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The Effects of Macaroni Wastes and Steam-Flaked Barley Feeding in Transition Period on Health and Lactation Performance of Holstein Cows

Research Article

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ABSTRACT

Thirty two multiparous Holstein cows were used in a randomized block design to investigate the effects of feeding diets included two different source of nonfiber carbohydrate during the transition period on dry matter intake (DMI), lactational performance, blood metabolites and parturitional characteristics. Cows received total mixed rations containing either macaroni wastes (MW) or steam-flaked barley (SFB) beginning 21 d prior to expected calving date. A common lactation total mixed ration was fed postpartum. Cows fed MW had greater pre and postpartum DMI than cows fed SFB (P<0.001). No treatment effects on milk yield, milk composition, body weight (BW) and body condition score (BCS) were observed. There was no effect of prepartum diets on pre and postpartum plasma concentrations of glucose, blood urea nitrogen (BUN), calcium, phosphor, protein, albumin, globulin and cholesterol. Prepartum concentrations of non-esterified fatty acids (NEFA) were not affected by treatments. Fecal and urine PH were not affected by treatments. Fecal consistency score was reduced for cows that received the SFB diet compared to cows received the MW diet (P≤0.05). Feeding MW prepartum decreased gestation period (P≤0.05). Other parturitional characteristics and health problems did not influence by treatments. MW compared with SFB improved dry matter intake. Lactation performance and metabolic parameters were similar between treatments. From the present results, it could be concluded that the MW might be as a good alternative energy and NFC source for use in transition rations.

KEY WORDS lactational performance, macaroni wastes, periparturient, transition Holstein cow.

INTRODUCTION

The transition period of a cow is generally defined as 21 d before calving to 21 d after calving (Grummer *et al.* 1995). In this period feed intake is reduced, while nutrient demand for the support of fetal growth and initiation of milk synthesis are being increased (Keady *et al.* 2001). Suitable nutrition and management during this transition period could lead to major benefits of health and lactational performance. Increasing the energy intake during this period might have positive effects on the health and lactation performance of high producing lactating cows (Grummer *et al.* 1995). The first way to increase the energy supply to the cow is to increase in dietary nonfiber carbohydrate (NFC) (Minor *et al.* 1997) and the second one to increase ruminal carbohydrate availability is through the use of grain processing (Lykos *et al.* 1995; Owens *et al.* 1997). Increased moisture, temperature, and pressure (which are all critical in the grains process) consistently increase hydrolysis of grains starch (Frederick *et al.* 1973), the proportion of starch digested in the rumen and the total starch digestibility by cattle.

Therefore, increasing carbohydrate availability in the rumen might be result in more nutrients supplied to the cow.

In the most Iranian factories, macaroni is mainly produced from durum wheat and it can be use for source of energy in dietary of cows in prepartum period. The wastes of macaroni are approximately 8 to 12% (with average of 10%) in these factories. One of the potential approaches to lower the costs of energy source in Iran is dietary utilization of such a waste product. To our knowledge, no studies have compared the feeding value of the MW during the transition period of the cow.

Thus, the objectives of this study were to compare the effects of feeding two source of energy with different processing method (MW and SFB) on DMI, lactation performance, blood metabolites and incidence of physiological and metabolic disorders in transition cows.

MATERIALS AND METHODS

Cows and diets

The protocol for this research was approved by the University of Zanjan Institutional Animal Care and Use Committee. Thirty two multiparous Holstein cows (average initial weight 719±31 kg) in second through sixth parities were used in the trial. The trial period ranged from 21 d prepartum to 21 d postpartum. Holstein cows were blocked according to parity (7 cows in second lactation and 9 cows in 3 and above lactation per treatment) and assigned at random to 1 of 2 treatment groups: 1) macaroni wastes (MW), 2) steam-flaked barley (SFB). Macaroni was made from semolina (coarse flour usually milled from durum wheat) and water, and extruded through a metal die under pressure. It was a dried product. Macaroni wastes were obtained from local factories. Barley was steamed for 30 to 60 min in a vertical, stainless steel steam chamber then after flaked between preheated large rollers. Diets were fed as total mixed ration (TMR) for approximately 5% refusal and cows were group fed. The amount of feed offered and refused was measured daily. Prepartum diets were fed from 21 d before expected calving until parturition and then all cows were fed a common lactation TMR. Diets formulating was according to NRC (2001) model (table 1). Nutrient composition of the diets fed during the prepartum periods are provided in Table 2.

Sampling and analysis

Diet samples analyzed for DM, NDF and ADF (AOAC, 2000), CP (AOAC, 2000; KjeltecAuto 1030), and EE (AOAC, 2000; Soxtec 1043) in nutrition laboratory of Zanjan university. Nonstructural carbohydrate content (percentage of DM) of diets was calculated by 100 - (NDF %+CP %+EE %+ash %).

Cows were milked 3 times daily at 0800, 1400, 2000 h in the milking parlor. Milk samples were taken from each cow and stored at +4 ˚C.

Table 1 Feed ingredient (% of DM) of the experimental diets fed to cows during the prepartum period

Composition	Prepartum		Postpartum
	MW	SFB	
Corn silage	29.22	29.22	46.65
Alfalfa hay	27.79	27.79	18.32
Macaroni wastes	13.06	-	-
Steam-flaked Barley	-	13.06	9.46
Corn grain	12.05	12.05	6.48
Corn gluten	-	-	1.4
Whole cottonseed	2.85	2.85	4.83
Cottonseed meal	0.85	0.85	1.05
Soybean meal	7.26	7.26	5.32
Canola meal	-	-	2.80
Fish meal	0.44	0.44	-
Glyco-Line[1]	2.65	2.65	0.88
Fat supplement	-	-	0.56
Calcium carbonate	1.16	1.16	-
Calcium chloride	0.44	0.44	-
Monensin	-	-	0.01
Magnesium sulphate	0.65	0.65	-
Ammonium chloride	0.23	0.23	-
Niacin	0.09	0.09	0.04
Mineral and vitamin mix[2]	1.16	1.16	0.53
Vitamin E	0.10	0.10	0.07

MW: macaroni wastes and SFB: steam-flaked barley.

[1] 1 kg of glycoline included: monopropilen glycol: 370 g; Calcium propionate: 100 g; glycerol: 50 g; Rumen protected niacin: 20 g and Cobalt carbonate: 0.05 g.

[2] 1 kg of mineral and vitamin mix contained: Ca: 180 g; P: 70 g; Mg: 20 g; Na: 60 g; Fe: 3 g; Cu: 0.3 g; Zn: 3 g; Mn: 2 g; I: 0.1 g; Co: 0.1 g; Se: 0.001 g; Anti oxidant: 3 g; vitamin A: 500000 IU; vitamin D: 100000 IU and vitamin E: 0.1 g.

Table 2 Chemical composition (% of DM) of the experimental diets fed to cows during the prepartum period

Composition	Prepartum	
	MW	SFB
NE_L (Mcal/kg)	1.6	1.58
CP	14.9	14.6
RDP	11	10.8
RUP	3.9	3.8
NDF	32	34.1
ADF	22.2	22.7
NFC	42	40.2
Ca	0.8	0.3
P	0.8	0.8
DCAD (mEq/kg)	-11	-7
Vitamin A (IU/kg)	9800	9800
Vitamin D (IU/kg)	6500	6500
Vitamin E (IU/kg)	103	103

MW: macaroni wastes; SFB: steam-flaked barley; NE_L: net energy for lactation; CP: crude protein; RDP: rumen degradable protein; RUP: rumen undegradable protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; NFC: nonfiber carbohydrates and DCAD: dietary cation anion difference: (Na+K) - (Cl+S).

Milk samples were taken at 3 consecutive milking once per 3 weeks and analyzed by Milko-O-Scan minor (78110; Foss, Denmark) for milk fat, protein and lactose.

BW was measured at beginning of experiment, 1 day postpartum and in last day of experiment. BCS were measured by four independent evaluators using a 0 to 5 scale (0= thin, 5= fat; Wildman *et al.* 1982). Blood samples were collected at 7-days before calving and on 1 day postpartum of coccygeal artery into red top (plain) vacutainer tubes; serum was separated by centrifuged (at 3000×g for 20 min at 4 ˚C) and stored at -20 ˚C until analysis. Plasma samples were analyzed for glucose, NEFA, calcium, phosphor, BUN, albumin, globulin, total protein and cholesterol using enzymatic method and appropriate kits (NEFA and Randox Laboratories Ltd., Crumlin, UK; other metabolites: Pars-azmon Co., Tehran, Iran). The absorbance was read using spectrophotometer (PERKIN-ELMWR-35, Colemen Instruments Division and Oak Brook, IL). Fecal samples were collected manually by rectal evacuation at 0700 h on 2 consecutive days before calving. Fecal consistency determined based on a 4-point score: 1= runny; 2= loose; 3= soft; and 4= dry (Ireland-pperry and Stallings., 1993). Fecal pH was measured by mixing fresh feces with distilled water in a 1:1 ratio, allowing 20 min for equilibration, and pH determined using a portable pH meter (Metrohm, 827, Swiss). Urinary pH was determined using a portable pH meter (Metrohm, 827, Swiss). Newborn calves were weighted within 1 h of birth. Calving difficulty was scored on a five point scale (1= no problem; 2= slight problem, 3= needed assistance, 4= considerable force, 5= caesarian). Placenta weight and the time interval between calving and placenta expulsion were recorded for individual cows. Health problems were recorded during the trial, including incidence of dystocia, mastitis, retained placenta, displaced abomasum, ketosis, milk fever and uterine problems.

Statistical analyses

The experiment was conducted as a completely randomized block design and parity initially were analyzed as block factor. All data were analyzed using the MIXED procedure of SAS (SAS, 2000).

$$Y_{ij} = \mu + T_i + B_j + Ck_{(j)} + e_{ijk}$$

Where:
Y_{ijk}: the observations for dependent variables.
μ: the overall mean.
B_j: the block effect of parity.
Ti: the effect of treatment.
$Ck_{(j)}$: the random effect of cow within treatment.
e_{ijk}: the residual error.

Significance level was set at P<0.05 and individual comparison of treatments was made by Tukey,s standardized multiple comparison tests.

RESULTS AND DISCUSSION

DMI, milk yield and composition, BW and BCS

Average DMI during the final three week of gestation was greater for cows fed MW than cows fed SFB (P<0.001). The mean prepartum DMI for cows fed MW and SFB was 13.69 and 11.26 kg/d, respectively. Cows fed MW had greater postpartum DMI than cows fed SFB (P<0.001) (Table 3). Milk yield and fat corrected milk (FCM) did not change among treatment groups. Milk fat percentage and milk fat yield were similar between treatments. Milk protein percentage and milk protein yield were not affect by treatments. No differences in BW change were observed due to prepartum treatments. Prepartum BCS did not differ between treatments (table 4). BCS did not change significantly during the postpartum period between treatments (table 4).

Blood metabolites

The influence of MW and SFB on blood metabolites is shown in table 5. There was no effect of prepartum diets on pre- and postpartum plasma concentrations of glucose and blood urea nitrogen (BUN). Prepartum intake of MW and SFB had no significant effects on prepartum and postpartum concentrations of calcium and phosphor in cows (Table 5). No significant differences found in prepartum and postpartum plasma protein, albumin, globulin and cholesterol concentrations (Table 5). NEFA concentrations for d 7 prepartum were not affected by treatments. Prepartum concentrations of NEFA were 0.238 and 0.256 for cows fed MW and SFB, respectively (Table 5).

Fecal and urine pH

There were no significant differences for cows fed MW or SFB diets prepartum regarding to fecal pH. Fecal consistency score (4-point scale: 1= runny; 2= loose; 3= soft; and 4= dry) was reduced for cows received the SFB diet compared to other cows received the MW diet (P<0.001). Urine pH was not affected by treatments (Table 6).

Parturitional characteristics and health problems

Treatment had no significant effect on calf birth weight or calving difficulty scores (scale of 1 to 5, where 5 needing cesarean) (Table 6). Gestation period was lower in cows fed MW comparing with cows fed SFB (P<0.05). Placental weights were not affected by treatments. The incidence of health problems is summarized in Table 7. Incidents of retained placenta, dystocia, displaced abomasum, milk fever, mastitis; metritis and ketosis were similar among treatments. Retained placenta was observed in 12% of the cows fed MW and SFB diets. Milk fever and ketosis were not seen in none of treatments.

Table 3 DMI, milk yield and milk composition of cows fed macaroni wastes (MW) or steam-flaked barley (SFB) during the prepartum period

Item	Prepartum diet		SEM	P-value
	MW	SFB		
Prepartum DMI (kg/d)	13.69[a]	11.26[b]	0.41	0.001
Postpartum DMI (kg/d)	17.46[a]	16.13[b]	0.33	0.001
Milk yield				
Day 0 to 21 (kg/d)	30.23	28.45	1.82	0.33
Month 1 (kg/d)	32.71	31.75	2.30	0.40
Month 2 (kg/d)	44.25	44.06	2.90	0.95
Month 3 (kg/d)	40.25	41.37	3.34	0.67
Milk composition				
4 % FCM (kg/d)	28.89	26.98	1.07	0.24
3.2 % FCM (kg/d)	32.42	30.72	0.43	0.37
Fat (%)	3.73	3.67	0.10	0.57
Fat (kg/d)	1.12	1.04	0.41	0.24
Protein (%)	3.28	3.20	0.09	0.20
Protein (kg/d)	0.98	0.90	0.06	0.39

MW: macaroni wastes; SFB: steam-flaked barley; DMI: dry matter intake and FCM: fat corrected milk.
[a,b]: the means within the same row with different letter, are significantly different ($P<0.05$).
SEM: standard error of means.

Table 4 BCS, BW and BCS and BW changes of cows fed macaroni wastes (MW) or steam-flaked barley (SFB) during the prepartum period

Item	Prepartum diet		SEM	P-value
	MW	SFB		
BCS[1]				
21 d prepartum	3.5	3.54	0.09	0.66
Last week of gestation	3.56	3.66	0.06	0.42
21 d postpartum	3.03	3.01	0.09	0.89
BCS change[2]	0.06	0.11	0.06	0.40
BCS change[3]	-0.53	-0.64	0.11	0.33
BW (kg)				
21 d prepartum	719.58	729.06	10.81	0.29
After calving	659.68	665.42	10.87	0.23
21 d postpartum	623.09	624.11	10.12	0.43
BW change[4]	-59.90	-63.64	0.31	0.55
BW change[5]	-36.59	-41.31	4.05	0.45

MW: macaroni wastes; SFB: steam-flaked barley; BCS: body condition score and BW: body weight.
[2] BCS scale= 1-to 5-point system (Wildman *et al*. 1982).
[3] 1 day prepartum to the last week of gestation.
[4] Last week of gestation to 21 d postpartum.
[5] 21 day prepartum to immediately after calving.
[6] Immediately after calving to 21 d postpartum.
SEM: standard error of means.

Data on processing wheat effects fed to dairy cows are lacking (NRC, 2001). We did not find any study regarding to use of the macaroni wastes during the transition period of cow. DMI increased in cows fed MW in the final three week of gestation.

This effect might be due to increasing digestibility of wheat with processing. In a study with nonlactating cows fed a diet with 33 percent wheat, OM digestibility of the diet was increased by 30 percent when the wheat was rolled rather than when fed whole. The digestibility of OM was 88 percent for rolled wheat and 41 percent for whole wheat grain (Nordin and Campling, 1976). Based on that study, wheat should undergo some mechanical processing prior to feeding to dairy cows (NRC, 2001). NFC content was greater for diets with MW than for diets with SFB (42 *vs*. 40).

Several studies (Johnson and Otterby, 1981; Minor *et al*. 1998) indicated that increasing dietary nonfiber carbohydrate (NFC) stimulated DMI during the late prepartum period.

In experiment of Minor *et al*. (1997) prepartum intakes of dry matter and energy and energy balance were greater for cows and heifers fed the high NFC diets. They concluded any increase of dietary NFC might be a feasible method to increase DMI and energy balance of dairy cows during the prepartum period.

Prepartum decrease in DMI might be due to high concentration of NDF in steam-flaked barley diet.

Macaroni processing increases the availability of carbohydrates in the rumen. Increasing ruminally available carbohydrates in diets improved DMI in dairy cows (Minor *et al*. 1998; Chen *et al*. 1994).

Table 5 Blood metabolites of cows fed macaroni wastes (MW) or steam-flaked barley (SFB) during the prepartum period

Item	Prepartum diet		SEM	P-value
	MW	SFB		
Prepartum				
Glucose (mg/dL)	55.20	53.25	3.26	0.55
NEFA (mmol/L)	0.238	0.256	0.02	0.46
BUN (mg/dL)	19.77	19.30	0.70	0.51
Total protein (g/dL)	7.16	7.33	0.46	0.71
Albumin (g/dL)	4.47	4.27	0.28	0.49
Globulin (g/dL)	2.69	3.06	0.33	0.41
Cholesterol (mg/dL)	74.31	77.54	5.33	0.55
Ca (mg/dL)	7.01	7.48	0.37	0.22
P (mg/dL)	7.19	7.93	0.38	0.32
Postpartum				
Glucose (mg/dL)	43.37	45.35	2.22	0.38
BUN (mg/dL)	19.41	19.22	0.51	0.71
Total protein (g/dL)	6.40	6.53	0.50	0.80
Albumin (g/dL)	4.03	3.86	0.22	0.44
Globulin (g/dL)	2.36	2.66	0.50	0.55
Cholesterol (mg/dL)	30.63	33.83	3.26	0.33
Ca (mg/dL)	6.90	7.28	0.34	0.27
P (mg/dL)	6.18	6.71	0.36	0.26

MW: macaroni wastes; SFB: steam-flaked barley; NEFA: nonesterified fatty acids and BUN: blood urea nitrogen.
SEM: standard error of means.

Table 6 Parturitional characteristics and fecal and urine pH of cows fed macaroni wastes (MW) or steam-flaked barley (SFB) during the prepartum period

Item	Prepartum diet		SEM	P-value
	MW	SFB		
Calf birth wt (kg)	42.36	41.12	1.48	0.40
Calving difficulty scores[1]	1.82	1.68	0.37	0.47
Gestation period (d)	275.58[a]	278.81[b]	1.33	0.05
Placental wt (kg)	5.45	5.11	0.22	0.27
Fecal pH	6.63	6.55	0.05	0.31
Fecal consistency[2]	3.43[a]	3.19[b]	0.13	0.05
Urine pH	7.23	6.83	0.21	0.27

MW: macaroni wastes and SFB: steam-flaked barley.
[a,b]: the means within the same row with different letter, are significantly different ($P<0.05$).
[1] Calving difficulty score; Five point scale: 1= no problem; 2= slight problem; 3= needed assistance; 4= considerable force and 5= caesarian.
[2] Fecal consistency score; 4-point scale: 1= runny; 2= loose; 3= soft and 4= dry.
SEM: standard error of means.

Dann *et al.* (1999) suggested that feeding diets with higher ruminally available carbohydrates to transition cows with high genetic potential for milk yield might be advantageous. Prepartum fed of MW increased postpartum DMI. In a summary of five experiments, Grummer *et al.* (1995) found that DMI at 1 d prepartum was positively correlated with DMI at 21 d postpartum and negatively correlated with plasma NEFA and liver TG concentrations. In the present study, Milk production and milk composition during the postpartum were not affected by prepartum treatment. This conclusion was in consistent with result of Smith *et al.* (2005), who reported prepartum carbohydrate source did not affect postpartum milk yield, milk component yields, and most milk component percentages, however Minor *et al.* (1997) reported milk production tended to be higher, milk fat percentage tended to be lower, and milk protein percentage and production were significantly greater when diets had high NFC. Dann *et al.* (1999) reported increased carbohydrate fermentability by including steam-flaked corn in the close up diet. Indeed, those cows produced more milk when they were fed steam-flaked corn during the prepartum period.

Smith *et al.* (2005) suggested that overall amount of energy provided by fermentable carbohydrate sources was likely a more important determinant of peripartal performance rather than content of NFC per se. No differences in BW and BCS were observed due to prepartum treatments. Similar to our findings, in several studies prepartum carbohydrate source did not affect BW, BCS and BCS change in dairy cows (Smith *et al.* 2005; Roche *et al.* 2010; Minor *et al.* 1998; Dann *et al.* 1999). There were no significant effect of prepartum diets on prepartum and postpartum concentrations of glucose, BUN, calcium, phosphor, protein, albumin, globulin and cholesterol. Prepartum concentrations of NEFA did not differ between treatments. Differences between treatments in metabolic variables in this experiment were minimal.

Table 7 Health parameters of cows fed macaroni wastes (MW) or steam-flaked barley (SFB) during the prepartum period

Item	Prepartum diet	
	MW	SFB
N (cow)	16	16
Retained placenta	2	2
Dystocia	1	2
Displaced abomasums	1	1
Milk fever	0	0
Mastitis	1	0
Metritis	0	1
Ketosis	0	0

In consistent with our study, Smith *et al*. (2008) observed no effect of prepartum carbohydrate source on pre and postpartum plasma concentrations of glucose, NEFA, BHB and insulin.

Putnam *et al*. (1999) demonstrated that changes in glucose kinetics could occur in prepartum cows without changes in plasma glucose concentrations. Minor *et al*. (1998) reported increased glucose concentrations in plasma and decreased plasma concentrations of NEFA and BHBA, when cows were fed with highly increasing concentrations of NFC during the prepartum diet. Furthermore, they reported diets containing high NFC increased concentrations of liver glycogen and tended to reduce concentrations of liver triglyceride.

Plasma NEFA concentration and triglyceride concentration in the liver were positively correlated. Indeed, the reduction in plasma NEFA concentration decreased risk of developing fatty liver and ketosis. In other study, blood urea N was reduced 9.5% for cows, which received the steam-flaked corn diet prepartum compared to cows received the cracked corn diet prepartum (Dann *et al*. 1999).

CONCLUSION

MW compared with SFB did not influence lactation performance or health problems of animals in this study. Cows fed a ration with MW during the last 3 wk of gestation consumed more DM than cows fed a ration with SFB. Blood metabolites were not affected by diets with MW and SFB. Feeding SFB pretpartum reduced fecal consistency in cows. Present study suggests the MW might be as a good alternative energy and NFC source to be utilized during transition rations, however further studies are needed to compare MW with other energy and NFC source, such as steam-flaked corn.

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