

Reproductive Responses, Metabolic Disorder, Ruminal Fermentation Characteristics, and Milk Production of Postpartum Holstein Cows Fed Steam Flaked of Corn and Barley Grains

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ABSTRACT

This study evaluated the effects of steam flaked of corn and barley grains on the reproductive response, ruminal fermentation characteristics, metabolic disorder, and milk production of postpartum Holstein cows. A total of 40 postpartum Holstein dairy cows were divided into 4 groups (n=10) and fed 1) ground grains (control), 2) steam flaked corn+milled barley, 3) steam flaked barely+milled corn, and 4) steam flaked corn and barley. The animals were treated for 0-30, 30-60, 60-90, and 90-120 days post-calving. Milk yield and compositions, total conception rate, endometritis, pyometra, ruminal fermentation characteristics, ketosis, and acidosis were assessed. This study was conducted in a completely randomized design. The results showed that dietary inclusion of steam flaked grains improved milk yield and compositions during the experimental period compared to the control group ($p<0.05$), except for cows treated for 0-30d days post-calving. Cows fed steam flaked grains showed a lower occurrence of reproduction and metabolic disorders compared to the control group ($p<0.01$). Cows fed a combination of steam flaked grains showed better pregnancy rates in the first 100 days and open days of postpartum cows compared to cows in control and a single form of steam flaked barley or corn ($p<0.05$). Total VFA, acetate, propionate, butyrate, and valerate were higher in cows fed steam flaked compared to the control group ($p<0.05$). Feeding steam flaked grains is advised for improving reproductive performance, milk variables, and rumen fermentation profiles in dairy cows.

Keywords: corn flaked; metabolic disorder; postpartum cow; reproduction performance

INTRODUCTION

Dairy cows produce a significant amount of milk (Atmakusuma *et al.*, 2019), but dairy husbandry faces major challenges for management and improvement of reproductive disorders and milk production during postpartum. Metabolic and reproductive disorders with the intensification of milk production have received much attention in high-producing dairy cows (Dobson *et al.*, 2008). The influence of dietary factors may positively and/or negatively influence microbial enzyme activity and animal production (Moharrery *et al.*, 2017).

Feed processing technology has received a growing interest in increasing the nutrient supply and nutritive value of feed in the diets of dairy cows during the recent decade. Feed grains containing starch such as barley and corn need processing prior to feeding for increasing accessibility of the endosperm by microbes in the rumen and the host enzymes in the intestine (Safaei & Yang, 2017). To provide high energy in dairy cow diets, the cereal grains are included and/or cereal starch is processed (Corato *et al.*, 2005; Koing & Beauchemin, 2011). Heat treatment of cereal grains by using high moisture may improve their feeding values for ruminants by influenc-

ing the total tract starch and protein digestions and their post-ruminal digestion during the steam flaking process (Zinn *et al.*, 2002, Razzaghi *et al.*, 2016). The steam flaking of cereal grains improves digestibility because this process causes physical damage to the starch-protein matrix, granule structure, and the starch gelatinization (Kokić *et al.*, 2013). Food processing increases the nutrient availability and causes a balance between maximizing and controlling the rate of starch digestion in the rumen (Koing & Beauchemin, 2011). A large scale of steam flaked corns is used in the dairy ration for maintaining a high level of milk production (Xu *et al.*, 2018). A few studies have also evaluated the effect of cereal grains processing methods on postpartum performance in the dairy cow industry. Nikkhah *et al.* (2004) showed that the inclusion of steam-flaked broom sorghum versus ground broom sorghum is a more efficient source of energy in lactating cows. Safaei *et al.* (2016) showed that processing methods such as steam flaking improves performance and feed utilization in dairy cows fed low-forage diets. It was reported that the steam flaking process of grains increases the proportion of fermented starch in the rumen and its intestinal digestion that increases the available energy for milk production (Theurer *et al.*,

1995). Seemingly, steam flaking can have beneficial effects on dairy cows. However, any study has not been conducted to evaluate the effects of steam flaking of barley and corn grains on the reproductive response, ruminal fermentation characteristics, and milk production of postpartum Holstein cows. This study was thus conducted for the first time to investigate the effects of steam flaking of barley and corn grains on ruminal fermentation characteristics, reproductive response, and milk production of postpartum Holstein cows.

MATERIALS AND METHODS

Location and Grain Processing

This study was performed at a dairy farm in Qom Province, Iran (34°40'N and 51°0'E) from January to April 2018. Qom Province is a region with annual temperature in the range from -10°C (January) to 45°C (July) with an average humidity of 30%. Barley and corn ground grains were obtained from one source that was used in all of the studies. Cereal grains were ground by a hammer mill (screen size= 3 mm). The barley and corn grains were firstly screened for removing small kernels and chaff, then steamed (inlet temperature of 60°F and outlet temperature of 212°F and PSI= 113.4) in a vertical steam chamber (stainless steel) for 30 min and then flaked by large rollers (46×90 Flaking Mill, Ferrell-Ross, Amarillo, factory of Aryadan, Khorasan-Razavi, Province) to obtain the desired flake density (360 g/L). The grains were dried processed by a clean and concrete commodity shed, transferred into the farm, and mixed with the other ingredients in a feed mixer.

Animals and Experimental Procedures

Forty postpartum multiparous lactation Holstein cows with a weight mean of 570±40 kg and milk yield mean of 30.00±2.1 kg/day were used in a completely randomized design. All the used procedures were in agreement with the Animal Care and Use Committee of Islamic Azad University, Arak Branch (IAUA4506). Cows were divided into 4 groups (n=10) and fed diets containing 1) Ground grains (control); 2) Steam flaked corn+milled barley (SCMB); 3) Steam flaked barley+milled corn (SBMC); and 4) Steam flaked corn and barley (SCB) for a 120-day period after calving. Diets were prepared on the basis of NRC requirements (NRC, 2001) for dairy cattle. Animals had free access to water and fed a total mixed ration twice at a day (09:00 and 17:00 h). All the feed ingredients were analyzed for chemical composition (Table 1).

Milk Production and Compositions

To determine milk production and compositions, milk yield was automatically recorded in four periods of 0-30, 30-60, 60-90, and 90-120 days after calving in the voluntary milking system after each milking (04:00 am, 12:00 pm, and 20:00 pm) and milk compositions (fat and protein) were weekly analyzed in all experimental period at the laboratory by a MilkoScan FT 120 (FOSS

Electric A/S, Hillerød, Denmark). A direct aseptic collection from the udder was used for the collection of samples through a sterile cannula.

Reproductive Performance

To evaluate the effects of the treatments on reproductive performance, the pregnancy rate in the first 100 days, total conception rate, average days to the first service (DFS), and open days. Diameters and the number of mature follicles were assessed by ultrasonography apparatus. The pregnancy rate in the first 100 days was defined as the percentage of cows confirmed pregnant within 100 days of calving, DFS was defined as mean days to the first service, and open days were defined as days from calving to conception, and total conception rate (%) was reported as the number of cows considered as pregnant in a period divided by the total number of inseminated cows.

Cows were inseminated after showing signs of heat. Pregnancy status was determined 3 times after artificial insemination (AI). To investigate the pregnancy status, milk progesterone concentration was measured on day 21 after AI by kits produced by OvuCheck Milk test Company (Biovet Inc., Canada) and trans rectal palpation and trans rectal ultrasonography were con-

Table 1. Feed and chemical composition of experimental diets

Item (%)	Treatments			
	Control	SCMB	SBMC	SBC
Alfalfa hay	19.95	19.95	19.95	19.95
Corn silage	22.0	22.0	22.0	22.0
Ground barley	15.03	15.03	0	0
Ground corn	17.33	0	17.33	0
Steam flaked barley	0	0	15.03	15.03
Steam flaked corn	0	17.33	0	17.33
Cotton seed	7.02	7.02	7.02	7.02
Soybean meal	9.43	9.43	9.43	9.43
Canola meal	3.01	3.01	3.01	3.01
Wheat bran	2.9	2.9	2.9	2.9
Sodium bicarbonate	1.09	1.09	1.09	1.09
Calcium carbonate	0.55	0.55	0.55	0.55
Salt, mineral, and vitamins*	1.69	1.69	1.69	1.69
Chemical composition				
DM, %	51	51	51	51
NEL, Mcal/kg	1.51	1.56	1.61	1.7
CP, %	15.4	15.4	15.4	15.4
TDN, %	72	74	74	74
NDF, %	25	25	25	25
Ca, %	0.69	0.69	0.69	0.69
P, %	0.44	0.44	0.44	0.44

Note: SCMB= Steam flaked corn with milled barley; SBMC= Steam flaked barley with milled corn; SBC= Steam flaked corn and barley; DM= dry matter; NE= net energy; TDN= total digestible nutrients; NDF= neutral detergent fiber.

*= Contained 19.6% Ca, 9.6% P, 7.1% Na, 1.9%Mg, 0.3% Fe, 0.03% Cu, 0.2% Mn, 0.3% Zn, 100 ppm Co, 100 ppm I, 0.1 ppm Se, 50 × 105 IU of vitamin A, 10 × 105 IU of vitamin D, and 0.1 g of vitamin E/kg.

ducted on days 35 and 60-90. Total conception rate was estimated as the number of cows considered as pregnant in a period divided by the total number of inseminated cows in 35 days after the first AI.

Reproduction and Metabolic Disorders

Reproductive disorders (endometritis and pyometra) and metabolic disorders (ketosis and acidosis) were investigated in all the experimental period as 0= not affected and 1= affected. Endometritis was characterized as a discharge containing flecks of pus from the cow vagina in 21 days to 42 days after calving (Williams *et al.*, 2005). Pyometra was characterized as a presence of purulent or mucopurulent fluid in the uterus with the presence of a corpus luteum and a closed cervix within 42 to 60 d after calving (Sheldon *et al.*, 2008). Acidosis was reported as a decreased alkali (excessive acid) in the body fluids (Dehkordi & Dehkordi, 2011). Clinical signs of ketosis were anorexia, depression, and odor of acetone in the breath (Güntner *et al.*, 2018).

Feed Intake

Feed consumption was separately and daily measured for all the experimental animals after collecting and weighing orts before the noon milking. To investigate the dry matter (DM) contents, the precision amount of feed consumption was subtracted from the DM content of orts.

Rumen pH and Fermentation

At the end of the trial period, a sample of rumen fluid per cow 4 h was collected after the first daily feeding by a stomach tube. The collection was based on 4-h sampling for showing a precise pH, as was reported by a previous study (Nordlund & Garrett, 1994). The initial 200 mL of fluid aspirated was removed for minimizing saliva contamination. A portable digital pH meter (HI 8318, Hanna Instruments Cluj-Napoca, Romania) was used for the assessment of pH. A cheese-cloth with a mesh size of 250 µm was used to squeeze the samples. We preserved 10-mL of the filtrate by adding 2 mL of 25% HPO₃ for the determination of volatile fatty acid (VFA) and then stored at 20°C for subsequent analyses. Following thawing in room temperature (i.e. 20°C), ruminal fluid was assessed by GC (Chrompack, Model CP-9002, Chrompack, EA Middelburg, the Netherlands) with a 50-m (0.32-mm i.d.) fused silica column (CP-Wax Chrompack Capillary Column, Varian, Palo Alto, CA). Crotonic acid and nitrogen were used as an internal standard and carrier gas, respectively. Initial and final oven temperatures were 55°C and 195°C, respectively, while the detector and injector temperatures were controlled at 250°C.

Statistical Analysis

Statistical procedures were conducted using SAS/STAT 9.4 (SAS Institute Inc., Cary, NC, 2013). Since the disorders have a binary nature and are not neces-

sarily distributed in a normal manner, a generalized linear mixed model linked by logistic regression (PROC GLIMMIXED) was used. The below model was used for the analysis of data:

$$\text{Logit}(\pi) = \alpha + \text{treat}_i + \text{parity}_j + \beta(DP_i - \overline{DP}) + \text{Cow}_m$$

A linear mixed model for the analysis of production and reproduction traits was used. The following model was used for the analysis:

$$Y_{ijklm} = \mu + \text{treat}_i + \text{parity}_j + \text{period}_k + (\text{treat} \times \text{period})_{ik} + \beta(DP_i - \overline{DP}) + \text{Cow}_m + e_{ijklm}$$

where Π was an odds ratio of disorder (acidosis, ketosis, endometritis, and Pyometra), α is an intercept, Y_{ijklm} was dependent variable (milk production traits or reproductive performance), μ was the overall mean, treat_i was the fixed effect of the treatment ($i=1, 2, 3$ and 4), parity_j was the fixed effect of the treatment parity ($j=1, 2, 3$ and 4), period_k was the fixed effect of 4 periods and is only used for production traits, $\text{treat} \times \text{period}$ was an interaction effect of the treatment and period (only for production traits), β was regression coefficient of observations in previous days (DP), Cow_m was cow effect, and e_{ijklm} was a residual effect. The significant differences among the treatment were considered at a significant level of $p < 0.05$.

RESULTS

Daily Dry Matter Intake (DMI)

DMI was significantly lower in steam flaked grains or combined form group compared to the other groups. Results showed that SCB had 17.8 kg/day and it was lower than other treatments.

Milk Yield and Compositions

The effects of dietary inclusion of steam flaking of barley and corn grains on milk yield and milk compositions are shown in Table 2. The results showed that average daily milk and the levels of fat and protein were not significantly different in the treatments in the first period of the experiment (0-30 d). The results also showed that the inclusion of steam flaking of barley and corn grains into the diet significantly increased the average daily milk and milk fat percentage during the second (30-60 d) and third (60-90 d) periods of the study compared to control group ($p < 0.05$). However, dietary inclusion of steam flaked grains significantly increased milk yield, milk compositions, and 4% fat corrected milk during the fourth period of the experiment (90-120 d) compared to the control group ($p < 0.05$).

Reproduction and Metabolic Disorders

Estimated odds ratios for the effects of dietary steam flaked of barley and corn on reproductive and metabolic disorders of postpartum cows are shown in Table 3. The results for logistic regression analysis showed that the cows in steam flaked treatments showed a lower occurrence for reproductive disorders (endometritis and pyometra) and metabolic disorders

Table 2. Milk yields and compositions in postpartum cows fed steam flaked of barley and corn

Variables	Treatments				p-value
	Control	SCMB	SBMC	SCB	
Milk (kg/d)					
0-30	29.66±1.21	29.80±1.13	29.95±1.43	31.00±1.09	0.412
30-60	30.77±0.98 ^c	34.19±1.41 ^b	36.15±0.85 ^a	34.45±1.01 ^b	0.021
60-90	33.46±0.51 ^b	35.00±0.82 ^a	36.10±0.93 ^a	38.55±2.21 ^a	0.012
90-120	34.45±0.58 ^c	37.12±1.01 ^b	36.81±0.91 ^b	39.20±0.81 ^a	0.011
Fat (%)					
0-30	3.32±0.11	3.25±0.09	3.25±0.09	3.25±0.08	0.751
30-60	3.23±0.07 ^b	3.41±0.07 ^a	3.39±0.06 ^a	3.42±0.08 ^a	0.023
60-90	3.23±0.05 ^b	3.40±0.07 ^a	3.36±0.08 ^a	3.42±0.09 ^a	0.031
90-120	3.28±0.08 ^b	3.41±0.05 ^a	3.44±0.04 ^a	3.55±0.10 ^a	0.026
Protein (%)					
0-30	3.14±0.06	3.12±0.05	3.11±0.09	3.12±0.09	0.358
30-60	3.20±0.04 ^b	3.37±0.09 ^a	3.36±0.08 ^a	3.40±0.09 ^a	0.031
60-90	3.15±0.08 ^b	3.36±0.07 ^a	3.38±0.06 ^a	3.39±0.09 ^a	0.028
90-120	3.16±0.08 ^b	3.36±0.11 ^a	3.38±0.10 ^a	3.34±0.10 ^a	0.035
4% FCM					
0-30	26.31±0.91	26.76±0.88	26.52±1.08	27.50±1.97	0.512
30-60	27.60±1.08 ^b	31.23±0.88 ^a	32.90±1.04 ^a	32.32±2.02 ^a	0.009
60-90	32.41±0.88 ^b	34.82±1.01 ^a	36.61±1.38 ^a	35.00±1.28 ^a	0.031
90-120	40.15±1.12 ^c	43.92±1.07 ^b	47.15±0.58 ^a	47.95±0.98 ^a	0.021
DMI (%)	18.40±0.21 ^a	18.50±0.18 ^a	18.50±0.21 ^a	17.80±0.11 ^b	0.021

Note: SCMB= Steam flaked corn with milled barley; SBMC= Steam flaked barley with milled corn; SCB: Steam flaked corn and barley; FCM= fat corrected milk: $0.432 \times \text{milk (kg)} + 16.23 \times \text{fat (kg)}$; DMI= dry matter intake. Means in the same row with different superscripts differ significantly ($p < 0.05$).

Table 3. Estimated odds ratios (95% confidence interval) for the effects of dietary steam flaked of barley and corn on incidence of reproduction and metabolic disorders in postpartum cows

Disorders	Treatments				p-value
	Control	SCMB	SBMC	SBC	
Endometritis	1 (0.8-1.0)	0.66 (0.46-0.86)	0.39 (0.16-0.52)	0.19 (0.12-0.35)	0.001
Pyometra	1 (0.8-1.0)	0.54 (0.38-0.75)	0.51 (0.36-0.67)	0.27 (0.13-0.48)	0.001
Ketosis	1 (0.8-1.0)	0.6 (0.39- 0.89)	0.57 (0.33-0.78)	0.001 (0.0-99.0)	0.001
Acidosis	1 (0.8-1.0)	0.42 (0.19-0.68)	0.27 (0.11-0.43)	0.001 (0.0-99.0)	0.001

Note: SCMB= Steam flaked corn with milled barley; SBMC= Steam flaked barley with milled corn; SCB= Steam flaked corn and barley.

(ketosis and acidosis) ($p < 0.001$). The occurrence of endometritis was reduced in animals fed with steam flaked grains so that the greatest odds of endometritis were observed in the control group (odds ratios=1, $p < 0.01$). In contrast, the animals fed SBC showed the lowest odds of endometritis (odds ratios= 0.19). The odds ratio of pyometra in the animals fed SCMB and SBMC was almost half of the control treatment, and it was decreased to 0.27 in the SBC group. The rate of ketosis in SCMB and SBMC groups was significantly lower compared to the control group ($p < 0.05$). The use of corn and barley steam flaked in dairy cattle during postpartum period decreased odds of acidosis abnormality ($p < 0.05$).

Ruminal Fermentation Characteristics

The results for ruminal fermentation characteristics are shown in Table 4. The results showed that pH was significantly higher in cows fed steam flaked compared

to the control group ($p < 0.05$). The results showed that total VFA, acetate, propionate, butyrate, and valerate were significantly higher in cow fed steam flaked compared to the control group ($p < 0.05$). Isovalerate and caproate were not influenced by the experimental treatments.

Reproduction Responses

The results in Table 5 showed that the number and diameter of mature follicles were not affected by dietary steam flaked of barley and corn treatments. The number of mature follicles in the cows treated with the steam flaked, especially SBC group, was numerically higher compared to the control group. The mature follicle diameter in the control and SBMC groups was the same (17.5 mm), but these parameters were significantly lower in the SCMB and SBC groups compared to the control group ($p = 0.08$). The results also showed that the

inclusion of a combination of steam flaked of barley and corn significantly increased pregnancy rate in the first 100 days of postpartum cows compared to control and a single form of steam flaked barley or corn ($p < 0.05$) (Table 6). The total conception rate was not influenced by the treatments. The average days to the first service tended to be a significant increase ($p = 0.06$) in the experimental treatments. The animals in experimental treatments containing steam flaked of barley and corn grains, either individually or in combination, showed favorable results on the average open days that were statistically significant ($p < 0.05$). The best results for the open days were observed in the treatment of steam flaked corn with milled barley (95.1 days). The results showed that the use of corn and barley steam flaked replaced with ground grains improved 11.5 d open days in postpartum cows (Table 6).

DISCUSSION

In the current study, the animals in control (ground grains) and steam flaked grains groups showed significant differences for open days, ruminal fermentation characteristics, metabolic disorders, milk yield, and milk

compositions that is likely attributed to the differences in the grain processing and diet composition. Grain processing provides starch accessibility for microbes and enhances the rate of starch degradation in the rumen (Dehghan-banadaky *et al.*, 2007). The use of steam flaked grains increases the digestibility of dry matter in the total digestive tract, the absorption of nutrients in the mammary glands, and in turn, increases the milk production in cows (Cooke *et al.*, 2008). Heat processes during the steam flaking process increase the fermentation efficiency by changing the endosperm protein matrix and starch structure (gelatinization) that result in improving microbial digestibility (Cooke *et al.*, 2008; Van Vuuren *et al.*, 2010).

Milk production and energy efficiency of commercial lactating dairy cows have enhanced during recent decades, parallel with the decreased reproductive performance (Lucy, 2001; Dobson *et al.*, 2008). Ansari-Lari *et al.* (2010) reported days open was increased 0.3 days per 100-kg increase for milk production. Based on reproductive response and milk production, feeding steam flaked barley and corn grain, especially in combination form improved reproductive health, productivity, and milk production through modulation in the intestinal

Table 4. Ruminal fermentation characteristics of postpartum cows fed steam flaked of barley and corn

Variables	Treatments				p-value
	Control	SCMB	SBMC	SCB	
pH	6.10±0.04 ^c	6.30±0.05 ^b	6.30±0.05 ^b	6.50±0.03 ^a	0.042
Total VFA (mmol/L)	81.20±2.31 ^b	97.10±3.18 ^a	96.31±3.73 ^a	100.20±4.17 ^a	0.003
Acetate (mol/100 mol)	51.20±2.14 ^b	57.60±3.13 ^a	57.31±3.19 ^a	60.10±3.48 ^a	0.002
Propionate (mol/100 mol)	17.10±1.15 ^b	21.10±0.98 ^a	22.31±1.08 ^a	22.10±0.99 ^a	0.032
Butyrate (mol/100 mol)	7.20±0.75 ^b	10.10±0.38 ^a	9.91±0.69 ^a	10.10±0.21 ^a	0.004
Valerate (mol/100 mol)	2.20±0.05 ^a	1.80±0.12 ^b	1.81±0.08 ^b	1.91±0.18 ^b	0.002
Isovalerate (mol/100 mol)	1.20±0.28	1.10±0.21	1.31±0.25	1.10±0.27	0.721
Caproate (mol/100 mol)	0.72±0.07	0.81±0.16	0.75±0.09	0.85±0.14	0.292

Note: SCMB= Steam flaked corn with milled barley; SBMC= Steam flaked barley with milled corn; SCB= Steam flaked corn and barley. Means in the same row with different superscripts differ significantly ($p < 0.05$).

Table 5. Diameter and number of mature follicles of postpartum cows fed steam flaked of barley and corn

Variables	Treatments				p-value
	Control	SCMB	SBMC	SBC	
Number of mature follicles	1.30±0.26	1.30±0.26	1.50±0.24	1.60±0.26	0.09
Mature follicle diameter (mm)	17.58±0.47	16.74±0.47	17.54±0.47	16.98±0.43	0.08

Note: SCMB= Steam flaked corn with milled barley; SBMC= Steam flaked barley with milled corn; SCB= Steam flaked corn and barley.

Table 6. Reproduction responses in postpartum cows fed steam flaked of barley and corn

Variables	Treatments				p-value
	Control	SCMB	SBMC	SBC	
Pregnancy rate in the first 100 days (%)	26.0±3.0 ^b	23.0±4.0 ^b	27.0±2.5 ^b	39.0±3.0 ^a	0.01
Total conception rate (%)	48.00±3.59	50.00±3.15	51.00±4.08	51.00±2.21	0.10
DFS (d)*	61.1±2.0	61.5±3.0	60.8±1.0	57.9±4.0	0.06
Open days (d)	106.6±3.0 ^a	95.1±2.0 ^b	97.5±2.0 ^b	96.2±2.0 ^b	0.04

Note: SCMB= Steam flaked corn with milled barley; SBMC= Steam flaked barley with milled corn; SCB= Steam flaked corn and barley. * = Average days to the first service. Means in the same row with different superscripts differ significantly ($p < 0.05$).

and ruminal microbial ecosystem and fermentation efficiency. Previous studies have shown milk response to steam flaked grain was higher than responses obtained with the other energy sources during postpartum period (Dehghan *et al.*, 2007; Safaei *et al.*, 2016, 2017). Milk yield and compositions (fat and protein) efficiency was higher in the cows treated with continuous feeding of steam flaking of barley and corn grains supplementation for 120 d. Using steam in the processing of grains improves the digestive efficiency due to the release of nutrients, increases feed and energy efficiency that is used for milk synthesis (Koenig *et al.*, 2013; Safaei *et al.*, 2017). Milk production and compositions are the main economic factors for dairy cow farmers. Our findings are in agreement with those reported by others (Dehghan *et al.*, 2007; Safaei *et al.*, 2016). Previous studies have shown that unprocessed grains reduced the fiber and protein digestion, and volatile fatty acids production, particularly propionic acid and increased microbial mass (Koing & Beauchemin, 2011). These happen likely decreased milk yield and milk fat content of cows fed milled grain compared to flaked grains.

Conversely, other studies have not observed the significant effect of steam flaking of corn and barley on milk production of dairy cows (Ghorbani *et al.*, 2016; Safaei *et al.* 2017). The differences between our findings and the others could be explained by breed, amount, and type of basal diet as well as different types of grain in the diet. The quality of processed cereal grain could be influenced by a combination of factors such as heat, moisture, time, and mechanical action (Kokić *et al.*, 2013). The results showed that ruminal pH was significantly lower in cows treated with steam flaked grains, but total VFA and fatty acids were higher in the treated cows.

Santos *et al.* (1997) showed that grains processed by steam improve digestive conditions and increases energy and protein intake that eventually reduced the need for food. Studies have reported that the use of steam in the processing of grains improves the digestive efficiency due to releasing nutrients, improving digestion in the rumen and increasing feed efficiency (Koenig *et al.*, 2013; Safaei *et al.*, 2017). Conversely, previous studies have shown that processing methods (grinding *vs.* steam flaking) did not have a significant effect on DMI (Ghorbani *et al.*, 2016; Safaei *et al.*, 2017). The mentioned studies show only limited effects of the steam flaking method on DMI in cows. A better understanding of the rate of feed intake can help to prepare better nutritional management programs for dairy cows.

The energetic state is a factor influencing fertility in dairy cows. Bodyweight was rapidly decreased in a negative energy balance in postpartum cows (Sirotkin *et al.*, 2013). Opsomer (2009) showed that high-producing cows were more susceptible to metabolic disorders due to their negative energy balances and due to the limited capacity of feed intake in the early postpartum and increased milk production in cows. A negative energy balance will be associated with the occurrence of disruptions of health and physiological condition (Garnsworthy *et al.*, 2008; Tajik *et al.*, 2009). On the other hand, Ferguson *et al.* (2006) reported that a sharp drop

in the body condition score increases the likelihood of infertility by 7 times. There is a direct correlation between high productions with the occurrence of abnormalities in cows. One of the parameters influencing the outbreak of rumen acidosis is the high levels of non-fiber carbohydrates in the ration (Razavi *et al.*, 2019). Our findings in Table 3 show that feeding flaked of barley and corn has beneficial effects on reproductive disorders (endometritis and pyometra) and metabolic disorders (acidosis and ketosis). The results showed that grain steam processing provides the required energy and protein for overcoming reproductive and metabolic disorders of dairy cows during postpartum. The results for rumen fermentation confirmed the decreased acidosis in cows treated with steam flaked grains. Rumen acidosis is defined by the decrease of rumen pH. The results showed a higher occurrence of acidosis in steam flaked groups. It means lower acidosis in the treated groups. It is well known that acidosis increases the fermentation of carbohydrates (Bramley *et al.*, 2008). The results show that ruminal fatty acids were lower in cows fed steam flaked grains that show the degradation of carbohydrates in the rumen and possible degradation in the intestine system. Acidosis is usually in pH<5.5, but our findings are higher. It can be implicated that acidosis is not only associated with pH and other factors influence it. In the current study, we considered several factors for acidosis as reported by Dehkordi & Dehkordi (2011), including rumen overload, hypovolemia, associated with loss or compartmentalization of containing fluid, pregnancy toxemia, loss of bicarbonate-rich saliva with oral disease or esophagostomy in cattle, gastrointestinal loss of bicarbonate as a result of diarrhea, and renal failure that may decrease the ability to excrete hydrogen and thus retain bicarbonate.

Physiological changes following parturition in dairy cows will influence the next lactation. Providing nutrients plays a key role in productive and reproductive performances in this period. The results showed that the inclusion of corn and barley steam flaked into diet improved the pregnancy rate, open days, and average days to the first service (Table 5). Cow's ability is faulted for inducing estrus and improving the health of the uterus for the subsequent pregnancy due to the decreased feed intake in early lactation and increased milk production at the same time. Duru & Can Baycan (2019) showed that calving interval and days to the first service were increased in high milk-yielding cows compared to low milk yielding cows. Providing nutrients, especially digestible energy, could thus improve the nutrients and requirements. On the basis of previous studies, flakes of seeds used in the ration of dairy cattle have positive effects on ovarian function and pregnancy rate (Garnsworthy *et al.*, 2008; Koenig *et al.*, 2013; Yang *et al.*, 2013). Based on the results of this study, feeding flaked barley and corn improved production and reproductive performance in the early lactation period in dairy cows. To avoid the costs of reproductive loss and early replacement costs in dairy cows feed, surplus costs required for processing the flakes are needed. In sum, high reproduction responses in commercial high-producing multiparous dairy cattle may be partly explained

by cow breeds that have sufficient energy and protein for supporting pregnancy and alleviating disorders that may change the ruminal fermentation pattern.

CONCLUSION

Feeding about 15%-17% steam flaked of barley and corn has significant interaction effects on milk production, ruminal fermentation, milk compositions, and pregnancy rate in the SBC group during postpartum period. It is suggested to assess the effects of steam flaked method on the expression of genes involved in metabolism and reproduction.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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