



## The Effect of Level of Wheat Inclusion in Diets for Growing and Finishing Pigs on Performance, Nutrient Digestibility and Gastric Ulceration

M. E. E. Ball\* and E. Magowan

Agri-Food and Biosciences Institute, Large Park, Hillsborough, Co Down BT26 6DR, Northern Ireland, UK

**ABSTRACT:** Four experimental diets were formulated to contain 700 g/kg cereal with decreasing levels of wheat:barley inclusion. Diet 1 contained 700 g/kg wheat, diet 2 contained 600 g/kg wheat and 100 g/kg barley, diet 3 contained 500 g/kg wheat and 200 g/kg barley and diet 4 contained 400 g/kg wheat and 300 g/kg barley. The diets were offered to pigs on three trials to investigate effects on the performance of individually ( $n = 72$ ) and group housed ( $n = 480$ ) pigs and on nutrient digestibility in pigs housed in metabolism crates ( $n = 24$ ). Performance was assessed from 10 wks of age until slaughter and carcass characteristics were measured. For the group performance study, one pig from each pen (in total 24) at 10, 15 wks and at finish were slaughtered to ascertain scores for stomach ulceration, stomach weights and intestinal length. Level of wheat inclusion did not significantly ( $p > 0.05$ ) affect liveweight gain (LWG) or feed conversion ratio (FCR). Feed intake was lowest ( $p < 0.05$ ) for individually housed pigs offered diets containing 700 g/kg wheat during the 10-15 wk period, which indicated that individually housed pigs attempted to eat to a constant energy intake. There was little evidence of stomach ulceration across treatments and increasing wheat inclusion had no detrimental effect. Higher levels of wheat inclusion tended to increase backfat depth at the P<sub>2</sub> position which could lead to increasing grading penalties in a commercial situation although more research is required in this area. Increasing level of wheat inclusion increased digestible energy (DE) content but the lack of effect on FCR and killing out percentage indicated that utilization of energy from barley and wheat was similar. Digestibility coefficients increased linearly with increasing wheat content, which can be attributed to the lower level of fibre and higher level of starch in wheat compared with barley. (**Key Words:** Pigs, Wheat, Barley, Performance, Digestibility)

### INTRODUCTION

Wheat and barley are important cereal grains, with world production of wheat being over 600 million tonnes and barley production being over 130 million tonnes (USDA, 2008). In the United Kingdom, over 40% of the wheat and barley produced is used in animal feeds and these grains are common sources of energy in diets for growing and finishing pigs. Traditionally, barley has been included at higher inclusion levels due to lower purchase cost and also because of reports that high levels of wheat inclusion (700 g/kg) can cause stomach ulceration (Nielsen and Ingvarsten, 2000). Smith and Edwards (1996) reported that wheat-based diets resulted in more gastric ulcers than barley-based diets, and suggested that this may be due to the lower fibre

content of wheat, which influences the firmness of the stomach contents (Johansen et al., 1996). Nielsen and Ingvarsten (2000) also found that wheat-based diets (700 g/kg) resulted in a higher incidence of stomach ulceration compared with pigs offered barley-based diets (3.3 vs. 2.0 on scale of 0 to 10).

High levels of wheat inclusion have also been reported to have negative implications for pig carcass grading (Hanrahan and O'Grady, 1984). These workers compared the performance and carcass quality of pigs offered wheat or barley-based diets containing 777 g/kg wheat or 792 g/kg barley. Wheat-based diets resulted in better performance in terms of liveweight gain (LWG), feed:carcass feed conversion ratio (FCR) and kill out percentage. However, backfat depth was increased when the wheat-based diets were offered. Wheat contains a higher digestible energy (DE) content than barley (15.2 vs. 13.9 MJ/kg dry matter (DM)) (Van Barneveld, 1999). However, the effect of wheat inclusion on carcass quality and stomach ulceration requires further investigation and the primary aim of this study was

\* Corresponding Author: M. E. E. Ball. Agri-Food and Biosciences Institute, Large Park, Hillsborough, Co Down, Northern Ireland, UK. Tel: +44-028-9268-2484, Fax: +44-028-9268-9594, E-mail: elizabeth.ball@afbini.gov.uk

Submitted Jul. 8, 2010; Accepted Sept. 6, 2010; Revised Oct. 2, 2010

to examine the effect of increasing the level of wheat inclusion in diets offered to growing/finishing pigs.

## MATERIAL AND METHODS

Four experimental diets were formulated to contain 700 g/kg cereal (Table 1). Diet 1 contained 700 g/kg wheat, diet 2 contained 600 g/kg wheat and 100 g/kg barley, diet 3 contained 500 g/kg wheat and 200 g/kg barley and diet 4 contained 400 g/kg wheat and 300 g/kg barley. Diets were mixed and cold pelleted on site. Cereals were ground using a hammer mill (screen size 5 mm) and raw materials were weighed prior to mixing in a Bental mixer. Diets were cold pelleted in a Lister 7.5 cuber using a 3 mm die, cooled, stored in sealed 25 kg bags, labelled and transferred to a cool, dry environment. The chemical composition and gross energy contents of the diets are presented in Table 1. Diets contained similar levels of crude protein, oil and gross energy but levels of fibre and ash increased with decreasing wheat inclusion.

### Trial 1 - Effect on performance of individually housed pigs

Seventy-two Landrace×Large White pigs (36 boars, 36 gilts) were selected at nine weeks of age and transferred to individual pens. Pigs were given one week to acclimatize to their new surroundings and then allocated to the four experimental diets on the basis of weight and gender, giving 18 pigs/treatment. Daily LWG, daily feed intake (FI) and FCR were calculated weekly over the experimental period. The experimental period ran from 10 wks of age to finish

and pigs were finished over a 3-wk period (20-22 wks) with equal numbers of pigs from each treatment slaughtered each week.

### Trial 2 - Effect on performance of group housed pigs

The experimental diets were offered to 480 Landrace×Large White pigs over six replicates. Pigs were housed in groups of 20, balanced for weight and gender. LWG, FI and FCR were determined between 28 kg and 100 kg (finish age was 21 weeks plus 5 days). At 10 and 15 weeks of age and at finish, one pig from each pen was slaughtered, the gastrointestinal tract eviscerated and the stomach dissected and scored for ulceration on a scale of 0-10, according to the method of Nielsen and Ingvarsten (2000). Weights of empty stomach, small and large intestines were recorded, as was the length of the small and large intestine.

### Trial 3 - Effect on nutrient digestibility in pigs housed in metabolism crates

A total of 24 (Large White×Landrace) boars of 40 kg were housed in metabolism crates for 14 days (7-day pre-feed and a 7-day total collection of faeces and urine). Diet and faeces were analyzed for DM, ash, CP and neutral detergent fibre (NDF) according to the methods described by the Association of Official Analytical Chemists (1990). Lipid content was analysed by the Oil Procedure B method as outlined in the Official Journal of the European Communities (1998). CP content of the urine samples was also determined. Gross energy of diets, faeces and urine were measured using an Isoperibol bomb calorimeter (Parr, Model 1271). Digestibility and retention coefficients were

**Table 1.** Ingredient and chemical composition of experimental diets

Component	Wheat 700 g/kg	Wheat 600 g/kg	Wheat 500 g/kg	Wheat 400 g/kg
Ingredient composition (g/kg)				
Wheat	700	600	500	400
Barley	-	100	200	300
Soyabean meal 50	192	192	192	192
Soya oil	30	30	30	30
L-lysine HCl	3	3	3	3
Molaferm <sup>1</sup>	30	30	30	30
Water	20	20	20	20
Minerals and vitamins <sup>2</sup>	25	25	25	25
Chemical composition (g/kg DM)				
Ash	52.9	53.7	53.5	55.6
Crude protein	210	207	207	208
Neutral detergent fibre	120	125	129	151
Oil	46.4	44.5	45.3	46.9
Gross energy (MJ/kg DM)	18.5	18.7	18.8	18.6

<sup>1</sup> Molaferm contains: crude protein 7%, total sugars 37%, ash 14.5%, calcium 0.8%, phosphorus 0.2%, sodium 0.4%, sodium chloride 1.0%, potassium 4%, sulphur 0.4%.

<sup>2</sup> Minerals and vitamins supplement supplied (per kg diet): vitamin A 480,000 IU, vitamin D3 80,000 IU, vitamin E 4,000 mg/kg, copper 600 mg/kg, selenium 12 mg/kg, calcium 22.04%, sodium 5.86%, phosphorus 6.66%.

**Table 2.** The effect of dietary inclusion level of wheat on performance of individually housed pigs

	Wheat 700 g/kg	Wheat 600 g/kg	Wheat 500 g/kg	Wheat 400 g/kg	SEM	p	p = Lin	p = Quad
Average daily feed intake (g/d)								
10-15 wk	1,895	2,051	2,016	1,963	36.7	<0.05	NS	<0.05
10-20 wk	2,191	2,346	2,300	2,264	43.4	NS	NS	<0.05
10-finish <sup>1</sup>	2,301	2,411	2,387	2,351	43.1	NS	NS	NS
15-20 wk	2,544	2,682	2,623	2,616	60.8	NS	NS	NS
15-finish	2,651	2,731	2,702	2,692	57.1	NS	NS	NS
Daily liveweight gain (g/d)								
10-15 wk	916	997	976	944	22.7	NS	NS	<0.05
10-20 wk	971	1,027	1,010	999	21.8	NS	NS	NS
10-finish	970	1,027	1,012	1,002	21.3	NS	NS	NS
15-20 wk	1,027	1,057	1,044	1,055	29.6	NS	NS	NS
15-finish	1,016	1,051	1,040	1,051	28.6	NS	NS	NS
Feed conversion ratio								
10-15 wk	2.07	2.06	2.08	2.09	0.030	NS	NS	NS
10-20 wk	2.26	2.29	2.28	2.27	0.032	NS	NS	NS
10-finish	2.38	2.36	2.37	2.35	0.034	NS	NS	NS
15-20 wk	2.50	2.55	2.53	2.49	0.052	NS	NS	NS
15-finish	2.64	2.61	2.61	2.57	0.054	NS	NS	NS
Carcass data								
Cold weight (kg)	77.5	79.3	79.8	77.6	1.53	NS	NS	NS
Killing out %	77.6	76.8	77.5	76.4	0.51	NS	NS	NS
P <sub>2</sub> (mm)	12.0	13.0	12.0	11.9	0.64	NS	NS	NS

<sup>1</sup> Pigs housed individually reached the weight of 100 kg approximately 12 days earlier than those housed in groups.

subsequently calculated.

### Statistical analysis

Analysis of variance was conducted using Genstat 8. For individually housed pigs and for stomach ulceration and intestinal measurements, pig was the experimental unit. For group housed pigs, the pen average was taken as the experimental unit. The effect of dietary treatment, linear and quadratic effects of wheat inclusion were tested for.

## RESULTS

### Effect on the performance of individually housed pigs

There was a quadratic effect on feed intake during the 10-15 wk and 10-20 wk period with feed intake increasing with decreasing wheat inclusion until 40 g/kg inclusion (Table 2). This quadratic effect was reflected in LWG for the 10-15 wk period. However, there were no significant differences in feed intake during the other time periods although the 700 g/kg wheat diet always resulted in numerically lower intakes compared with those achieved with the other dietary treatments. Similarly, LWG was numerically lower for pigs offered the 700 g/kg wheat diet but the differences were not significant (Table 2). There were no significant differences in FCR, kill out percentage

or backfat at the P<sub>2</sub> position as a result of dietary treatment.

### Effect on performance of group housed pigs

There was no significant effect of offering the diets containing different levels of wheat on performance of group housed pigs (Table 3). There was little evidence of stomach ulceration across the treatments with scores of 1.0 or less on the scale of 0-10 (Table 4). Furthermore, the level of wheat inclusion did not significantly affect the degree of stomach ulceration. However, the pigs offered the diet containing 700 g/kg wheat had heavier ( $p < 0.05$ ) empty small intestines than those offered diets containing 600 or 500 g/kg wheat. There was a quadratic effect on empty small intestine weight and length as these parameters decreased with decreasing wheat inclusion and then increased at the 400 g/kg inclusion level.

### Effect on nutrient digestibility in pigs housed in metabolism crates

Digestibility decreased linearly as the level of dietary wheat inclusion decreased (Table 5). Similarly, DE content of the diet was lower for diets containing less wheat. DE contents were 16.40, 16.38, 16.20 and 15.87 MJ/kg DM for diets containing 700, 600, 500 and 400 g/kg wheat. The level of dietary wheat inclusion had no significant effect on

**Table 3.** The effect of dietary inclusion level of wheat on performance of group housed pigs

	Wheat 700 g/kg	Wheat 600 g/kg	Wheat 500 g/kg	Wheat 400 g/kg	SEM	p	p = Lin	p = Quad
Average daily feed intake (g/d)								
10-15 wk	1,553	1,649	1,560	1,649	40.6	NS	NS	NS
10-finish	2,011	2,133	2,040	2,114	41.3	NS	NS	NS
15-finish	2,367	2,545	2,431	2,514	65.0	NS	NS	NS
Daily liveweight gain (g/d)								
10-15 wk	703	758	711	743	21.3	NS	NS	NS
10-finish	857	897	850	879	14.4	NS	NS	NS
15-finish	972	1,015	955	989	18.2	NS	NS	NS
Feed conversion ratio								
10-15 wk	2.22	2.18	2.21	2.23	0.055	NS	NS	NS
10-finish	2.35	2.38	2.40	2.40	0.025	NS	NS	NS
15-finish	2.44	2.51	2.54	2.55	0.043	NS	NS	NS
Carcass data								
Cold weight (kg)	74.2	76.1	74.7	75.5	1.37	NS	NS	NS
Killing out %	76.5	75.8	76.5	76.2	0.78	NS	NS	NS
P <sub>2</sub> (mm)	13.5	13.7	12.1	12.9	0.56	NS	NS	NS

N balance with average N retention and excretion values being 32.8 and 19.4 respectively.

## DISCUSSION

The DE content of the diets increased as the inclusion of wheat increased and this was due to the higher level of DE in wheat, when compared with barley (Van Barneveld et al., 1999). On the whole, there were no significant differences in feed intake as a result of wheat inclusion, although there

was a trend for pigs offered the diets containing higher levels of wheat to eat less (especially in individually housed pigs). This is in keeping with the results of Weatherup et al. (2002). These workers found that pigs housed individually were able to increase feed intake as DE was reduced, which indicated that pigs housed individually attempted to eat to a constant energy intake. However, it must be highlighted that pigs offered the 600 g/kg wheat diet had numerically higher feed intakes over the entire experimental period. The differences in feed intake between individually and group

**Table 4.** The effect of dietary inclusion level of wheat on stomach ulceration, weight of empty stomach and empty large intestine (LI) and weight and length of empty small intestines (SI) (LWT applied as covariate)

	Wheat 700 g/kg	Wheat 600 g/kg	Wheat 500 g/kg	Wheat 400 g/kg	SEM	p	p = Lin	p = Quad
Stomach ulceration	1.01	0.08	0.43	0.64	0.484	NS	NS	NS
Empty stomach wt (kg)	0.511	0.452	0.457	0.465	0.0798	NS	NS	NS
Empty SI wt (kg)	2.012 <sup>b</sup>	1.576 <sup>a</sup>	1.639 <sup>a</sup>	1.706 <sup>ab</sup>	0.1069	<0.05	NS	<0.05
Empty LI wt (kg)	1.414	1.381	1.290	1.336	0.1286	NS	NS	NS
Length of SI (m)	20.48	19.37	18.19	19.40	0.536	NS	NS	<0.05

**Table 5.** The effect of dietary inclusion level of wheat on nutrient digestibility and nitrogen balance in finishing pigs housed in metabolism crates

	Wheat 700 g/kg	Wheat 600 g/kg	Wheat 500 g/kg	Wheat 400 g/kg	SEM	p	p = Lin	p = Quad
DM digestibility	0.891	0.881	0.869	0.859	0.0057	<0.01	<0.001	NS
Energy digestibility	0.886	0.877	0.863	0.853	0.0061	<0.01	<0.001	NS
NDF digestibility	0.627	0.590	0.555	0.572	0.0192	NS	<0.05	NS
Oil digestibility	0.790	0.768	0.751	0.757	0.0122	NS	<0.05	NS
CP digestibility	0.866	0.849	0.838	0.828	0.0091	<0.05	<0.01	NS
Digestible energy (MJ/kg DM)	16.40	16.38	16.20	15.87	0.136	<0.05	<0.01	NS

housed pigs reported by Weatherup et al. (2002) was observed within the current study. Over the period of 10-15 weeks of age, individually housed pigs consumed on average 379 g/d more feed than those housed in groups. This higher feed intake was reflected in increased LWG with individually housed pigs growing at a faster rate (958 vs. 729 g/d). There was no significant effect of level of wheat inclusion on carcass parameters, although wheat at the higher levels of inclusion tended to increase backfat depth at the P<sub>2</sub> position, which could lead to increased grading penalties in a commercial situation. Hanrahan and O'Grady (1984) also reported that wheat resulted in greater backfat depth when compared to barley-based diets and this may be attributed to the lower level of dietary lysine as a proportion of DE in the wheat-based diets. However, when the wheat-based diets were supplemented with additional lysine, the effect on backfat was still apparent indicating that the utilization of wheat DE was less efficient than that of barley DE. In the current study there was no significant difference in FCR and no effect of wheat inclusion on kill out percentage indicating that the utilization of energy from barley and wheat was equal (Cole et al., 1972).

The level of stomach ulceration was low across all the treatments (<1.01 on scale of 0-10) (Nielsen and Ingvarsten, 2000) and increasing the level of wheat inclusion had no significant effect. This finding is in contrast to Smith and Edwards (1996) who found that ulceration score was higher for wheat compared with barley-based diets (3.73 cf 2.16,  $p < 0.001$ ) (level of ulceration was scored using a modification of the method described by Potkins et al., 1989). These workers concluded that there was a 'factor' in the wheat which contributed to ulceration. This 'factor' may be the lower fibre content of wheat which results in more fluid stomach contents (Johansen et al., 1996). However, the pelleting process may have negated the difference between wheat and barley. Pelleting has been shown to increase keratinisation and ulceration (Wonda et al., 1992) although other workers have reported no negative effect of pelleting (Chae et al., 1899). It was expected that stomach weights for pigs offered barley-based diets would be heavier than those offered wheat-based diets in accord with previous work reported by Nielsen and Ingvarsten (2000). However, stomach weight was not significantly different in this study and the small intestine weight was highest for the diet containing the highest level of wheat. This may be a result of the increased digestibility with the higher levels of wheat inclusion, which contributed to the development of the small intestine (Morel and Cottam, 2007). The digestibility coefficients followed the expected pattern with digestibility and DE content increasing linearly with increasing wheat content. This effect can be attributed to the chemical composition of the cereals, with wheat containing a higher level of starch and a lower level of fibre than

barley (Bach Knudsen, 1997).

## CONCLUSIONS

While increasing level of wheat inclusion increased dietary DE content and nutrient digestibility, there was no effect on performance, although individually housed pigs tended to reduce intake and attempted to eat to a constant energy intake. None of the treatments resulted in high levels of stomach ulceration and there was no effect of increasing wheat level. However, higher dietary levels of wheat tended to increase backfat depth which could have negative grading implications although more research is required to fully elucidate the effect of high wheat levels on carcass quality.

## ACKNOWLEDGMENTS

The authors acknowledge financial support from the Department of Agriculture and Rural Development for Northern Ireland and Pig Regen Ltd. The assistance given by the staff of the Agri-Food and Biosciences Institute for care of pigs, sample collection and analysis is also gratefully acknowledged.

## REFERENCES

- Association of Official Analytical Chemists, 1990. Official Methods of Analysis of the Association of Official Analytical Chemists, 15<sup>th</sup> Edition. AOAC Press, Gaithersburg, USA.
- Bach Knudsen, K. E. 1997. Carbohydrate and lignin contents of plant materials used in animal feeding. *Anim. Feed Sci. Technol.* 67:319-338.
- Chae, B. J., I. K. Han, J. H. Kim, C. J. Yang, S. J. Ohh, Y. C. Rhee and Y. K. Chung. 1997. Effects of feed processing and feeding methods on growth and carcass traits for growing-finishing pigs. *Asian-Aust. J. Anim. Sci.* 10:164-169.
- Cole, D. J. A., B. Hardy and D. Lewis. 1972. In: *Pig Production* (Ed. D. J. A. Cole), pp. 243-257. London, Butterworths.
- Hanrahan, T. J. and J. F. O'Grady. 1984. Wheat as an ingredient in pig feeds. *Ir. J. Agric. Res.* 23:117-125.
- Johansen, H. N., K. E. Bach Knudsen, B. Sandström and F. Skjøth. 1996. Effects of varying content of soluble fibre from wheat flour and oat milling fractions on gastric emptying in pigs. *Br. J. Nutr.* 75:339-351.
- Morel, P. and Y. H. Cottam. 2007. Effects of particle size of barley on intestinal morphology, growth performance and nutrient digestibility in pigs. *Asian-Aust. J. Anim. Sci.* 20:1738-1745.
- Nielsen, E. K. and K. L. Ingvarsten. 2000. Effect of cereal type, disintegration method and pelleting on stomach content, weight and ulcers and performance in growing pigs. *Livest. Prod. Sci.* 66:271-282.
- Official Journal of the European Communities, 1998. L257, 19/09/1998, p. 14.
- Potkins, Z. V., T. L. J. Lawrence and J. R. Thomlinson. 1989. Oesphagogastric parakeratosis in the growing pigs: Effects of

- the physical form of barley-based diets and added fibre. *Res. Vet. Sci.* 47:60-67.
- Smith, W. J. and S. A. Edwards. 1996. Ulceration of the pars oesophagea - the role of a factor in wheat. *The Pig - J. Proc. Section*, 36:194-200.
- United States Department of Agriculture (USDA) 2008. Grain: World Markets and Trade. United States Department of Agriculture, Foreign Agricultural Service - Circular Series FG0508, May 2008.
- Van Barneveld, R. J. 1999. Chemical and physical characteristics of grains related to variability in energy and amino acid availability in pigs: a Review. *Aust. J. Agric. Res.* 50:667-687.
- Weatherup, R. N., V. E. Beattie, K. J. McCracken, R. W. Henry, S. G. McIlroy and S. Smyth. 2002. The effects of energy and lysine concentrations in grower diets for pigs on performance from 8 to 12 weeks of age. *Ir. J. Agric. Food Res.* 41:95-104.
- Wonda, K. J., J. D. Hancock, K. C. Behnke, G. H. Kennedy and R. H. Hines. 1992. In: *Kansas State University Swine Day Report of Progress 667* (Eds B. Goodband and M. Tokach), pp. 127-130. Kansas, USA.