SHORT COMMUNICATION

Adjusting roller settings based on kernel size increased ruminal starch digestibility of dry-rolled barley grain in cattle

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[1]Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5; [2]Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, Alberta, Canada T1J 4B1; and [3]Alberta Agriculture and Rural Development, Field Crop Development Centre, Lacombe, Alberta, Canada T4L 1W8. *LRC contribution no. 38710019. Received 20 July 2009, accepted 4 January 2010.*

Ahmad, M., Gibb, D., McAllister, T. A., Yang, W. Z., Zijlstra, R. T. and Oba, M. 2010. **Adjusting roller settings based on kernel size increased starch digestibility of dry-rolled barley grain in cattle.** Can. J. Anim. Sci. **90**: 275–278. Barley grain samples were dry-rolled using two different methods: multiple roller settings (MRS) vs. single roller setting (SRS). In the MRS method, samples were first separated through 4-, 6-, and 7-mm sieves and then dry-rolled with roller gap settings of 1.000, 1.194, and 1.487 mm, respectively. In the SRS method, samples were dry-rolled using a single roller gap setting of 1.194 mm. The MRS method increased in situ rate of starch disappearance (18.6 vs. 11.9% h^{-1}; $P < 0.01$) compared with the SRS method. Screening to specific kernel sizes and adjusting roller settings accordingly could enhance the starch utilization of starch in barley grain by ruminants.

Key words: Barley grain processing, dry-rolling, starch digestibility

Ahmad, M., Gibb, D., McAllister, T. A., Yang, W. Z., Zijlstra, R. T. et Oba, M. 2010. **Régler l'écartement des cylindres en fonction du calibre du grain accroît la digestibilité de l'amidon des flocons d'orge dans le rumen des bovins**. Can. J. Anim. Sci. **90**: 275–278. Des échantillons d'orge ont été aplatis à sec selon deux méthodes : plusieurs réglages de l'écartement des cylindres et un seul réglage. Dans le premier cas, on a séparé le grain des échantillons au moyen de tamis de 4, de 6 et de 7 mm, puis on l'a aplati à sec après avoir réglé l'écartement des cylindres à 1,000, à 1,194 et à 1,487 mm, respectivement. Pour la seconde méthode, les échantillons ont été aplatis à sec à un écartement unique de 1,194 mm. Comparativement à la seconde, la première méthode augmente le taux de disparition in situ de l'amidon (18,6 c. 11,9 % par heure; $P < 0,01$). Trier le grain en fonction d'un calibre spécifique puis régler les cylindres en conséquence pourrait rehausser l'assimilation de l'amidon de l'orge par les ruminants.

Mots clés: Transformation de l'orge, aplatissage à sec, digestibilité de l'amidon

Whole barley grain is only minimally digestible due to its fibrous hull and pericarp (Beauchemin et al. 1994). Processing improves digestibility of barley grain, and the effects of various processing methods on cattle performance have recently been reviewed (Dehghan-Banadaky et al. 2008). Barley grain varies considerably in its physical characteristics; Khorasani et al. (2000) reported that the weight of 1000 kernels ranged from 42.9 to 53.9 g among 60 cultivar lots. Kernel uniformity is influenced by barley variety as well as growing conditions. Kernel uniformity is a major concern for the efficiency of dry-rolling. Variance in the size and shape of grain kernels makes it impossible to achieve optimal processing with a single roller setting. Rolling large kernels with a narrow roller gap setting may pulverize grain kernels producing large quantities of fines, while smaller kernels may pass through the rollers unprocessed. Overprocessing may reduce feed intake and increase the risk of digestive upsets, whereas underprocessing results in the starch in whole kernels being unavailable for fermentation by rumen microbial populations. Adjusting roller settings based on kernel size is expected to decrease the variation in particle size after dry-rolling. We hypothesized that ruminal starch digestibility of barley grain would increase if the grain was separated first by kernel size

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Abbreviations: **MRS**, multiple roller settings; **PI**, processing index; **SRS**, single roller setting and then dry-rolled with an optimum roller setting for each kernel size. The objective of this research was to evaluate the effect of adjusting roller settings based on kernel size on starch digestibility of dry-rolled barley grain.

Sixty barley samples were chosen from 200 samples collected from across western Canada. Based on their geographical and agronomic origin, these 60 samples were thought to best represent western Canadian barley. These 60 lots of barley grain were each divided and dry-rolled using two methods: multiple roller setting (MRS) and single roller setting (SRS). In the MRS method, barley grain was sieved using three screens with mesh sizes of 4, 6, and 7 mm. The grain kernels remaining on each screen were designated as small (accounting for 50.0 ± 28.5 of the original sample sieved), medium ($41.0 \pm 23.3\%$), and large ($8.9 \pm 8.0\%$) kernel sizes and they were dry-rolled with roller gap settings of 1.000, 1.194, and 1.487 mm, respectively. Rolled products from each barley sample were then pooled into a single lot, maintaining the proportions of kernel sizes that were determined after seiving. In the SRS method, the second sub-set of barley grain samples was dry-rolled with a single roller gap setting of 1.194 mm. The processing index (PI; volume weight after processing/volume weight before processing $\times$ 100%) was 77.0 and 87.0% for MRS and SRS, respectively.

In situ disappearance studies were conducted at Agriculture and Agri-Food Canada, Lethbridge Research Centre (Lethbridge, AB) with three non-pregnant, non-lactating Holstein cows fitted with rumen cannulas. Animals were cared for according to the guidelines of the Canadian Council on Animal Care (1993). Cows (635 kg average weight) were fed for ad libitum intake a diet comprising 75% dry rolled barley, 5% supplement, and 20% barley silage. The diet contained 68% DM, 12.5% protein, and 24% NDF. In Study 1, triplicate sub-samples (3.00 ± 0.05 g) of each of the 60 rolled barley samples were placed in Dacron bags (5×10 cm internal dimension; pore size, 51 ± 2 μm) and incubated in the rumen for 3 and 12 h (60 samples $\times$ 2 processing methods $\times$ 2 time points $\times$ triplicate samples = 720 nylon bags). Three cows were used in the trial, but each pair (MRS and SRS) of triplicate samples of rolled barley were incubated in only one cow. Each cow incubated 20 barley samples. In Study 2, 20 samples were randomly selected from the previous set of 60 samples and were incubated in the rumen of one cow in triplicate for 3, 6, 12, 24, and 48 h to estimate the rate of starch digestion. Prior to placing in the rumen, bags were placed in warm water for 10 min (without agitation) and used as 0-h samples.

After ruminal incubation, all samples were dried at 55°C in a forced-air drying oven for 48 h, ground through a 1-mm screen with a centrifugal mill (ZM 200, Retsch Inc., Newton, PA), and analyzed for starch concentration. Samples were first gelatinized with NaOH and starch content was measured by an enzymatic method (Karkalas 1985). Glucose concentration was measured using a glucose oxidase-peroxidise enzyme (No. P7119, Sigma, St. Louis, MO) and dianisidine dihydrochloride (No. F5803, Sigma). A plate reader (SpectraMax 190, Molecular Devices Corp., Sunnyvale, CA) was used to determine absorbance. Rate of starch disappearance (% h^{-1}) was calculated assuming that all starch is potentially digested and that the rate of starch disappearance follows the first order kinetics using the equation below:

$$R_t = R_0 \times e^{-kt}$$

where R_t = residue (g) at time t (h), R_0 = the amount of starch (g) prior to the incubation, t = time of ruminal incubation, k = rate of disappearance (% h^{-1}). For both studies, data were analyzed using the ANOVA procedure of JMP (SAS Institute, Inc., Cary, NC) with individual lots as random variables ($n = 60$ per treatment for Study 1, $n = 20$ per treatment for Study 2) to compare starch digestibility and rate of starch disappearance between MRS and SRS methods:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where μ = overall mean, T_i = fixed effect of treatment ($i = 1$ to 2), and e_{ij} = residual.

In Study 1, the MRS method increased in situ starch digestibility at 3 h (48.3 ± 1.0 vs. 39.7 ± 1.1; $P < 0.01$) and at 12 h (79.9 ± 0.8 vs. $67.5 \pm 0.8\%$; $P < 0.01$) compared with the SRS method (Fig. 1). The 3-h starch digestibility is expected to indicate the potential impact of ruminal starch fermentation on voluntary feed intake, given that excess ruminal fermentation often decreases feed intake by ruminants (Allen 2000). The 12-h starch digestibility is expected to approximate actual starch digestibility in the rumen.

In Study 2, the MRS method increased in situ starch digestibility at 0 h (22.8 vs. 14.9%; $P < 0.01$), 3 h (55.0

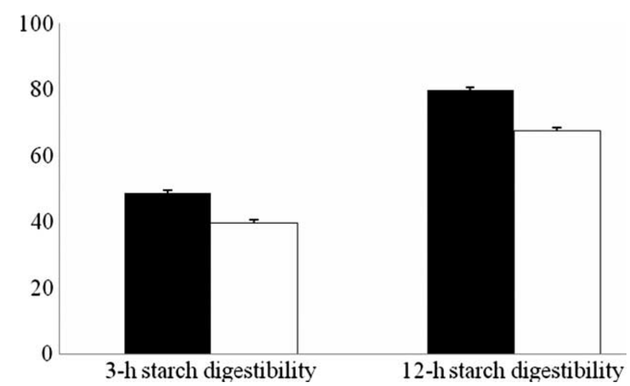

Fig. 1. Effect of multiple roller settings (closed box) relative to single roller setting (open box) on in situ starch digestibility of 60 lots of barley grain at 3 h ($P < 0.01$) or 6 h ($P < 0.01$) of rumen incubation (Study 1; mean $\pm$ SEM).

Table 1. Effect of multiple roller settings (MRS) relative to single roller setting (SRS) on in situ starch digestibility and rate of starch digestion of 20 cultivar lots of barley grains (Study 2; $n = 20$ for each treatment)

Item	MRS	SRS	SEM	*P* value
In situ starch digestibility (%)				
0 h	22.8	14.9	1.1	<0.01
3-h	55.0	38.6	1.8	<0.01
6-h	62.6	54.4	1.9	<0.01
12-h	78.9	69.7	1.2	<0.01
24-h	85.3	83.0	0.7	<0.05
48-h	93.1	93.4	0.5	0.76
Rate of starch disappearance (% h^{-1})	18.6	11.9	0.8	<0.01
Effective disappearance (%)[z]	74.7	65.5	0.01	<0.01

[z]Estimated assuming a passage rate of 6% h^{-1}.

vs. 38.6%; $P < 0.01$), 6 h (62.6 vs. 54.4%; $P < 0.01$), 12 h (78.9 vs. 69.7%; $P < 0.01$), and 24 h (85.3 vs. 83.0%; $P < 0.05$) compared with the SRS method (Table 1). However, 48-h ruminal starch digestibility was not affected by treatment ($P = 0.76$), averaging 93.3%. The rate of starch disappearance was greater with MRS than with SRS (18.6 vs. 11.9% h^{-1}; $P < 0.01$). It should be noted that the rate of starch disappearance observed in the current study may underestimate the actual rate of starch digestion in the rumen, because grain enclosed in the nylon bags during the ruminal incubation was not exposed to mastication or extensive abrasion. Thus, the rate of particle size reduction would likely have been slower for these incubated grains than for those fully exposed to the ruminal environment. This would lead to an underestimation of starch digestibility. However, greater starch disappearance observed for the MRS method indicates greater ruminal starch digestion for the MRS compared with SRS but also possibly a greater risk of ruminal acidosis if grains are fed beyond animals' capacity to neutralize and absorb fermentation acids.

Lower starch digestibility for the SRS method in the current study is likely due to under-processed kernels or unprocessed small kernels limiting the access of ruminal microorganisms to starch encased within the endosperm. Wang et al. (2003) processed barley grain using two roller gap settings, and reported greater ruminal dry matter degradation for thinner kernels compared with thicker kernels (1.98 vs. 2.23 mm). Similarly, Bengochea et al. (2005) fed steers with coarse-, moderate-and fine-rolled barley (i.e., roller settings of 2569, 1980 and 1324 μm, respectively), and reported a linear increase in total tract starch digestibility as the roller gap decreased.

Extensively rolled barley can have negative effects on dry matter intake and animal performance as a result of rumen acidosis. Feeding finely rolled barley grain (PI = 67.2%) to feedlot steers, compared with coarsely rolled barley grain (PI = 80.9%), decreased dry matter intake and average daily gain (Wang et al. 2003). Beauchemin et al. (2001) reported that starch digestibility increases linearly as the PI decreases from 81.8 to 65.2%, but also observed that rumination time decreased for temper-rolled barley with PI less than 75% and suggested that further processing might lead to acidosis. Yang et al. (2000) also reported that starch digestibility increases with increased processing of steam-rolled barley in lactating cows (PI from 82.0 to 55.5%), but found that milk yield peaked for cows fed medium-flat (PI = 64%) barley and that further processing decreased milk yield.

Extensive processing with a narrow roller gap setting may increase production of fines especially if grain is dry-rolled (Wang et al. 2003). Galyean et al. (1981) separated dry-rolled corn with sieves of 750, 1500, 3000, and 6000 μm, and showed that in situ starch digestion is greater for small kernel fractions than large fractions. Smaller grain particles increases ruminal fermentation as they have more surface area for microbial attachment per a unit of mass (McAllister et al. 2006).

In the current study, the narrower gap settings were used to roll smaller kernels without increasing production of fines. Separation of barley grain by kernel size and employing optimum roller setting for each kernel size enables thorough processing without generating the excess fines that can result from over-processing the large kernels. Further studies are warranted to evaluate the effect of feeding barley grain dry-rolled with MRS on feed intake, ruminal pH and productivity of ruminants. Development of on-line processes that automatically adjusts roller settings to variations in kernel uniformity could prove to be a useful approach to improve the utilization of barley grain by ruminants.

Acknowledgment is made to Alberta Crop Industry Development Fund for financial support of this research. The authors thank C. Owen, A. Reiz, A. Ruiz-Sanchez, W. Smart, and F. Van Herk for technical assistance.

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