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EFFECTS OF SUBSTITUTING SORGHUM GRAIN FOR BARLEY ON MILK YIELD AND COMPOSITION OF DAIRY COWS

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ABSTRACT

A 5×5 Latin-square experiment (21-d periods) was conducted to measure the effects of replacing of barley by sorghum grain on milk yield, milk composition, feed efficiency, dry matter intake (DMI), body weight and apparent digestibility of organic matter (OM). Five primiparous and five multiparous (n=10) lactating Holstein cows, 85±10 d in milk, were given a total mixed ration of 46: 54 forage: grain ratio (DM basis). Sorghum grain substituted barley in ratios of 0:100, 25:75, 50:50, 75:25 and 100:0 in diets 1, 2, 3, 4 and 5, respectively. The results showed significant differences ($P<0.05$) in many parameters in response to increasing sorghum levels. Diet 5 showed higher DMI (20.3 vs. 19.4 kg d^{-1}), daily milk yield (25.8 vs. 24.8 kg d^{-1}), production of 3.2 % FCM (27.4 vs. 24.7 kg d^{-1}), milk fat (3.58 vs. 3.02 %), fat yield (0.92 vs. 0.75 kg d^{-1}), milk protein (3.0 vs. 2.7 %), protein yield (0.75 vs. 0.67 kg d^{-1}), milk lactose (4.93 vs. 4.47 %) and milk solids-not-fat (8.58 vs. 8.17 %), as compared with diet 1. However, feed efficiency, body weight, and apparent

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digestibility of organic matter were not affected by any of the treatments (P>0.05). It is concluded that substitution of sorghum grain for barley may manipulate rumen metabolism and improves milk composition.

Key words: Dairy cows, Milk, Sorghum.

تحقیقات کشاورزی ایران

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جایگزینی سورگوم دانه ای به جای جو در جیره گاوهای شیری و اثر آن بر تولید و ترکیب شیر

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به ترتیب دانشجوی سابق کارشناسی ارشد (کارشناس ارشد مرکز تحقیقات منابع طبیعی و امور دام جهادسازندگی استان اصفهان)، دانشیار گروه علوم دامی دانشکده کشاورزی دانشگاه صنعتی اصفهان و استاد یاران گروه علوم دامی دانشکده کشاورزی دانشگاه صنعتی اصفهان، اصفهان، جمهوری اسلامی ایران.

چکیده

به منظور بررسی جایگزینی دانه سورگوم به جای جو در جیره گاوهای شیری و اثر آن بر تولید و ترکیب شیر، تعداد ۱۰ رأس گاو نژاد هولشتین (پنج رأس در زایش اول و پنج رأس در زایش دوم به بعد) که در فاصله ۱۰± ۸۵ روز بعد از زایش بودند، انتخاب شدند. دانه سورگوم به نسبت های صفر، ۲۵، ۵۰، ۷۵ و ۱۰۰ درصد به ترتیب در جیره های شماره یک تا پنج جایگزین جو گردید. این آزمایش در قالب طرح مربع لاتین ۵ ×۵ طی دوره های آزمایشی ۲۱ روزه انجام شد. جیره های کاملاً مخلوط، شامل مواد متراکم و علوفه به نسبت ۵۴ به ۴۶ درصد بود. با افزایش دانه سورگوم در

جیره ها، بسیاری از معیارهای مورد بررسی تفاوت معنی داری را نشان دادند (P<۰/۰۵). جیره شماره ۵ در مقایسه با جیره شماره ۱ باعث افزایش مصرف ماده خشک روزانه (۱۹/۴۰ در برابر ۲۰/۳۰ کیلوگرم)، تولید شیر روزانه (۲۵/۸ در برابر ۲۴/۸ کیلو گرم در روز)، درصد چربی شیر (۳/۵۸ در برابر ۳/۰۲)، مقدار چربی تولید شده در روز (۰/۹۲ در برابر ۰/۷۵ کیلو گرم) ، در صد پروئین شیر (۳/۰ در برابر ۲/۷)، مقدار پروئین تولید شده در روز (۰/۷۵ در برابر ۰/۶۷ کیلو گرم)، درصد لاکتوز (۴/۹۳ در برابر ۴/۴۷) و درصد مواد جامد بدون چربی (۸/۵۸ در برابر ۸/۱۷) شد. ضریب تبدیل خوراک، وزن بدن، قابلیت هضم ظاهری ماده آلی، pH ادرار و pH شکمبه تحت تاثیر سطوح مختلف جایگزینی سورگوم به جای جو قرار نگرفت (P>۰/۰۵). استفاده از دانه سورگوم به جای جو بهبود قابل ملاحظه ای در میزان تولید و ترکیب شیر گاوها ایجاد کرد.

INTRODUCTION

Cereal grains furnish a high portion of energy in the form of dietary starch in dairy cow diets. Starch forms about 25 to 30% of dry matter (DM) in diets of high-yielding cows. Thus, efficient utilization of starch is fundamental to improve feed efficiency in lactating dairy cows (4). Barley is an important component of dairy concentrates in many parts of the world (2). Waldo (30) reported that 94% of barley starch was fermented in the rumen compared with only 74% of corn starch. Because of the differences in starch availability among cereals, type of cereal is related to milk fat composition (22). High ruminal fermentability of barley starch increases risk of acidosis occurrence and decreases ruminal digestion of fiber (11, 14).

Sorghum grain has a resistant protein matrix and corneous endosperm. Because of these characteristics, starch degradability of sorghum grain by ruminal bacteria is reduced and is slower than starch degradability of corn, oats, or barley (19). Utilization of a mixture of ruminally degradable and undegradable starch is more preferable. Digestion of starch in the small intestine has been suggested to be energetically more efficient than that

degraded in the rumen (16). However, starch degraded in the rumen supports synthesis of microbial protein and volatile fatty acids (VFA) (18). Meanwhile, rapid or excessive degradation of starch might induce ruminal acidosis and decrease milk fat content (23). Conversely, too much undegraded starch existing in the rumen may exceed the digestive and/or the absorptive capacity of the small intestine or both (14, 16).

The objectives of this study were to determine the effects of substituting sorghum for barley grain on milk yield, milk composition, dry matter intake (DMI), feed efficiency, apparent digestibility of organic matter (OM), and ruminal pH.

MATERIALS AND METHODS

Five primiparous and five multiparous lactating Holstein cows averaging 85±10 d in milk and milk yield of 28± 4 kg d^{-1}, were arranged in a replicated 5×5 Latin-square experiment, with primiparous and multiparous cows in separate square (21-d periods). Barley, which comprised 16.24 % of DM for control diets, was replaced by sorghum grain in ratios of 0, 25, 50, 75 and 100% of the concentrate portion of the diets. Chemical composition of barley and sorghum is shown in Table 1. Based upon dry matter a total mixed ration (TMR) was used for all treatments, containing a forage:grain ratio of 46:54 (Table 2). Sorghum and barley were finely ground, with a mean particle size of about 1 mm. The animals were divided into two blocks, based on lactation number. The first block (n=5) was composed of first lactation cows, and the second block (n=5) included multiparous ones. Treatment periods lasted 21 d, including 14 d of adaptation and 7 d for measurement of animal responses. The diets were balanced to meet NRC recommendations for energy, protein, calcium and phosphorus (13). Acid-insoluble ash (AIA) was used as an internal marker for determining apparent digestibility (5, 27, 28). Cows were fed *ad libitum* three times daily in individual stanchions at 07:00, 15:00 and 23:00 h. Cows were offered sufficient feed throughout the trial to have 5% feed refusals. The animals had free access to water and salt.

Table 1. Chemical composition of barley and sorghum grains.

	DM %	NEL Mcal kg^{-1}	CP %	CF %	EE %	Ash %	Ca %	P %
Sorghum	95.6	1.82	11.0	2.30	3.5	1.43	0.04	0.38
Barley	91.9	1.94	12.2	5.95	2.05	3.5	0.05	0.30

NEL, Ca and P values were taken from NRC (13).

Feed consumption was recorded daily and samples of the diet were collected daily and composited weekly. A portion of each daily sampling was dried at 55°C for determination of dry matter. The remainder was stored for analysis. Fecal samples were taken from the rectum twice daily during each collection period (15 to 21d), composited for each cow, and frozen for later analysis. Body weights were recorded at the end of each period after a 12 h fasting.

Table 2. Ingredients and chemical composition of the diets (DM basis).

	Substitution of sorghum for barley in concentrate (%)				
Item	0	25	50	75	100
Ingredients (%)					
Corn silage	38.20	38.20	38.20	38.20	38.20
Beet pulp	8.00	8.00	8.00	8.00	8.00
Sorghum	0.00	4.10	8.15	12.11	16.12
Barley	16.24	12.10	8.13	4.02	0.00
Cotton seed meal	18.62	18.16	19.20	19.43	19.60
Wheat bran	14.83	14.50	14.84	14.76	14.60
Sodium bicarbonate	0.80	0.80	0.80	0.80	0.80
Dicalcium phosphate	0.50	0.50	0.50	0.50	0.50
Urea	0.40	0.40	0.40	0.40	0.40
Calcium carbonate	1.12	1.13	1.13	1.13	1.13
Minerals and vitamins	0.50	0.50	0.50	0.50	0.50
Salt	0.15	0.15	0.15	0.15	0.15
Chemical composition					
DM %	46.37	46.47	46.60	46.72	46.82
OM %	90.79	90.58	90.39	90.97	90.97
NEL, (Mcal kg^{-1})	1.54	1.54	1.55	1.55	1.54
CP %	15.56	15.55	15.55	15.61	15.60
ADF %	23.94	23.70	23.90	24.51	24.01
NDF %	38.70	38.30	37.80	37.40	37.20
Ca %	1.10	1.09	1.10	1.10	1.10
P %	0.66	0.66	0.65	0.65	0.65
AIA %	1.44	1.43	1.42	1.38	1.36

NEL, Ca and P values were obtained from NRC (13).

The cows were milked three times daily and the milk was weighed and recorded. Milk samples were collected three times daily during the last 7 d of each treatment period, composited for each cow and analyzed for fat, protein, lactose, and solids-not-fat (SNF) by Milk -O- Scan (134 BN Foss Electric). Fat-corrected milk (FCM) was calculated by the formula of Overman and Gains (15). Composite feed and fecal samples were dried at 55°C for 72 h and ground with a cyclone mill to a maximum particle size of 2 mm. Samples were analyzed for DM, ash and N (1), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid insoluble ash. NDF and ADF were determined by the method used by Van Soest (28) and Cherney *et al.* (5). AIA was used as an internal indigestible marker to determine apparent digestibility of dietary fractions.

Samples of ruminal fluid, urine and feces were collected via an esophageal tube, manual stimulation of the vulva, and directly from the rectum, respectively. Ruminal fluid was collected on the last d of each period at 0, 2, 4 and 6 h post-feeding. Ruminal fluid was collected from five multiparous cows (one of the squares). Samples of fecal material and urine were obtained 4 h after feeding for pH determination.

Data on feed intake, apparent digestibility, feed efficiency, milk yield, milk composition and urinary and fecal pH were analyzed in a replicated 5×5 Latin square design, with 21 d period. The following model was used for analysis of data:

$$Yijk = \mu + Si + Cij + Pik + Rj + eijk$$

where:

μ = mean

Si = square replicate

Cij = cow effect within square

Pik = period effect within square

Rj = treatment effect

eijk = residual (error)

Data on ruminal pH were analyzed only for one of the squares and the model used was:

$$Yij = \mu + Ci + Pj + Rj + eij + Tijk$$

where:

μ = mean

Ci = cow effect

Pj = period

Rj = treatment effect

eij = experimental error

Tijk = sampling error

The data were analyzed by using the general linear models procedures of SAS (20), and the difference between means was determined by Duncan's test (6).

RESULTS AND DISCUSSION

The DM intake was higher ($P<0.05$) for cows fed ration 5 (100% sorghum substitution) than for all other rations (Table 3). Dietary NDF for barley containing diets in this study was about equal with the diets containing sorghum (Table 2). In studies in which feeding of barley depressed DMI, dietary NDF was greater for barley containing diets (7). Several percentages increase in NDF may have resulted in the DMI depression observed by others (3). However, the current study does not agree with previous researchers (8, 10, 19) who reported lower palatability for sorghum than barley. Milk yield and composition values are summarized in Table 3. Milk production and yield of 3.2 % FCM of cows fed concentrates based on sorghum and sorghum mixture (ration 2-5) were similar or greater than the cows fed 100% barley (ration 1). Milk production was significantly increased ($P<0.01$) as the ratio of sorghum in the ration increased. However, milk production and the yield of 3.2% FCM of cows fed ration 5 were significantly higher for cows fed ration 1.These results are in contrast with those of Tommervik and Waldern (26) who found no differences between sorghum, barley, corn, oats and wheat for milk yield but are in agreement with those of Herrera-Saldana, and Huber (9). Possible explanations for higher milk production are: 1) higher DM intake and 2) greater supply of digested nutrients. Rooney and Pflagfelder (19) also suggested that when diets were based on corn, the shift in the site of starch digestion in intestine probably increased the availability of

glucose for lactose synthesis. This might have been responsible for the increased milk production of cows fed sorghum diets.

No differences (P>0.05) were noted in the percentage and yield of milk fat and protein and the production for the rations containing sorghum grain (rations 2-5), whereas, ration 1, containing 100% barley, caused a significant depression (P< 0.05) in yield and the percentage of milk fat and protein. The reason that cows fed barley had lower milk fat percentage may be due to greater solubility of non-starch carbohydrates in barley. Orskov (14) suggested that increased ruminal starch degradation would decrease milk fat percentage. Waldo (30) reported that 94% of barley starch fermented in rumen as compared to only 74% of corn starch. Because of the differences in starch availability among cereals, type of cereal is related to milk fat composition.

Table 3. Feed intake and milk production of cows with sorghum substituted for barley in the diets.

Item	Replacement in the diets† (%)					SEM
	0	25	50	75	100	
DMI, kg d^{-1}	19.40^{b}	19.20^{b}	19.40^{b}	19.50^{b}	20.30^{a}	0.25
OMI, kg d^{-1}	17.46^{b}	17.25^{b}	17.39^{b}	17.68^{b}	18.32^{a}	0.22
Total milk production, kg	24.80^{b}	25.30^{ab}	25.23^{ab}	25.50^{ab}	25.80^{a}	0.29
3.2 % FCM, kg	24.10^{b}	26.80^{ab}	26.40^{ab}	27.00^{ab}	27.40^{a}	0.38
Fat, kg	0.75^{b}	0.90^{a}	0.88^{a}	0.91^{a}	0.92^{a}	0.01
Protein, kg	0.67^{b}	0.74^{a}	0.75^{a}	0.76^{a}	0.77^{a}	0.01
Body weight, kg	551.20^{a}	548.10^{a}	550.80^{a}	549.60^{a}	556.50^{a}	2.84
Feed efficiency§	1.27^{a}	1.31^{a}	1.29^{a}	1.30^{a}	1.28^{a}	0.01
Milk composition%						
Fat	3.02^{b}	3.56^{a}	3.48^{a}	3.55^{a}	3.58^{a}	0.06
Protein	2.70^{b}	2.93^{a}	2.97^{a}	2.98^{a}	3.00^{a}	0.04
Lactose	4.47^{b}	4.87^{a}	4.90^{a}	4.90^{a}	4.93^{a}	0.06
SNF	8.15^{b}	8.52^{a}	8.57^{a}	8.57^{a}	8.58^{a}	0.07

† Refer to the percentage substitution for sorghum.

§ Efficiency was calculated by dividing milk production (kg d^{-1}) by DMI (kg d^{-1}).

a, b Means within a row with a common superscript do not differ (P>0.05).

The average dry matter intake and structural fiber were adequate for normal fat production, since the rations contained approximately 24% ADF and appeared to be adequate to avoid milk fat depression (21). The ADF content of the rations in this trial ranged from 23.93 to 24.52%. However, despite all diets being adequate for ADF content, ration 1 (100% barley)

resulted in lower percentage of milk fat, which may be associated with higher degradability of barley starch.

A consistent increase in milk protein content and yield was observed for diet 5 (Table 3). One possible reason for this effect is that the diets containing sorghum provided an increased supply of energy and essential amino acids to the mammary gland. Thomas (25) also suggested that cereal type may affect milk protein. No significant differences ($P>0.05$) were noted for the SNF and lactose percentage in the rations containing sorghum. While the values were significantly lower for 100% barley ration (Table 3). The body weight (BW) changes during the experimental period were unaffected by grain source. Cows fed rations 2, 3, and 4 were still able to maintain acceptable milk production, compared to ration 5 despite lower DMI (Table 3). Variation in feed efficiency was not significant among treatments. Therefore, no differences for apparent digestibility of OM were observed among the rations. Urinary pH and ruminal pH were not affected by the treatments (Table 4). Despite of the high ratio of concentrate in the rations, the pH of ruminal fluid was considerably higher than the minimal value of 6.0 suggested by Owens and Goetsh (17) to be detrimental for ruminal cellulolytic bacteria. The high pH levels indicate probable salivary contamination. Significant differences ($P<0.05$) existed between all the diets for fecal pH (Table 4). Cows fed diets containing sorghum (2 - 5) had lower fecal pH than diet 1.

Table 4. Digestibility and ruminal, urinary and fecal pH's of different diets.

	Replacement in the diets (%)					
Item	0	25	50	75	100	SEM
Ruminal pH	6.31^{a}	6.33^{a}	6.33^{a}	6.34^{a}	6.39^{a}	0.04
Fecal pH	6.70^{a}	6.59^{b}	6.55^{bc}	6.48^{cd}	6.41^{d}	0.03
Urine pH	7.47^{a}	7.72^{a}	7.84^{a}	7.83^{a}	7.82^{a}	0.05
Digestibility of OM%	62.40^{a}	61.50^{a}	60.10^{a}	59.40^{a}	60.00^{a}	1.45

a, b, c, d Means within a row with common superscripts do not differ ($P>0.05$).

Since sorghum grain is digested more slowly than barley and particle size of ground sorghum is larger than particle size of ground barley, more sorghum grain passes to the large intestine than barley. Finer particles are

digested more than coarse particles and tend not to be transfered to the feces to the same extent (12, 19, 21, 24). In conclusion, utilization of sorghum grain in diets of lactating cows significantly improved milk yield and milk composition when compared with barley. The diet of 100% sorghum grain was notably superior to the 100% barley diet.

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