# High grain diets perturb rumen and plasma metabolites and induce inflammatory responses in early lactation dairy cows

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**ABSTRACT**: Immediately after parturition dairy cows are fed diets containing high proportions of grain which are associated with high incidence of metabolic disorders. However, the reason behind these effects is not clear. The goal of this study was to investigate metabolic and immune responses of early postpartum dairy cows to feeding increasing proportions of barley grain in the diet. Rumen endotoxin content increased several fold and rumen fluid pH was lower in cows fed the highest amount of barley grain. Results indicate that feeding high proportions of barley grain in early lactation dairy cows was associated with induction of an acute phase response and changes in multiple plasma metabolites. Further research is warranted to understand the mechanism(s) by which feeding of barley grain causes disturbances in plasma metabolites and stimulates an inflammatory response in dairy cows.

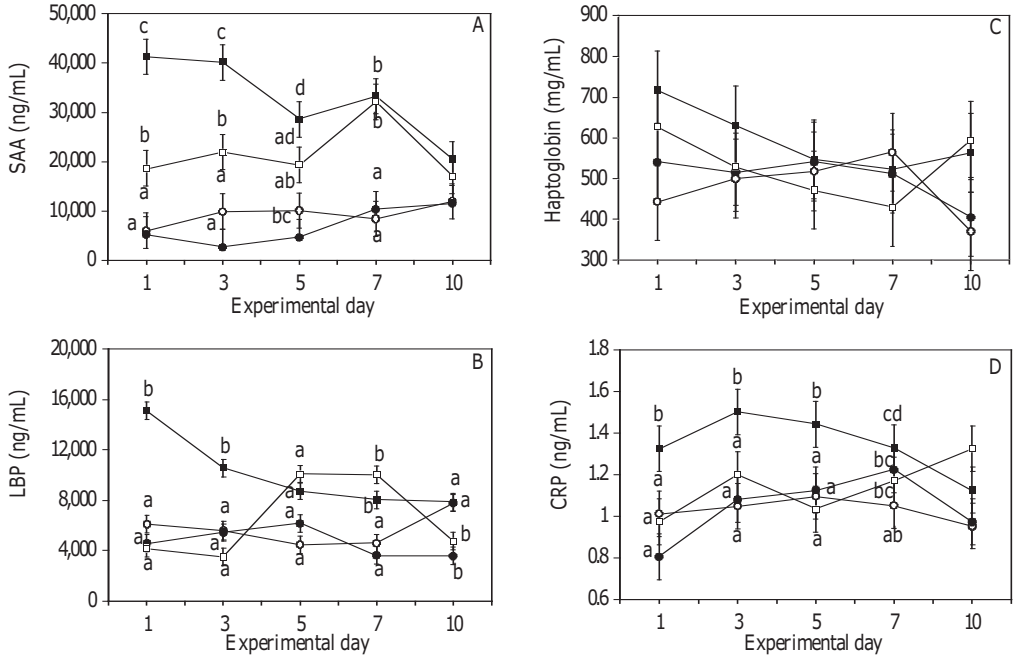
**Key words**: Barley grain, Dairy cows, Plasma metabolites, Acute phase proteins.

**INTRODUCTION** – Feeding high amounts of grain to dairy cattle immediately after parturition is associated with multiple metabolic disorders like acidosis, laminitis, fatty liver, displaced abomasum, and bloat (Nagaraja *et al*., 1978; Andersen, 2003; Ametaj *et al*., 2005; Ametaj, 2005). The reason behind these effects of grain is not known. There are indications that feeding grain is associated with increased release of endotoxin in the rumen and its translocation into the bloostream (Andersen *et al.*, 1994). Administration of endotoxin to dairy cattle also is associated with disturbances of carbohydrate, lipid, and mineral metabolism (Andersen, 1994; Waldron *et al*., 2003). Feeding high-grain diets is associated with clinical signs very similar to endotoxemia. The goal of this investigation was to evaluate changes in the rumen fluid, plasma metabolites, and plasma acute phase proteins during feeding of increasing proportions of barley grain in the diet of dairy cows.

**MATERIAL AND METHODS** – Eight ruminally cannulated Holstein cows received 0, 15, 30 and 45% barley grain (DM basis), barley silage, and 15% concentrate mix in their TMR diets, in a 4 x 4 Latin square design, with four squares, two cows in each square, and four periods. The length of each period was 21-d, with an 11-d adaptation period and 10-d measurement period. The squares within the experiment were run concurrently. All groups of cows received isoenergetic and isonitrogenous diets as well as similar amounts of a mineral and vitamin mix. Blood and rumen fluid samples were collected before the morning meal on days 1, 3, 5, 7, and 10 of the measurement period. On the last day of the measurement period (d 10), intensive blood and rumen sampling were conducted before the morning meal as well as every two hours for twelve hours at 0, 2, 4, 6, 8, 10, and 12 h after the morning meal. Concentrations of several blood metabolites such as glucose, β-hydroxy butyric acid (BHBA), non-esterified fatty acids (NEFA), cholesterol, lactate, calcium, zinc, iron, and copper in plasma as well as acute phase proteins such as serum amyloid A (SAA), haptoglobin, lipopolysaccharide-binding protein (LBP), and C-reactive protein (CRP) were measured colorimetrically, by microplate reader. Data on feed intake, milk yield, and health status were collected every day during both the adaptation and measurement periods. All data were analyzed by MIXED procedure of SAS.

**RESULTS AND CONCLUSIONS** – Concentration of endotoxin in the rumen fluid increased as the amount of barley grain in the diet increased ($P < 0.001$). The group of cows fed 45% barley grain had the highest concentration of endotoxin in the rumen at 8,869 ng/mL, whereas, the control group had the lowest amount of endotoxin at 654

Figure 1. Plasma concentration of serum amyloid A (SAA) (A), lipopolysaccharide-binding protein (LBP) (B), haptoglobin (C), C-reactive protein (CRP) (D) in cows (n = 8) fed 0 (○), 15 (●), 30 (□), and 45% (■) barley grain in a 4 x 4 Latin square design with an 11-d adaptation period and a 10-d experimental period.




ng/mL. The 15 and the 30% grain groups had intermediate endotoxin levels at 791 and 5,021 ng/mL, respectively. Both day and day ? treatment were significant in increasing concentration of endotoxin in the rumen ($P < 0.05$ and $P < 0.001$, respectively). Differences in ruminal fluid pH were also obtained among the treatment groups. Thus, the group receiving 45% barley grain had the lowest overall rumen pH value of 6.5, whereas, the group fed no barley grain had the highest overall rumen pH value of 6.8. Groups of cows fed 15 and 30% barley grain had an average rumen pH value of 6.7. Time after feeding also affected rumen pH in all treatment groups with the lowest pH values at 6 h after the morning feeding. Six hours after the morning feeding rumen pH fell at 6.2 in cows fed no grain and at 5.9 in the groups of cows fed barley grain (i.e., 15, 30, and 45% DM basis).

Plasma SAA, LBP, and CRP increased in cows fed high grain diets; however, no changes in plasma haptoglobin were obtained between different treatments (Figure 1A, B, C, and D). Also, plasma metabolites such as BHBA, NEFA, and cholesterol declined in relation with the amount of grain in the diet, whereas plasma glucose and lactate increased with increasing of the amount of barley grain in the diet. Diurnal measurements showed plasma glucose, BHBA, NEFA, and lactate increased after the morning feeding, whereas, plasma cholesterol declined during the last day of the experimental period. Increasing the amount of grain in diet was associated with decreased plasma $Ca^{2+}$, $Fe^{2+}$ and increased plasma $Cu^{2+}$. On the last day of experimental period, plasma $Ca^{2+}$, $Zn^{2+}$, and $Cu^{2+}$ increased and plasma $Fe^{2+}$ decreased after the morning feeding.

Overall, results of this study indicate that feeding increasing proportions of barley grain in the diet was associated with decreased rumen pH, enhanced concentration of endotoxin in the rumen fluid as well as with enhanced concentrations of plasma acute phase proteins such as SAA, LBP, and CRP. The latter are part of a general non-specific immune response directed at eliminating translocated endotoxin or bacteria from circulation as well as in mounting an immune response. It is possible that enhanced concentrations of endotoxin

are associated with its translocation into the bloodstream and stimulation of acute phase response as well as perturbation of carbohydrate, lipid and mineral metabolism in dairy cows. More research is warranted to understand the mechanism by which feeding high proportions of grain and translocation of endotoxin affect health and immune status of dairy cows.

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