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Effect of variety, endosperm hardness, the 1B/1R translocation and enzyme addition on the nutritive value of wheat for growing pigs

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It has been widely recognised that wheat chemical composition and nutritive value can vary as a result of genotypic differences, but there is a lack of information on wheat grown in Northern Ireland. Furthermore, there have been conflicting reports regarding the effect of endosperm hardness, the 1B/1R translocation and enzyme addition on the nutritive value of wheat for growing pigs. The effects of wheat variety, endosperm hardness, the presence of the 1B/1R translocation and enzyme addition were examined in four experiments involving a total of 326 Large White × Landrace pigs. Performance traits of individually housed pigs were measured in Experiments 1, 3 and 4 and apparent *in vivo* digestibility coefficients were determined at the total tract and ileal level from post-valve-T-caecum cannulated pigs in Experiment 2. The results obtained for the analysis of the chemical composition of the eight varieties were mainly within reported limits. However, there was a wide range of crude protein concentrations (97.8 to 138.7 g/kg dry matter) suggesting varietal differences. There was no effect of endosperm hardness or the 1B/1R translocation on chemical composition. In contrast to other research reports, there were no significant differences in pig performance as a result of either variety, endosperm hardness or the presence of the 1B/1R translocation. However, there were significant variety effects on apparent total-tract digestibility coefficients. Enzyme supplementation had no significant effect on pig performance, despite the fact that the basal diet did not have a high nutrient specification.

Keywords: 1B/1R translocation; enzyme; pigs; variety; wheat

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Introduction

Although wheat is a major component of many pig diets, it has been reported to be the most variable component in terms of chemical composition and nutritive value. This variation arises from a number of factors, including genotype, environmental conditions, maturity at harvest and level of fertilizer applied during crop growth (McDonald, Edwards and Greenhalgh, 1995).

The work of Lewis (1999) indicated that wheats produced in Northern Ireland vary in terms of chemical composition and nutritive value for growing pigs. In one study, Lewis (1999) evaluated 12 varieties of winter wheat formulated into high wheat (79%) diets and offered to cannulated pigs. There were significant varietal differences in apparent total-tract digestibility coefficients. Apparent ileal digestibility coefficients for dry matter (DM), neutral detergent fibre (NDF), oil and energy were also significantly affected by variety. In addition, the digestible energy (DE) concentrations for the wheat varieties were significantly different with a range between 16.1 and 16.7 MJ/kg DM. In a further study by Lewis (1999), six of the wheat varieties were evaluated in terms of pig performance and no significant varietal effect was reported for any performance trait. This is in contrast to the results of research conducted in Australia where Cadogan *et al*. (1999) reported that wheat variety had a significant influence on performance and DM digestibility.

A number of research reports have indicated that hard wheats are more efficiently utilized by pigs and poultry than soft wheats. Pearce *et al*. (1997) reported a positive correlation (R^2 0.42) between voluntary feed intake and endosperm hardness for post weaning pigs. In keeping with these findings, Lewis (1999) reported that hard wheat varieties resulted in higher apparent total-tract digestibility of DM and energy and significantly increased gain:feed ratio compared to the soft wheats. However, intake was not significantly affected by endosperm hardness. Therefore, it was concluded by Lewis (1999) that the effect of hard and soft wheats on nutrient digestibility and pig performance should be the focus of further investigation.

In recent years, wheat breeders have incorporated the short arm of the rye chromosome 1R into the wheat genome, replacing the short arm of the wheat chromosome 1B to improve disease resistance and yield (Zellor and Hsam, 1983). However, this translocation has negative implications for chemical composition, i.e., lower crude protein (CP) and starch concentrations and higher *in vitro* viscosity (Fenn *et al*., 1994; Burnett, Lorenz and Carver, 1995). Lewis (1999) investigated three hard and three soft wheats and reported no significant differences in CP concentration, although *in vitro* viscosity was slightly higher for wheats containing the 1B/1R translocation (+1B/1R). In one study Lewis (1999) found that the 1B/1R translocation did not significantly affect total tract or apparent ileal digestibility in growing pigs (except for ileal digestibility of NDF which was 3.4% higher for +1B/1R wheat). However, in a second study +1B/1R wheat yielded higher apparent total-tract digestibility coefficients for CP, oil, NDF and ash but did not significantly affect pig performance. There is therefore a need to further evaluate the effect of the 1B/1R translocation on pig performance and nutrient digestibility.

The major non-starch polysaccharides (NSP) in wheat are the pentosans which comprise approximately 85% of the total NSP, with the two most abundant pentosans being arabinoxylan and xylan (Goodlad and Mathers, 1991; Baidoo and

Liu, 1998). NSP are said to be anti-nutritive (Steenfeldt *et al*., 1995) as they increase the viscosity of the digesta, slowing down the rate of digestion and inhibiting enzyme accessibility (Ikegami *et al*., 1990). Some researchers have reported a beneficial effect of supplementing wheat diets with exogenous NSP degrading enzymes. For example, Yin (1997) reported that xylanase inclusion in wheat bran diets significantly increased ileal digestibility of CP and energy. However, research conducted by Lewis (1999) indicated that xylanase addition had little effect on apparent digestibility coefficients at either the total tract or ileal level.

The main objectives of this study were to determine the effects of wheat variety, endosperm hardness, the 1B/1R translocation and enzyme addition on production performance and on apparent total-tract and ileal digestibilities in growing pigs. A further aim was to examine the relationship between wheat chemical composition, performance and digestibility.

Materials and Methods

Eight locally produced wheat varieties classified as hard or soft, with or without the 1B/1R translocation, were obtained from the 2001 harvest (Table 1). All wheats were grown at the Agri-Food and Biosciences Institute, Plant Testing Centre in Crossnacreevy, Belfast.

Table 1. Categorisation of the wheat varieties on the basis of endosperm type and IB/IR translocation

Variety	Endosperm	1B/1R translocation
Falstaff	Hard	+
Napier	Hard	+
Savannah	Hard	+
Malacca	Hard	–
Buchan	Soft	+
Claire	Soft	–
Consort	Soft	–
Riband	Soft	–

Experiment 1 – The effect of wheat variety, endosperm hardness and the 1B/1R gene on production performance of growing pigs

Experimental diets were formulated from each variety in Table 1 to contain 700 g/kg wheat (Table 2). Wheats were ground using a hammer mill (Christy Hunt; screen size 3 mm) and mixed with other raw materials in a vertical mixer (Christy Hunt) for 30 min. Some components (i.e., minerals and vitamins, oils and amino acids) were pre-mixed with a small quantity of cereal in a Hobart bowl mixer before being transferred to the vertical mixer. After mixing, diets were cold-pelleted in a Lister HP cuber using

Table 2. Ingredient composition (g/kg) of experimental diets

Ingredient	Experiments 1 and 2	Experiments 3 and 4
Wheat	700	597
Pollards	0	80
Soyabean meal (48%)	217	292
Soya oil	20	0
Lysine HCL	4.6	1.4
L-Threonine	2	0.2
DL-Methionine	1.4	0.2
Minerals and vitamins[1]	25	12.2
Molaferm[2]	30	17
Chemical analysis (formulated)		
Crude protein	184.4	217.8
Oil	33.6	16.2
Crude fibre	25.8	32.7
Ash	28.6	33.8
Lysine	12.71	12.8
Digestible energy (MJ/kg)	14.15	13.78

[1]Colborn Growplus 25 (Roche Vitamins Europe Ltd) supplying (per kg diet): Vitamin A 12000 IU (international units); Vitamin 03 2000 IU; Vitamin E 100 IU; copper from copper sulphate 156.25 mg; selenium from sodium selenite 0.3 mg; sodium 0.15%; phosphorus 0.17%.

[2]Molaferm is a molasses-based product formulated to contain 70 g/kg crude protein and 9.5 MJ/kg digestibility energy on a fresh basis (United Molasses).

a 3 mm dye, cooled, stored in sealed bags (25 kg), labelled and transferred to a cool, dry environment.

A total of 144 crossbred (Large White × Landrace) pigs were used in this trial. Due to constraints on experimental facilities it was necessary to split the trial into two replicates each involving 72 pigs. For each replicate of the trial 7-week-old pigs (36 males, 36 females) were placed in individual pens and offered a commercial diet for 7 days to allow adjustment to surroundings. The pigs were weighed on 2 consecutive days prior to start of the experiment and were allocated to experimental diets on the basis of their weight and gender. Pigs were fed *ad libitum* and dry matter intake (DMI), live-weight gain (LWG) and feed conversion ratio (FCR) were determined weekly for a 4-week period.

Experiment 2 – The effect of wheat variety, endosperm hardness and the 1B/1R gene on apparent total tract and ileal digestibility in growing pigs

Six of the wheat varieties used in Experiment 1 (Falstaff, Napier, Savannah, Claire, Consort and Riband) were selected for further investigation and formulated into diets as for Experiment 1.

Titanium dioxide (TiO_2) was added (2 g/kg) as an indigestible marker. At approximately 8 weeks of age, 14 male Large White × Landrace pigs had cannulae inserted according to the post-valve-T-caecum (PVTC) cannulation procedure developed by Van Leeuwen *et al*. (1991). Twelve of these cannulated pigs were used in the experiment and were randomised into a 4-period partially balanced design. For each period there were two replicates, therefore in total eight pigs were used per treatment. Each period consisted of a 5-day pre-feed, 7-day faecal collection and 2 × 12 h ileal collections.

Experiment 3 – The effect of wheat variety and enzyme supplementation on the production performance of growing pigs

The six wheat varieties used in Experiment 2 were formulated into 12 diets (Table 2), differing in wheat variety, with or without supplementation with exogenous xylanase enzyme (Porzyme 9300; inclusion rate 1 g/kg, Danisco Animal Nutrition, Denmark). A total of 120 crossbred (Large White × Landrace) pigs were used in this trial. As for Experiment 1, the trial was split into two replicates; replicate 1 consisted of 72 pigs (36 males, 36 females) while replicate 2 consisted of 48 pigs (24 males and 24 females). For each replicate 7-week old pigs were placed in individual pens and offered a commercial diet for 7 days to allow adjustment to surroundings. The pigs were weighed on consecutive days prior to the experiment and allocated to experimental diets on the basis of weight and gender. Pigs were fed *ad libitum* and DMI, LWG and FCR were determined weekly for a 4-week period.

Experiment 4 – The effect of wheat variety and enzyme supplementation on the production performance of growing pigs

The two remaining wheat varieties (Malacca and Buchan) were formulated into diets as for Experiment 3 (Table 2) with or without enzyme supplementation (Porzyme 9300; 1 g/kg). Forty-eight pigs (24 male and 24 female; Large White × Landrace) were placed in individual pens and offered a commercial diet for 7 days to allow adjustment to surroundings. After two consecutive weighings prior to the start of the trial, pigs were allocated to experimental diets on the basis of their weight and gender. DMI, LWG and FCR were determined weekly for a 4-week period.

Analysis of wheat, diets, faeces and ileal digesta

Proximate analyses were performed according to the methods outlined by the Association of Official Analytical Chemists (1990). Dry matter was measured in a forced draught oven at 102 °C ± 1 °C for 24 h. Gross energy (GE) was determined using a Parr, Model 1271, bomb calorimeter. Starch and amylose concentrations were determined by the Megazyme enzyme method (Megazyme International). The Bedford and Classen (1993) method was used for the measurement of *in vitro* viscosity. Non-starch polysaccharide (NSP) measurements were carried out using the Englyst GLC Fiberzym kit (Englyst, Quigley and Hudson, 1994). Amino acids were determined by ion exchange chromatography (LKB 440 Amino Acid Analyser). Titanium dioxide was determined by the method of Leone (1973) with modifications by Peddie *et al.* (1982).

Statistical analysis

Experiment 1

The two replicates of the trial were combined and analysis of variance (ANOVA) was conducted using Genstat 6. The model used had effects for replicate and variety.

Experiment 2

Restricted maximum likelihood (REML) was carried out using Genstat 6 to evaluate differences among varieties and contrasts were used to compare varieties with and without the 1B/1R translocation. The effects of pigs, period and variety were included in the model.

Experiment 3

The two replicates were combined (10 pigs/treatment) and ANOVA was conducted using Genstat 6. Effects for replicate, variety and enzyme level were included in the model.

Experiment 4

Data were analysed using ANOVA as for Experiment 3.

Correlation analysis

Correlation coefficients were determined using Excel Statistical Data Analysis Pack. Relationships between wheat chemical parameters and performance/digestibility traits were tested.

Results

Chemical composition

The chemical composition of the eight wheat varieties is presented in Table 3. The ranges of values were mainly within reported limits in the literature. Chemical composition of hard and soft wheats was similar. Likewise, the presence of the 1B/1R translocation did not affect chemical composition.

Table 4 presents the correlation matrix for the chemical composition variables. Starch concentration was negatively correlated with CP concentration ($P < 0.01$) and GE ($P < 0.05$). Amylose concentration was positively correlated with oil concentration ($P < 0.01$), as was GE with CP ($P < 0.01$). There was also a positive relationship between soluble NSP and total NSP concentration. No significant relationships were detected between the other variables.

The effect of wheat variety, endosperm hardness and the 1B/1R translocation on production performance of growing pigs

There were no significant differences in pig performance due to variety, endosperm hardness or presence of the 1B/1R translocation (Table 5).

Correlation analyses of the association between chemical composition of the wheat used and animal performance traits yielded no significant relationships.

The effect of wheat variety, endosperm hardness and the 1B/1R translocation on apparent total tract and ileal digestibility in growing pigs

While TiO_2 was included in the diet at 2.0 g/kg analysis showed that the actual

Table 3. Chemical composition[1] of wheat varieties and effect of endosperm hardness and presence of 1B/1R translocation

Factor	Crude protein	Neutral detergent fibre	Oil	Ash	Starch	Amylose	Non-starch polysaccharides			Gross energy (MJ/kg DM)	IVV[2] (mPa s)
							Soluble	Insoluble	Total		
Wheat variety											
Falstaff	97.8	160.6	9.9	18.4	659.2	135.5	23.0	84.9	107.9	18.2	10.0
Napier	114.0	166.2	11.8	15.1	639.8	165.7	19.7	98.2	117.9	18.3	15.2
Savannah	122.0	148.0	10.2	18.0	631.0	134.9	22.5	92.6	115.1	18.3	12.3
Malacca	128.9	191.1	11.5	19.9	620.6	156.4	20.2	84.0	104.2	18.4	13.5
Buchan	113.7	154.1	14.3	17.7	640.9	171.7	21.0	92.6	113.6	18.3	10.9
Claire	138.7	182.6	12.1	16.2	629.1	153.2	24.5	89.7	114.2	18.4	11.5
Consort	116.8	153.6	13.0	17.6	634.8	163.8	22.8	86.4	109.2	18.4	7.9
Riband	108.7	137.3	12.5	16.2	659.2	151.1	21.8	82.0	103.8	18.3	9.7
Endosperm hardness											
Hard	115.8	166.5	10.9	17.9	637.7	148.1	21.4	89.9	111.3	18.3	12.8
Soft	119.5	156.9	13.0	16.9	641.0	160.0	22.5	87.7	110.2	18.4	10.0
1B/1R translocation											
+	111.9	157.2	11.5	17.3	642.7	152.0	21.6	92.1	113.7	18.3	12.1
–	123.3	166.2	12.3	17.5	635.9	156.1	22.3	85.5	107.8	18.4	10.7

[1]Expressed as g/kg dry matter (DM) unless stated otherwise.
[2]IVV = *in vitro* viscosity.

Table 4. Correlations[1] between chemical components for a set of 8 varieties

Component	Neutral detergent fibre	Oil	Ash	Starch	Amylose	Non-starch polysaccharides			Gross energy	IVV[2] (mPa s)
						Soluble	Insoluble	Total		
Crude protein	0.62	0.13	0.03	–0.86	0.17	0.20	0.15	0.30	0.83	0.32
Neutral detergent fibre		0.14	0.29	0.65	0.15	0.07	0.04	0.02	0.49	0.50
Oil			0.25	0.07	0.88	0.19	0.09	0.04	0.41	0.26
Ash				0.31	0.28	0.05	0.48	0.51	0.07	0.14
Starch					0.24	0.09	0.27	0.25	–0.78	0.42
Amylose						0.47	0.31	0.18	0.45	0.09
Non-starch polysaccharides										
Soluble							0.28	0.96	0.08	0.60
Insoluble								0.01	0.09	0.59
Total									0.07	0.45
Gross energy										0.01

[1]Correlations ≥0.707, 0.834, 0.925 are significant at $P < 0.05$, 0.01 and 0.001, respectively.
[2]IVV = *in vitro* viscosity.

Table 5. The effect of wheat variety, endosperm hardness and the 1B/1R translocation on production performance of growing pigs (Experiment 1)

Factor[1]	Initial weight (kg)	Finish weight (kg)	Live-weight gain (g/d)	Dry matter intake (g/d)	Feed conversion ratio
Wheat variety					
Falstaff	20.2	45.3	895	1271	1.43
Napier	20.1	45.1	892	1253	1.41
Savannah	20.3	46.0	918	1212	1.33
Malacca	19.9	45.7	922	1254	1.38
Buchan	20.0	44.9	889	1240	1.41
Claire	20.0	44.9	889	1232	1.40
Consort	19.8	45.6	923	1299	1.41
Riband	19.9	45.7	921	1274	1.39
s.e.	0.22	0.73	24.4	25.4	0.036
Endosperm hardness					
Hard	20.1	45.5	907	1247	1.39
Soft	19.9	45.3	906	1262	1.40
s.e.	0.11	0.36	12.1	12.8	0.018
1B/1R translocation					
+ 1B/1R	20.1	45.3	899	1243	1.40
– 1B/1R	19.9	45.5	914	1266	1.40
s.e.	0.11	0.36	12.1	12.8	0.018

[1]No significant effects were detected for any performance trait due to variety, endosperm hardness or 1B/1R translocation.

concentration ranged from 1.93 (Falstaff) to 2.79 (Consort) g/kg DM. Apparent total-tract digestibility coefficients of DM and energy were not affected by wheat variety (Table 6). However there were significant differences among varieties for the apparent total-tract digestibility of CP, oil and NDF. Apparent total-tract digestibility of CP, oil and NDF were lower ($P < 0.05$) for variety Consort than for variety Claire.

Ileal digestibility of NDF was also lower ($P < 0.001$) for variety Consort than for the other varieties (Table 6). Endosperm hardness combined with the 1B/1R translocation had no significant effect on any digestibility coefficients except for ileal digestibility of NDF, which was higher ($P < 0.001$) for hard wheats with the 1B/1R translocation.

The relationship between apparent total-tract and ileal digestibility coefficients were examined and the only significant ($P < 0.05$) correlations observed were for apparent ileal digestibility of CP with apparent-total tract digestibility of DM and CP (r 0.83 and 0.86, respectively).

There were few significant relationships between wheat chemical composition and apparent total-tract digestibility coefficients but CP concentration was found to be positively related ($P < 0.01$) to total tract digestibility of CP (r 0.92) and NDF concentration was positively related ($P < 0.01$) to total tract digestibility of oil (r 0.90). *In vitro* viscosity was positively correlated ($P < 0.01$) with ileal digestibility of NDF (r 0.91) and phenylalanine (r 0.95). Positive relationships were observed between NDF concentration and ileal digestibility of tyrosine (r 0.86) and for soluble NSP and total NSP with ileal digestibility of threonine (r 0.95 and 0.93, respectively). Negative correlations were observed between wheat amylose concentration and ileal digestibility of

Table 6. The effects of wheat variety, endosperm hardness and the 1B/1R translocation on apparent total-tract and ileal digestibility (Experiment 2)

Dietary component	Variety						s.e.d.	Significance level	
	Claire	Consort	Riband	Falstaff	Napier	Savannah		Variety	Contrast[1]
Apparent total-tract digestibility									
Dry matter	0.930	0.913	0.923	0.922	0.919	0.921	0.0059		
Crude protein	0.930^{b}	0.914^{a}	0.918^{ab}	0.909^{a}	0.914^{a}	0.920^{ab}	0.0069	<0.05	
Oil	0.858^{b}	0.819^{a}	0.823^{ab}	0.843^{ab}	0.846^{ab}	0.824^{ab}	0.0132	<0.05	
Neutral detergent fibre	0.750^{c}	0.667^{a}	0.700^{ab}	0.721^{bc}	0.708^{abc}	0.728^{bc}	0.0214	<0.01	
Gross energy	0.929	0.913	0.922	0.923	0.919	0.922	0.0587		
Apparent ileal digestibility									
Dry matter	0.784	0.774	0.794	0.785	0.790	0.791	0.0072		
Crude protein	0.823	0.804	0.818	0.807	0.812	0.818	0.0110		
Oil	0.831	0.815	0.817	0.839	0.842	0.835	0.0114		
Neutral detergent fibre	0.462^{b}	0.388^{a}	0.442^{b}	0.462^{b}	0.507^{c}	0.498^{c}	0.0159	<0.001	<0.001
Ash	0.410	0.414	0.428	0.422	0.378	0.421	0.0269		
Starch	0.998	0.998	0.999	0.998	0.999	0.999	0.0001		
Gross energy	0.794	0.785	0.802	0.796	0.800	0.800	0.0069		

[1]Contrast = Soft endosperm with 1B/1R translocation (Claire, Consort and Riband) vs. hard endosperm with +1B/1R translocation (Falstaff, Napier and Savannah).

[a,b,c]Values, within a row, without a common superscript are significantly different ($P < 0.05$).

valine (r 0.96, P < 0.01) and between soluble NSP concentration and ileal digestibility of ash (r –0.84, P < 0.05).

Total tract digestibility of CP was positively correlated (P < 0.01) with LWG (r 0.98) and total tract digestibility of NDF was inversely related (P < 0.05) to DMI (r –0.82). There were no consistent relationships between ileal digestibility and performance traits. Ileal digestibility of leucine, glycine and serine were all negatively correlated with DMI (r –0.91, –0.80 and –0.87, respectively). However ileal digestibility of glutamate was positively related to DMI (r 0.83). Inverse relationships were detected between ileal digestibility of asparate, glutamate and glycine and FCR (r –0.83, –0.92 and –0.97, respectively).

The effect of wheat variety, enzyme supplementation, endosperm hardness and the 1B/1R translocation on the production performance of growing pigs

There were no significant effects on pig performance due to variety, enzyme addition, endosperm hardness or the presence of the 1B/1R translocation (Experiment 3, Table 7). However, wide ranges in LWG, DMI and FCR were observed for pigs offered the 12 experimental diets (650 to 772 g/d, 1063 to 1171 g/d and 1.52 to 1.72, respectively).

There were no significant variety effects on pig performance in Experiment 4 (Table 8). However, enzyme addition to both Malacca and Buchan-based diets significantly reduced feed intake. LWG was 11% lower for pigs offered enzyme supplemented diets, but this effect was not significant.

Table 7. The effect of wheat variety, enzyme addition, endosperm hardness and the 1B/1R translocation on performance (Experiment 3)

Factor[1]	Enzyme inclusion	Initial weight (kg)	Finish weight (kg)	Live-weight gain (g/d)	Dry matter intake (g/d)	Feed conversion ratio
Variety						
Falstaff	–	17.6	35.8	650	1078	1.67
Napier	–	17.4	36.7	691	1115	1.63
Savannah	–	17.7	37.9	721	1130	1.57
Claire	–	18.6	39.2	738	1134	1.57
Consort	–	19.4	41.0	772	1171	1.52
Riband	–	18.1	38.9	746	1129	1.52
Falstaff	+	16.9	36.6	702	1148	1.67
Napier	+	17.8	37.5	705	1121	1.62
Savannah	+	17.3	36.5	688	1063	1.56
Claire	+	17.3	36.4	685	1076	1.58
Consort	+	17.3	36.8	696	1142	1.67
Riband	+	17.4	36.6	685	1147	1.72
s.e.		0.79	1.51	35.8	45.0	0.073
Enzyme inclusion						
+		17.3	36.7	694	1117	1.64
–		18.1	38.3	720	1127	1.58
s.e.		0.31	0.61	14.4	17.9	0.029
Endosperm and 1B/1R						
Hard +1B/1R		17.4	36.8	691	1109	1.62
Soft –1B/1R		18.0	38.2	721	1134	1.60
s.e.		0.31	0.61	14.3	17.8	0.029

[1]No differences for any variable due to variety, enzyme inclusion or endosperm–translocation combination.

Table 8. The effect of wheat variety and enzyme addition on performance (Experiment 4)

Factor	Enzyme	Initial weight (kg)	Finish weight (kg)	Live-weight gain (g/d)	Dry matter intake[1] (g/d)	Feed conversion ratio
Variety						
Malacca	–	18.0	36.9	673	1191[b]	1.85
Buchan	–	17.9	37.4	698	1185[b]	1.73
Malacca	+	17.6	35.2	630	1067[a]	1.76
Buchan	+	17.5	34.6	611	1082[a]	1.84
s.e.		0.394	1.098	42.2	31.9	0.104
Enzyme inclusion						
+		17.5	34.9	619	1075	1.81
–		17.9	37.1	686	1187	1.79
s.e.		0.271	0.758	29.1	22.0	0.072

[1]Significant differences in dry matter intake due to variety ($P < 0.05$) and enzyme inclusion ($P < 0.001$).
[a, b]Values, within a column, without a common superscript are significantly different ($P < 0.05$).

Discussion

Wheat chemical composition

While results of the chemical analysis of the eight varieties were mainly within reported limits in the literature (Gooding and Davis, 1996), the CP concentration for Falstaff was lower than for other varieties produced in Northern Ireland, both within the current study and that reported by Lewis (1999). The relatively large range (97.8 to 138.7 g/kg DM) in CP concentration was in keeping with the results obtained by Nichol *et al*. (1993) (95.7 to 146.9 g/kg DM). However, George (2000) investigated over 20 varieties of wheat produced at three sites over 4 years and reported only narrow ranges in CP concentration. The wide range in CP concentration observed in the current study suggests that there were differences between the varieties, as all wheats were grown at the same site under standard conditions. This finding is in keeping with results reported by Johnson, Griffey and Harris (1999).

The chemical composition of hard and soft wheats were similar. This result is in contrast to other studies (e.g., Fenn *et al*., 1994; Burnett *et al*., 1995). Similarly, there were only small differences between the average values for the chemical components for the varieties with or without the 1B/1R translocation. This was unexpected as the presence of this translocation has been reported to reduce starch and CP concentrations and increase *in vitro* viscosity (Fenn *et al*., 1994; Burnett, Lorenz and Carver, 1995).

The relationships determined between chemical components of the wheat varieties followed similar trends to those reported in the literature for both wheat and barley. The negative relationship between starch and CP (r –0.86) is stronger than that reported by Choct, Hughes and Annison (1999) (r –0.30) or George (2000) (r –0.60, –0.51 and –0.59 for wheat produced in 1996, 1997 and 1998, respectively). In contrast to George (2000) no significant relationship was observed between *in vitro* viscosity and NSP concentration. This is an unexpected finding as *in vitro* viscosity and NSP concentration have been shown to be correlated in a number of studies (e.g., Martinant *et al*., 1998). However, the lack of a significant relationship in the current study may be attributable to the small sample of varieties examined.

Pig performance

In Experiments 1 and 3, no significant differences in performance were observed as a result of either variety, endosperm hardness or the presence of the 1B/1R translocation. This is in contrast to the work of Pearce *et al.* (1997) and Cadogan *et al.* (1999) who reported that variety had a significant influence on performance. Lewis (1999) reported that hard wheat varieties resulted in significantly increased gain:feed ratio compared to soft wheats. No such effect was observed in this study. The lack of an effect of the 1B/1R translocation on performance was in keeping with previous studies and is consistent with the lack of differences in chemical composition.

There are a number of possible reasons for the differences in performance between pigs in Experiment 1 and those in Experiments 3 and 4, which include; the lower initial weight for pigs on Experiments 3 and 4 and the lower dietary specification used compared to Experiment 1. The average initial weight for pigs in Experiment 1 was 20.0 kg compared to 17.7 kg for pigs on Experiments 3 and 4. The pigs on each trial were the same age, had the same genetic potential and were under identical management and dietary regimes prior to allocation to treatment. The differences in dietary specification may further explain the difference in performance between the trials. One of the objectives of Experiments 3 and 4 was to investigate the effect of enzyme supplementation on performance and it has been widely reported that there is a larger response to supplementation when used in conjunction with diets of reduced nutritive value. For this reason, the proportion of wheat was reduced and replaced by wheat pollards. The difference in performance certainly indicates that the nutritive value was successfully reduced. Despite this, there was no significant effect of enzyme addition. This is in contrast to Choct, Hughes and Annison (1999) who reported improvements in daily gain and intake with xylanase addition. However, these workers conducted their studies on younger pigs (initial weight 7 kg). Moughan and Ravindran (2001) stated that exogenous enzymes are more effective in young pigs. However, the research by Lewis (1999) appears to contradict this as no significant improvement in performance of pigs from 10 to 20 kg was reported when xylanase was added to the diet. Furthermore, McCann (2001) indicated that addition of β-glucanase to barley-based diets had no effect on performance of pigs between 7 and 11 weeks of age.

Digestibility coefficients

The significant effects of variety on apparent total-tract digestibility of CP, oil and NDF, are in line with previous work by Lewis (1999). The digestibility coefficients in the current study were higher than those reported for other studies. For example, the average apparent total-tract digestibility of DM was 0.921, but in the study by Lewis (1999) the average value was 0.906. This difference may be explained by the higher level of wheat inclusion in the present study (700 vs. 500 g/kg). However, Millar *et al.* (2001) also reported lower coefficients for apparent total-tract digestibility of wheat-based diets (670 g/kg) than the present study. This may be attributed to the higher level of NDF for the wheats used in their study (161.7 vs. 132.7 g/kg DM), probably resulting in a greater level of hind gut fermentation.

The absence of a significant effect of either endosperm hardness or the 1B/1R translocation on apparent total-tract digestibility directly contradicts the conclusions of other researchers (e.g., Ivan and Farrell, 1976). However, there was a significant effect of both endosperm hardness and the 1B/1R translocation on ileal digestibility of NDF. However, since endosperm hardness and translocation status were confounded in Experiment 2, it is impossible to distinguish effects of endosperm hardness and the 1B/1R translocation.

Relationship between chemical composition, performance and digestibility

The absence of significant relationships between wheat chemical composition and performance is in contrast to results reported by Froseth *et al*. (1981) and may be due to the small sample size. Certainly, the correlation coefficients suggest that relationships existed, but these were not statistically significant. This hypothesis is strengthened by the fact that few significant relationships were observed between apparent total-tract and ileal digestibility or between wheat chemical composition and digestibility.

Conclusions

While variety did not affect performance, nutrient digestibility was significantly affected indicating that wheat variety is an important consideration when formulating diets for growing pigs.

The hardness of the wheat endosperm or the presence of the 1B/1R translocation did not affect performance and thus have minimum influence on wheat utilization by pigs. Enzyme addition to wheat-based diets was not beneficial under the conditions of this study.

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