی پیشین دوره کارشناسی ارشد (اکنون دانشجوی دوره دکتری) و دانشیار گروه علوم دامی، دانشکده کشاورزی دانشگاه صنعتی اصفهان، اصفهان جمهوری اسلامی ایران.

چکیده

برای مقایسه یونجه با کاه گندم در تیمارهایی با دیواره سلولی برابر (۳۵ درصد) و تعادل کاتیون- آنیون متفاوت، ۸ گاو هولشتین که در میانه دوره شیردهی قرار داشتند، در یک طرح مربع لاتین ٤×٤ با ۲ تکرار، بر اساس میزان تولید شیر و تعداد زایش قرار داده شدند: ۱) علوفه یونجه با ۳۵+ میلی اکی والان، ۲) کاه گندم با ۳۵+ میلی اکی والان ، ۳) کاه گندم با ٤٥+ میلی اکی والان و ٤) کاه گندم با ٥٥+ میلی اکی والان متعادل کاتیون – آنیون به ازای هر ۱۰۰ گرم ماده خشک جیره. دوره هر تیمار۱۵ روز بود که ۱۰ روز اول برای عادت پذیری در نظر گرفته شد. نسبت علوفه به کنسانتره از ٤۳:٥۷ به ۲٦:۷٤ با جایگزینی کاه گندم بجای علوفه یونجه کاهش یافت. قابلیت هضم ظاهری ماده خشک، ماده آلی، نیتروژن و میزان ناپدید شدن ماده خشک در ۲٤ ساعت پس از تغذیه

در جیره های دارای کاه گندم نسبت به یونجه به طـور معنـی‌داری (P<۰/۰۱) کـاهش یافـت، ولـی بـا افزایش متعادل کاتیون – آنیون در جیره های دارای کاه گندم تغییـری نکـرد. تفـاوت معنـی داری در ماده خشک مصرفی بین تیمارها دیده نشد. تولید شیر واقعی و تولید شیر تصـحیح شده بر اسـاس ٤ درصد چربی، تفاوت آماری معنی داری نداشت. در جیره های دارای کاه گنـدم ، بـا افـزایش متعـادل کاتیون- آنیون، درصد چربی شیر به طور معنی داری (P<۰/۰۱) افزایش ولی درصد لاکتوز شیر) به طور معنی داری (P<۰/۰۵) کاهش یافت. بنابراین، جیره دارای کاه گندم با ۵۵+ میلـی اکـی والانـت در ۱۰۰ گرم ماده خشک، در مقایسه با جیره دارای علوفه یونجه، تولید شیر واقعـی و شـیر تصـحیح شده بر اساس ٤ درصد چربی را حفظ و درصد چربی شیر را افزایش داد.

INTRODUCTION

Neutral detergent fiber (NDF) has been proposed as an alternative for assessing total fiber content of feeds and formulating dairy rations (15, 31). Although much research has been done on fiber, the precise amount of fiber needed in diets remains unclear, primarily because many variables need to be considered (14). NDF content is closely related to digestibility (32) and the depression in digestibility occurs with increasing feed intake (18). Van Soest (31) found that NDF is highly correlated with intake, which in turn is associated with many physical factors such as bulk density or volume, rumination time, total chewing time, and the rate of particle size reduction required for feed to escape from the rumen (16, 28, 33). Mertens (16) evaluated the use of NDF in formulating rations for lactating dairy cows using coastal Bermuda grass hay, corn silage and alfalfa hay as forage sources, at four different percentages of NDF in the diet (35 to 55% of total DM). Rations containing 35% NDF resulted in highest production of 4% FCM across all three forage sources. However, cows consuming the 35% NDF ration based on alfalfa hay produced on average 3.4 kg d^{-1} more 4% FCM than cows consuming the corn silage diets, and 5 kg d^{-1} more 4% FCM than cows consuming the coastal Bermuda grass hay diets, suggesting that other factors affected milk production besides percent NDF in the diet. Van Soest *et al.* (32) suggested that higher intake of legume than grass based diets is due to faster rate of fermentation and greater buffer capacity of legume cell walls. Fiber sources with low cation exchange capacity tend to have a low buffering capacity, and long and slow rates of fermentation in the rumen (32).

Cereal straw is available in large amounts in many regions of the world and there has been considerable recent interest in using chopped straw in diets for lactating cows (4, 19, 24). When chopped wheat straw was substituted for part or all of the alfalfa hay in the diet, milk fat and 3.5% FCM decreased with increasing dietary straw (23).

Dietary cation-anion balance (DCAB), the balance of positively and negatively charged ions in the diet, is useful in predicting performance in non-ruminant and ruminant species (19, 29). Tucker *et al.* (29) observed an 8.6% increase in actual milk yield of cows when DCAB was +20 meq as compared with those fed a +10 meq 100 g^{-1}, diet DM. Ghorbani *et al.* (13) observed linear increases in DM intake and milk yield when DCAB ranged from +12 to +64 meq 100 g^{-1} diet DM. Electrolyte balance can affect acid-base balance in many species because of the respective deficit or excess in cation and anions present in the diet and their respective buffering capacity (9).

The objective of this experiment was to examine the effects of replacing alfalfa hay (AH) with wheat straw (WS) in diets containing 35% NDF and different levels of DCAB in WS containing rations on production responses of Holstein cows in mid-lactation.

MATERIALS AND METHODS

Eight lactating Holstein cows, 96-150 d post-partum, were arranged in a replicated 4×4 Latin Square design. Cows in each square were assigned according to parity and daily milk production (15-20 kg). Treatment periods were 15 d with the first 10 d serving as an adaptation period and the last 5 d as the data collection period (12). Cows were housed in individual tie stalls and diets as total mixed ration (TMR) were fed *ad libitum* twice daily at 8.00 and 16.00 o'clock. Diets were formulated to provide DCAB of +35, +45 and +55 meq (Na^+ + K^+) - Cl^-/100 g diet DM. These values were achieved via manipulation of dietary Na^+, K^+ and Cl^- concentrations. Diets were 1) alfalfa hay (AH) with +35 meq, 2) wheat straw (WS) with +35 meq, 3) WS with +45 meq, and 4) WS with +55 meq DCAB 100 g^{-1} diet DM. Diets were formulated to contain 35% NDF (Table 1).

Table 1. Composition of iso-fibrous (35% NDF) diets containing different cation-anion balance (DM basis).

	Dietary cation-anion balance			
Ingredients (%)	AH+35	WS+35	WS+45	WS+55
Alfalfa	43.00	-	-	-
Wheat straw	-	26.00	26.00	25.70
Barley	38.00	49.50	49.40	48.00
Wheat bran	10.90	10.30	10.20	10.20
Cotton seed meal	5.00	10.30	10.20	10.20
Potassium sulfate	0.27	0.28	0.28	0.95
Sodium bicarbonate	1.50	0.66	1.50	1.80
NaCl	0.53	0.55	-	-
Limestone	0.53	1.60	1.60	1.60
Urea	0.27	0.82	0.82	0.82

AH: Alfalfa hay WS: Wheat straw

Daily measurements included milk production and feed intake. Milk samples were collected weekly during three consecutive milking and analyzed for milk fat, protein, lactose, solids-not-fat (SNF) and total solids (TS) by Milk-O-Scan (133 BN, Foss Electric). Feed and fecal samples were taken at 8:00 and 18:00 o'clock for 5 consecutive days and the method of acid insoluble ash (30) was used as an indigestible marker for measuring the apparent digestibility.

Ruminal DM disappearance was estimated by the nylon bag technique in two fistulated sheep receiving the same diet as the experimental cows. For measurement of feces, urine and ruminal fluid pH, sampling was done at the end of each collection period. Samples of ruminal fluid were obtained via an esophageal tube; urine was collected by manual stimulation of the vulva and fecal materials via the rectum. Urine samples and rumen fluid was collected at 0, 2.5, and 5 h post-feeding and the pH was measured immediately by a portable pH meter.

Chemical analysis of the diets (Table 2) was made according to the methods of the Association of Official Analytical Chemists (1). Statistical analysis was done by Statistical Analysis Systems (SAS) general linear models procedure (27). The Duncan's test was used to compare treatment means with significant F values. Comparisons included diets with and without AH and also with different levels (+35, +45 and +55 meq 100 g^{-1}

DM) of DCAB. The model employed was $Y_{ijk} = \mu + C_i + P_j + T_k + E_{ijk}$, in which μ= overall mean, C_j= cow effect, p_j= period effect, T_k= treatment effect and E_{ijk}= residual.

Table 2. Chemical composition of the diets (DM basis).

Item	$(Na^+ + K^+) - Cl^-$, meq 100 g^{-1}			
	AH+35	WS+35	WS+45	WS+55
Dry matter (%)	93.00	94.00	94.00	94.00
Crude protein (%)	14.80	14.45	14.20	14.10
NE_l† (Mcal kg^{-1})	1.57	1.55	1.55	1.45
Ether extract (%)	4.00	3.20	3.10	3.05
Ash (%)	11.90	11.10	11.20	11.84
NDF (%)	36.50	35.50	35.50	35.50
ADF (%)	21.00	22.9.0	23.00	23.00
NSC§ (%)	33.6	35.95	36.5	35.51
FNDF¶ (%)	20.80	18.60	18.60	18.60
NSC:NDF	0.9:1	1:1	1:1	1:1
Ca†† (%)	0.80	0.73	0.74	0.74
P (%)	0.40	0.32	0.30	0.30
Na (%)	0.70	0.72	0.72	0.76
K (%)	0.99	1.07	1.07	1.31
Cl (%)	0.72	0.82	0.46	0.46

AH: Alfalfa hay; WS: Wheat straw.

† Net energy for lactating cows was calculated according to NRC (22).

§ Non- structural carbohydrates=100-[protein + lipid + NDF + ash]

¶ FNDF=NDF from forage.

†† Minerals were analyzed by AOAC methods (1).

RESULTS AND DISCUSSION

Feed Intake

Dry matter intake (Table 3), and NDF intake based on DM and body weight percent (Table 4) were not influenced by forage NDF or DCAB levels in the diets and averaged 20.4 kg, 1.28%, and 7.27 kg, respectively. Poore *et al.* (25) also observed no differences in DMI of the cows receiving AH or WS. Tucker *et al.* (29) and West *et al.* (36) observed a linear increase in voluntary feed intake as DCAB increased. Summarizing several experiments, Mertens (17) suggested an NDF intake of 1.2 ± 0.1% of BW for maintaining milk production in cows from mid to late lactation. At all stages of lactation, total intake of NDF and ADF were increased by increasing DCAB (5, 8, 9, 21).

Apparent Digestibility of DM, OM and N

The apparent digestibility of DM, OM and N was significantly affected by forage source (Table 4) and cows fed AH+35 had a significantly higher digestibility compared to all other treatments. It is recommended (16) that at least 21% of the diet DM should consist of NDF from forages, and that forages should provide 75% of the total diet NDF. On this basis, diets in the present study were low in forage NDF especially for rations containing WS, and the decreasing contribution of forage to total diet NDF as WS content of diets increased probably contributed to the observed differences in DM, OM, and N digestibility and DM disappearance. As AH was replaced by WS, the barley grain also increased. Barley starch is highly degradable in the rumen and could exert a negative effect on digestibility (26). Montgomery and Baumgardt (20) reported that with increasing WS percentage in the diet, the apparent digestibility of DM and energy decreased, but the protein digestibility did not change. Delaquis and Block (9) reported that increasing DCAB in early and mid-lactation without altering DM digestibility increased the body weight significantly. Although intake, absorption, retention and balance of N were increased by a higher DCAB in mid-lactation, the effects were not detected in late lactation (8).

NSC to NDF Ratio and Forage NDF

Regardless of DCAB, major differences between treatment AH +35 and other treatments (Table 2), were only the NDF type (alfalfa hay vs. WS). The treatments were almost similar in NDF content and NSC to NDF ratio. There were no differences between AH and WS for milk yield, composition, and pH, but NDF type appeared to influence the apparent digestibility. Even though total NDF was maintained, forage NDF decreased from 20.8 to 18.6% as the forage type in the diets changed from all AH to all WS (Table 2). Varga and Hoover (34) found that in addition to dietary NDF content and type, NSC to NDF ratio also affected milk yield. Nocek and Russell (23) reported that milk yield was maximized when the ratio of NSC to NDF was between 0.9 and 1.2, in the diet, whereas Poore *et al.* (25) suggested a 1:1 ratio. Beauchemin and Rode (3) found that the best performance was achieved when the ratio of NSC to NDF in barley containing diets was 0.9. The NSC: NDF ratio in this study was almost 1:1.

Table 3. Feed intake, milk yield, milk composition and efficiency of cows fed diets containing forage NDF from alfalfa hay or wheat straw with varying cation-anion balance.

	$[(Na^+ + K^+) - Cl^-]$ meq 100 g^{-1}					Effect	
Items	AH^1+35	WS^2+35	WS+45	WS+55	SEM	F^3	B^4
DMI (kg d^{-1})	20.36^a	20.18^a	20.35^a	20.62^a	0.39	NS^5	NS
Actual milk yield (kg day^{-1})	17.09^a	15.85^a	15.98^a	16.00^a	0.37	NS	NS
4% FCM (kg day^{-1})	16.0^a	15.30^a	15.80^a	16.20^a	0.32	NS	NS
Fat (%)	3.56^b	3.63^b	3.70^b	3.90^a	0.63	NS	0.01
Fat (kg day^{-1})	0.6^a	0.57^a	0.59^a	0.63^a	0.02	NS	NS
Protein (%)	3.66^a	3.62^a	3.62^a	3.67^a	0.02	NS	NS
Protein (kg day^{-1})	0.63^a	0.57^a	0.58^a	0.59^a	0.02	NS	NS
Lactose (%)	4.91^{ab}	4.90^{ab}	4.96^a	4.81^b	0.04	NS	0.05
Lactose (kg day^{-1})	0.84^a	0.78^a	0.79^a	0.77^a	0.04	NS	NS
Total solids (%)	12.13^a	12.20^a	12.23^a	12.37^a	0.07	NS	NS
Solids-not-fat (%)	8.57^a	8.57^a	8.52^a	8.47^a	0.04	NS	NS
Efficiency (FCM:DMI)	0.79^a	0.76^a	0.78^a	3.67^a	0.02	NS	NS

1= AH: Alfalfa hay; 2- WS: Wheat straw, 3= Main effect of forage NDF source; 4= Main effect of cation-anion balance; 5= Non-significant.

a, b Within each row, means with similar superscripts are not significantly different (P<0.05).

Table 4. NDF intake, digestibility, DM disappearance rate and pH changes in cows fed diets containing forage NDF from alfalfa hay or wheat straw with varying cation-anion balance.

Items	$[(Na^+ + K^+)- Cl^-]$ meq 100^{-1}g				SEM	Effect	
	AH[1]+35	WS[2]+35	WS+45	WS+55		F[3]	B[4]
NDF intake (% of BW)	1.30^a	1.25^a	1.27^a	1.29^a	-	-	-
NDF intake (kg d^{-1})	7.40^a	7.13^a	7.23^a	7.32^a	0.20	NS[5]	NS
Digestibility (%)							
DM	78.27^a	67.95^b	68.10^b	68. 78^b	0.44	0.01	NS
OM	79.69^a	69.00^b	69.03^b	69.76^b	0.43	0.01	NS
N	80.40^a	72.62^b	72.97^b	73.60^b	0.59	0.01	NS
DM disappearance rate[6]	76.62^a	66.00^c	68.50^b	69.20^b	0.18	0.05	0.05
pH							
Ruminal fluid	7.18^a	7.14^a	7.30^a	7.34^a	0.08	NS	NS
Feces	6.82^a	6.75^a	6.75^a	6.65^a	0.08	NS	NS
Urine	8.40^a	8.34^a	8.31^a	8.39^a	0.05	NS	NS

1-AH: Alfalfa hay; 2- WS: Wheat straw, 3= Main effect of forage. NDF source; 4= main effect of cation-anion balance; 5=Non-significant; 6=After 24 h post-feeding ($\%h^{-1}$).

a,b : within each row, means with similar superscripts are not significantly different ($P<0.05$)

Milk Yield and Composition

The milk yield and composition data are shown in Table 3. Actual milk yield, 4% FCM yield, and milk composition except for milk fat percentage were not influenced by forage NDF source and increasing the DCAB in rations containing WS.

Milk fat percentage was significantly ($P<0.05$) higher in cows fed WS +55 compared to cows fed the other diets. This was probably the result of increasing the cations in the rations. Several studies (6, 10, 35) showed that NDF source had a significant effect on FCM yield. Substitution of WS in diets of lactating cows with AH showed that milk yield (2, 25, 26) 3.5% FCM yield, milk fat percentage, milk lactose percentage, protein percentage and SNF (25, 26) were unaffected by forage type. But Brown *et al.* (7) reported that with increasing the substitution level of AH with WS, milk fat percentage, and FCM yield increased. Tucker *et al.* (29) and West *et al.* (37) reported that with increasing DCAB, the actual milk yield increased linearly.

Milk lactose percentage was unaffected by forage source in the diets, but significantly decreased ($P<0.05$) in cows fed WS +55. Poore *et al.* (25) and West *et al.* (37) found that with increasing DCAB, milk protein percentage increased, but Tucker *et al.* (29) and Ghorbani *et al.* (13) reported that milk protein percentage decreased with increasing DCAB.

DM Disappearance Rate

DM disappearance rate in the rumen at 24 h post-feeding was significantly higher ($P<0.05$) for cows fed AH +35 compared to cows receiving WS. Among the cows receiving WS, cows fed WS+35 had a significantly lower ($P<0.05$) DM disappearance rate (Table 4). With replacement of AH with WS, DM disappearance rate at 24 h post-feeding decreased by 10.6% points. Probable reasons for this difference are: 1) concentrate percentage in WS containing rations was higher than in the AH containing diet, and 2) degradability rates of WS vs. AH are different. In the WS containing rations, with increasing DCAB from +35 to +55 meq 100 g^{-1} diet DM, DM disappearance rate increased significantly; this is probably the result of an increase in ruminal cation capacity and increasing rumen microbial activity, especially of cellulolytic bacteria.

Ruminal Fluid, Urinary and Fecal pH

The total ruminal fluid pH is presented in Table 4. Ruminal fluid pH was unaffected by forage type and DCAB. The high rumen pH levels indicate probable salivary contamination.

The urinary pH was not affected by the forage type and DCAB (Table 4). These results are in agreement with the results reported by Ghorbani *et al.* (13), Tucker *et al.* (29) and West *et al.* (37).

The fecal pH was also unaffected with replacement of AH with WS (Table 4), or increasing the DCAB in diets containing WS. Escobosa *et al.* (11) reported that fecal pH was higher for cows fed large amounts of chloride (Negative DCAB). Their observation may be a result of increased exchange of HCO_3^- with Cl^- in the large intestine.

CONCLUSIONS

Diets containing equal NDF from alfalfa hay and WS were consumed in similar amounts by lactating cows and supported similar milk level. It is suggested that formulating diets with an NDF:NSC ratio of 1:1 and a DCAB of 35-55 meq 100 g^{-1} DM would enable substitution of higher quality forage with low quality forage. Apparent digestibility of DM, OM, N and DM disappearance rate at 24 h post-feeding were significantly affected by the forage source. In WS containing rations, milk fat percentage and DM disappearance rate increased significantly with increasing DCAB; however, milk lactose percentage showed a non-significant decrease. Manipulation of DCAB in WS containing rations may have useful effects on the performance of lactating cows.

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