

# JOURNAL OF ANIMAL SCIENCE

*The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science*

## **Degradation and fermentation characteristics of wheat coproducts from flour milling in the pig intestine studied in vitro**

R. Jha, A. Owusu-Asiedu, P. H. Simmins, A. Pharazyn and R. T. Zijlstra

*J ANIM SCI* 2012, 90:173-175.

doi: 10.2527/jas.53874

The online version of this article, along with updated information and services, is located on  
the World Wide Web at:

[http://www.journalofanimalscience.org/content/90/Supplement\\_4/173](http://www.journalofanimalscience.org/content/90/Supplement_4/173)



**American Society of Animal Science**

[www.asas.org](http://www.asas.org)

# Degradation and fermentation characteristics of wheat coproducts from flour milling in the pig intestine studied *in vitro*<sup>1</sup>

R. Jha,\* A. Owusu-Asiedu,† P. H. Simmins,† A. Pharazyn,‡ and R. T. Zijlstra\*<sup>2</sup>

\*University of Alberta, Edmonton, Alberta, Canada T6G 2P5; †Danisco Animal Nutrition, Marlborough, UK SN8 1AA; and ‡Nutreco Canada, Guelph, ON, Canada N1G 4T2.

**ABSTRACT:** Use of wheat (*Triticum aestivum*) flour milling coproducts (WFM) in pig diets may ameliorate high feed cost. However, digestibility of WFM is lower than feed grains, and limited information exists about their fermentation characteristics. *In vitro* degradation and fermentation characteristics of 6 WFM samples (2 Shorts, 2 Millrun, middlings, and bran) with varying fiber and protein contents were studied. After a pepsin-pancreatin hydrolysis, WFM were incubated in a buffer solution with minerals and fresh pig feces as inoculum. Accumulated gas production was measured for 72 h and modeled. The VFA concentration was measured in the fermented solutions. The DM degradability during

fermentation ranged from 31 to 52% and correlated negatively with ADF ( $r = -0.65$ ;  $P < 0.01$ ) and positively with CP ( $r = 0.50$ ;  $P < 0.01$ ) content of WFM. Total gas production ranged from 101 to 148 mL/g DM incubated and was negatively correlated with ADF and crude fiber ( $r = -0.70$  and  $-0.59$ , respectively;  $P < 0.01$ ). The VFA production ranged from 2.0 to 3.0 mmol/g and the fractional rate of degradation ranged from 0.08 to 0.11/h. In conclusion, fiber components were associated with degradability and fermentability of WFM. Therefore, treatments targeted to reduce the impact of fiber and protein may increase the digestibility and fermentability of wheat coproducts from flour milling.

**Key words:** degradation, fermentation, pig, volatile fatty acids, wheat coproducts

© 2012 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 2012.90:173–175  
doi:10.2527/jas53874

## INTRODUCTION

The wheat milling industry generates a number of coproducts including Wheat Shorts, Millrun, middlings, and bran with these being classified according to fiber content. These wheat flour milling coproducts (WFM) may be used in pig diets to ameliorate high feed cost, a critical issue in swine production. Several studies report poor and variable digestibility of WFM in the pig intestine (Nortey et al., 2008; Shrestha et al., 2011). Supplemental fiber-degrading enzymes have been used with WFM-containing diets to improve energy and nutrient digestibility, with limited success (Nortey et al., 2008; Shrestha et al., 2011), indicating that limitations other than fiber may exist in WFM.

The WFM contain more fiber than cereal grains. Fiber and protein influence digestibility and fermentability of nontraditional and coproduct feedstuffs in the pig intestine (Jha and Leterme,

2012). Little information is available on degradation and fermentation characteristics of WFM in the pig intestine and such information may help explain the limitations in nutrient digestion. Furthermore, information on fermentation characteristics may be useful for feed formulation and use of coproducts in pig diets and may support feed formulation to modulate gut environment and nutrient management. Therefore, an *in vitro* experiment was conducted to determine the degradation and fermentation characteristics of WFM in the pig large intestine.

## MATERIALS AND METHODS

### Samples

Six WFM samples (2 Shorts: Shorts A and Shorts B; 2 Millrun: Millrun A and Millrun B; middlings and bran) were selected from the larger samples set sourced from Nutreco Canada (Guelph, ON, Canada). These samples were selected based on their diversity of fiber and protein content (Table 1).

<sup>1</sup>Danisco Animal Nutrition and the Canadian Swine Research and Development Cluster are acknowledged for funding the project.

<sup>2</sup>Corresponding author: ruurd.zijlstra@ualberta.ca

**Table 1.** Composition of wheat coproducts from flour milling samples, % DM basis

Variables, % DM	Shorts		Millrun		Middlings	Bran	SD
	A	B	A	B			
DM, %	90.1	89.9	89.1	90.4	88.6	91.0	0.9
Ash	7.3	5.5	6.5	6.2	5.3	6.7	0.8
Ether extract	2.9	3.4	4.8	4.1	4.1	3.0	0.7
CP	27.8	24.9	18.7	19.0	22.1	15.9	4.4
ADF	11.5	8.0	12.9	15.0	10.8	15.5	2.8
NDF	31.7	22.9	34.0	36.3	26.6	49.2	9.1
Crude fiber	7.9	5.2	8.3	9.9	7.1	12.0	2.3

### *In Vitro Enzymatic Hydrolysis and Microbial Fermentation*

The ingredients underwent an in vitro pepsin-pancreatin hydrolysis (Boisen and Fernandez, 1997). Residues were filtered and used subsequently for an in vitro gas fermentation test using pig feces as inoculum (Jha et al., 2011a). The experiment was conducted in the following experimental scheme, {(6 WFM × 6 replicates) + 6 blanks} × 2 batches, yielding 12 observations per WFM. Gas production was recorded at regular intervals for 72 h. Subsequently, the liquid phase of the residue was taken out quantitatively and subjected to VFA analysis using gas chromatography. The solid residue was freeze-dried and used to determine DM degradation (DMD) during fermentation.

### *Kinetics of Gas Production*

Gas accumulation was modeled according to France et al. (1993) and described with the following parameters: cumulative total gas production (Gf; mL/g DM), lag time prior to fermentation start (h), half time to asymptote when gas production is half of Gf (T/2; h) and fractional rate of degradation of the substrate at T/2 (per h).

### *Chemical and Statistical Analyses*

The WFM samples were analyzed for DM (AOAC International 930.15), N (AOAC International 968.06 using a LECO FP528 elemental analyzer; CP = N × 6.25), ether extract using a Soxhlet apparatus and petroleum

ether (AOAC International 920.39), ash (AOAC International 942.05), crude fiber (AOAC International 978.10), NDF (AOAC International 2002.04), and ADF (AOAC International 973.18). The VFA were analyzed by gas chromatograph (Varian model 3400; Varian, Walnut Creek, CA) using 4-methyl-valeric acid as internal standard.

The DMD and fermentation characteristics were compared using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with the WFM as fixed factor and batch as random factor. Means were separated using the Tukey method with a significance level of 0.05.

## RESULTS

The fermentation variables varied according to sample type ( $P < 0.05$ ; Table 2). The DMD during fermentation ranged from 31 to 52% and correlated negatively with ADF ( $r = -0.65$ ;  $P < 0.001$ ) and positively with CP ( $r = 0.50$ ;  $P < 0.001$ ) content of WFM. The fractional rate of degradation was highest ( $P < 0.001$ ) for bran and lowest for Shorts A. The bran had the longest ( $P < 0.001$ ) lag time and Shorts A took the longest time to reach half time of asymptote gas production. Total gas production was highest ( $P < 0.001$ ) for middlings and Shorts A and lowest for Millrun B and was negatively correlated with ADF and crude fiber ( $r = -0.70$  and  $-0.59$ , respectively;  $P < 0.001$ ). Total VFA production had trends similar to total gas and ranged from 2.0 to 3.0 mmol/g DM incubated.

**Table 2.** Dry matter degradation, fermentation kinetics, and VFA production after in vitro fermentation of wheat coproducts from flour milling samples

Item <sup>1</sup>	Shorts		Millrun		Middlings	Bran	SEM	P-value
	A	B	A	B				
DMD	46.1 <sup>bc</sup>	52.4 <sup>a</sup>	37.3 <sup>d</sup>	30.5 <sup>e</sup>	47.9 <sup>ab</sup>	41.9 <sup>c</sup>	4.1	<0.001
Lag time	4.01 <sup>ab</sup>	3.95 <sup>b</sup>	3.44 <sup>c</sup>	3.45 <sup>c</sup>	3.39 <sup>c</sup>	4.29 <sup>a</sup>	0.12	<0.001
Half time	11.5 <sup>a</sup>	10.2 <sup>b</sup>	10.2 <sup>b</sup>	10.4 <sup>b</sup>	9.82 <sup>b</sup>	10.1 <sup>b</sup>	1.89	<0.001
FRD	0.075 <sup>c</sup>	0.097 <sup>ab</sup>	0.085 <sup>bc</sup>	0.093 <sup>b</sup>	0.094 <sup>b</sup>	0.111 <sup>a</sup>	0.028	<0.001
Total gas	136 <sup>b</sup>	147 <sup>a</sup>	125 <sup>c</sup>	101 <sup>d</sup>	148 <sup>a</sup>	125 <sup>c</sup>	10.4	<0.001
Total VFA	2.6 <sup>ab</sup>	3.0 <sup>a</sup>	2.1 <sup>b</sup>	2.0 <sup>b</sup>	2.9 <sup>a</sup>	2.7 <sup>ab</sup>	0.2	0.001

<sup>a-e</sup>Within a row, means without a common superscript differ ( $P < 0.05$ ).

<sup>1</sup>DMD = dry matter degradability, during fermentation (%); Lag time = time taken to start fermentation (h); Half time = half time to asymptote (h); FRD = fractional rate of degradation, (per h) at half time (h); Total gas = cumulative total gas production (mL/g sample incubated); Total VFA = mmol/g sample incubated.

## DISCUSSION

Overall, differences in fermentation characteristics among WFM can be attributed to their fiber and protein fractions, which are the key components influencing digestibility and fermentability of coproducts in the pig intestine (Jha and Leterme, 2012). The range of total gas production from WFM fermentation was similar in range to that of wheat bran (Jha et al., 2011b) and less than half of the total gas produced by wheat flour (Jha et al., 2011a) with similar trends for the total VFA production. This fermentation capacity seems to be associated with the matrix. The starch and proteins in the WFM are potentially embedded with fiber (with some variation among WFM) whereas that of wheat is loosely embedded. This matrix complexity makes nutrients in WFM less accessible to enzymes and microbes for digestion and fermentation (Bach Knudsen, 2001). The difference in the total gas and the VFA produced suggests that fermentability among WFM samples varies. The difference is associated to their fiber and protein content as suggested by correlation between ADF and CP with DM degradability and total gas production. Also, a study in pigs with such feedstuffs, including wheat bran, revealed similar functionality (Jha and Leterme, 2012).

The WFM samples studied varied widely in fiber and protein content within and among sample types. With respect to chemical composition, Shorts A was more consistent with middlings, having a lower than average crude fiber and ADF content and resulting in a similar fermentation profile. Also, the composition of products and their fermentability varied within same group of WMF such as the 2 Shorts and 2 Millrun samples. However, the reason for such variation could not be explained for the current data set and WFM sample set. Therefore, further study is required to explore the matrix in detail and potential effect of enzymatic treatments to enhance the fermentation and degradation of WFM

samples in the pig intestine. In conclusion, in vitro degradation and fermentation characteristics of different WFM vary in the pig intestine and are mainly associated with the fiber and protein content. Therefore, treatments targeted to reduce the impact of fiber and protein may increase the digestibility and fermentability of wheat coproducts from flour milling.

## LITERATURE CITED

- Bach Knudsen, K. E. 2001. The nutritional significance of “dietary fibre” analysis. *Anim. Feed Sci. Technol.* 90:3–20.
- Boisen, S., and J. A. Fernandez. 1997. Prediction of the total tract digestibility of energy in feedstuffs and pig diets by in vitro analyses. *Anim. Feed Sci. Technol.* 68:277–286.
- France, J., M. S. Dhanoa, M. K. Theodorou, S. J. Lister, D. R. Davies, and D. Isac. 1993. A model to interpret gas accumulation profiles associated with in vitro degradation of ruminant feeds. *J. Theor. Biol.* 163:99–111.
- Jha, R., J. Bindelle, B. Rossnagel, A. Van Kessel, and P. Leterme. 2011a. In vitro evaluation of the fermentation characteristics of the carbohydrate fractions of hulless barley and other cereals in the gastrointestinal tract of pigs. *Anim. Feed Sci. Technol.* 163:185–193.
- Jha, R., J. Bindelle, A. Van Kessel, and P. Leterme. 2011b. In vitro fibre fermentation of feed ingredients with varying fermentable carbohydrate and protein levels and protein synthesis by colonic bacteria isolated from pigs. *Anim. Feed Sci. Technol.* 165:191–200.
- Jha, R., and P. Leterme. 2012. Feed ingredients differing in fermentable fibre and indigestible protein content affect fermentation metabolites and faecal nitrogen excretion in growing pigs. *Animal* 6:603–611.
- Nortey, T. N., J. F. Patience, J. S. Sands, N. L. Trottier, and R. T. Zijlstra. 2008. Effects of xylanase supplementation on digestibility and digestible content of energy, amino acids, phosphorus, and calcium in wheat by-products from dry milling in grower pigs. *J. Anim. Sci.* 86:3450–3464.
- Shrestha, D., J. Broz, and R. T. Zijlstra. 2011. Effects of supplemented NSP-degrading enzymes on nutrient digestibility of diets containing wheat and wheat millrun fed to grower pigs. *J. Anim. Sci.* 89(E-Suppl. 1):88.

## References

This article cites 8 articles, 1 of which you can access for free at:  
[http://www.journalofanimalscience.org/content/90/Supplement\\_4/173#BL](http://www.journalofanimalscience.org/content/90/Supplement_4/173#BL)