PROJECT REPORT No. 260

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by

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ABSTRACT

The primary aim of this project was to determine whether specific weight of wheat indicates its nutritive value to farm livestock. To achieve this a matrix of 4 known varieties of wheat each at 4 specific weights was fed to poultry, pigs and sheep in a series of feeding trials at 4 research centres: University of Leeds, Queen's University Belfast, the Roslin Institute and Harper Adams University College. Specific weights ranged between 60 and 78 kg/hl. In addition a further 46 wheat samples, comprising known varieties each at least 2 specific weights, were tested in poultry.

Parameters measured included true metabolisable energy (TME), apparent metabolisable energy (AME), amino acid availability, growth rate and feed conversion ratio in poultry; digestible energy (DE), digestibility, growth rate and feed conversion ratio in growing pigs and metabolisable energy (ME) and digestibility in adult sheep.

There was a significant regression relationship between specific weight and TME measured in adult cockerels; however this amounted to 0.3 MJ/kg per 10 points increase in specific weight and is therefore of no commercial significance. In contrast linear relationships between AME (broiler chickens) or DE (grower pigs) and specific weight were only just significant and were negative. There was no relationship between ME measured in sheep and specific weight. There were no differences in animal performance due to wheat specific weight in any of the trials conducted. We concluded that specific weight, at least between 60 and 78 kg/hl, does not indicate the nutritive value of wheat.

The second aim of the project was to determine a characteristic of wheat which could be used to predict its nutritional value. With this end in view all wheats used in the trials were extensively analysed for physical and compositional traits. These traits were then correlated against animal performance. Despite the comprehensive range of analyses performed no factor of the wheat was consistently found to correlate with animal performance. The best results were found for near infrared reflectance spectroscopy but the equations derived were not effective in predicting the nutritive value of wheats not used in their derivation.

CHAPTER 1
SUMMARY

Background

Six million tonnes of wheat per year are used in animal feeds in the UK, making the livestock feed industry the largest national user of wheat. Of this tonnage more than 50% is used for poultry, almost 30% for pigs and less than 20% for ruminants.

Specific weight of wheat is the trading standard used by the feed industry to determine purchase price and is therefore assumed to be an indicator of nutritive value. However evidence suggests that specific weight is not an appropriate measure of wheat quality for animal feed. Work investigating the effects of low specific weight wheat on its nutritive value for livestock is limited and generally confounded with variety. In a review of the literature on the relationship between specific weight and nutritional value of wheat when used as a livestock feed, Miller and Wilkinson (1998) concluded:

i) Specific weight appears to be a poor measure of wheat quality for animal feed.
ii) The results of previous studies were often compromised because wheat samples had been selected on the basis of specific weight without regard for variety
iii) Further studies were required to develop a better predictor of nutritional value.

Objectives

The main objective of this work was therefore to establish whether specific weight of wheat does indicate nutritive value by conducting a comprehensive series of trials at four research centres utilising three species of farm livestock.

When wheat was traded by volume, specific weight was a sensible measure on which to base the price since it reflected the weight of grain that was being purchased, indicating that our ancestors realised that it was the weight of grain that mattered! It was logical to pay less for a lighter bushel weight. Somewhat surprisingly, now that grain is traded on a weight basis this logic has become reinterpreted such that relative density of wheat is assumed to have merit as a measure of quality in its own right. One reason that specific weight has persisted as a trading standard for feed wheat is because, so far, we have failed to find an adequate rapid assessment of nutritive value that can be made at point of purchase which would form a justifiable basis for payment. Therefore the second objective of this work was to try to identify such a technique.

In order to meet these objectives we aimed to:

- Collect wheat samples of known variety by a range of specific weights

- Measure the physical and chemical components of these wheats
- Measure animal performance in a range of species when fed these wheats
- Relate wheat composition and specific weight to variation in nutritive value as indicated by animal performance
- Develop a rapid technique to predict animal performance.

Key criteria used in experimentation

This project exceeded the scope of previous work in this area by meeting the following key criteria:

- Wheat variety of all samples used in the trials was confirmed by electrophoresis performed by the National Institute of Agricultural Botany (NIAB).
- Wheat was incorporated in all the diets at a minimum of 65%. This level was chosen to maximise the effect of the wheat in the diet whilst remaining within the extremes of commercial practice.
- Within each set of trials identical ingredient inclusion levels were utilised and, with the exception of the test wheats, the same batches of ingredients were used.
- Diets were formulated to have marginally excess protein content and were balanced for lysine, methionine, threonine and tryptophan so that protein inadequacy could not be a factor affecting measured nutritional value (does not apply to Chapters 3 or 4).
- All diets were prepared at the same mill, namely Roslin Institute, thus ensuring that all diets were prepared to the same standards. This was particularly important for the poultry trials which were conducted at more than one site but using identical diets.
- The main matrix of 16 wheat samples were tested across a range of species, namely broiler chickens, pigs and sheep. In addition a further 46 wheat samples were used in broiler trials (Chapters 3, 4 and 5).
- Experimentation occurred at 4 research centres.
- Animal performance was measured as the key indicator of nutritive value.
- The wheat samples were tested under commercial conditions in all species.
- Statistical analysis and interpretation was independently confirmed by Biomathematics and Statistics Scotland (BioSS).

Organisation of trial work

The research reported here was a co-operative programme of work conducted by four institutions: The University of Leeds Centre for Animal Sciences, Queen's University Belfast, The Roslin Institute and Harper Adams University College. Each group was responsible for separate areas of activity as follows:

Leeds University –	Performance trials with grower pigs, determination of digestibility and DE. Assessment of digestibility and estimated ME in sheep.
Queen's University-	Cage trials with broiler chickens, determination of AME and performance.
Roslin Institute -	TMEn and amino acid availability assessment in cockerels.
Harper Adams -	Cage trials and larger scale floor trials to assess broiler chicken performance.

Collection of samples

It proved to be surprisingly difficult to collect a suitable matrix of wheat samples for use in this project. We had originally hoped to use thirty samples comprising 6 varieties by 5 specific weights, however in the end we had to be content with 16 samples; 4 varieties by 4 specific weights, of which 3 samples were generated by gravity separation. These sixteen samples were used for trials in all test species and at all centres.

We actually collected 85 wheat samples in total but we took the precaution of confirming both variety and specific weight after purchase and discovered that by far the majority of wheat samples we had procured had been incorrectly described. The most common problems were:

1. Specific weight was incorrect, in particular initial assessments of specific weight on the farm of origin were frequently much lower than subsequent determinations in the store or laboratory.
2. Variety was either completely different to that stated or the wheat sample proved to be a blend of two or more varieties.

These problems in obtaining correctly described wheat throw doubt on the validity of studies in which specific weights and variety have not been confirmed.

The 16 commercially sourced wheat samples used in all trials were augmented by an additional 46 wheat samples supplied by the Northern Ireland Department of Agriculture and Rural Development. These samples had been grown in Recommended List trials and therefore only sufficient wheat was available to run evaluation trials with poultry and not the other two animal species.

Effect of specific weight on chemical composition

Starch concentration increased with increasing specific weight of wheat, whilst modified acid detergent fibre (MADF) decreased thus indicating a shift in the composition of the complex carbohydrate fraction of the grain with changing specific weight. Such changes in composition have been reported elsewhere (see Chapter 2). There was a trend for crude protein content to

decrease with increasing specific weight. In the matrix of 16 wheats used across the whole study there was no change in fat content with changing specific weight.

Effect of specific weight on energy value

TMEn (Poultry) - There was a small but significant fall in TMEn value with decreasing specific weight (r^2= 0.31). When Haven 66 was excluded from the analysis the correlation coefficient for the whole data set was improved (r^2= 0.64). The regression relationship so derived indicated that for every 10 kg/hl increase in specific weight there should be a 0.3 MJ/kg increase in TMEn of the wheat. This is likely to be of limited commercial significance. It is interesting to note that Haven 66 (the third lowest specific weight) had the highest TMEn value.

AME (Poultry) - In the first study, utilising non-commercial high wheat and casein diets, (Chapter 3) there was a weak positive relationship between wheat AME and SW (r^2 = 0.16). In the second study the weak linear relationship was negative but there was a significant quadratic relationship between wheat AME and specific weight (r^2= 0.31) associated with low values for a few of the intermediate specific weight samples!

DE (Pigs) – There was a significant, though extremely weak (r^2= 0.06), negative correlation between DE and specific weight. For every 10kg/hl increase in specific weight there was a 0.2 MJ/kg decrease in DE.

ME (Sheep) – There was no effect of specific weight on ME value.

Across all experiments it was evident that there was no consistent effect of specific weight on energy value.

Effect of specific weight on animal performance

In all trials animal performance was normal for the appropriate facility. In fact Belfast reported exceptionally high growth rates in their caged broiler trials (Chapter 5).

Although there were some changes in chemical composition with changing specific weight of wheat this was not reflected in animal performance. Indeed the low specific weight wheats performed just as well as the other wheats and there were no consistent effects of specific weight on animal performance in any of the three species studied. It was quite clear that performance differences between individual wheats were far greater than those between different specific

weights. This finding emphasises the need for a good measurable indicator of nutritive value of wheat since specific weight clearly is not.

Alternative methods of rapid assessment

Unfortunately the extensive work performed here was unable to yield a rapid method of assessment of the nutritive value of wheat. NIR was considered to be the most encouraging method investigated but although reasonable calibrations were obtained these proved ineffective in predicting values for wheats not used in the initial calibration. *In vitro* viscosity was also a possible candidate but was only correlated with performance in certain studies and was not able to predict performance across studies. Starch content was reasonably correlated with specific weight but not with performance, illustrating the inadequacy of either measure as an indicator of nutritive value.

In addition to measuring specific weight we also performed two other assessments of wheat density, pour density and tap density. We perceived the advantages with these measures would be that they would remove any differences in density relating purely to unusual morphology of grains. They might therefore be better correlated to grain composition and hence nutritive value. However since no differences in grain composition were correlated to animal performance it is unsurprising that these measures were equally unrelated to performance.

Conclusions

- **Specific weight of wheat does not indicate its nutritive value.**
- **Currently no rapid technique has been identified for assessing nutritive value of wheat.**

CHAPTER 2

CHARACTERISTICS OF THE WHEAT SAMPLES USED IN THE ANIMAL FEEDING EXPERIMENTS

2.1 Sourcing of samples

Obtaining an appropriate set of test wheat samples proved surprisingly difficult. Suitable wheats were identified principally through grain merchants who allowed us access to their databases of wheat available for purchase. Initially it was our intention to obtain a matrix of 30 wheat samples comprising 6 varieties by 5 specific weights, ranging in specific weight from 60 to 80 kg/hl. A constraint was that the moisture content of the wheat should not exceed 150 g/kg fresh weight, since it was recognised that specific weight was influenced by moisture content (Lockwood, 1960; Hook, 1984).

When suitable samples of wheat had been identified, the appropriate farmers were contacted, 2-tonne lots of wheat were purchased and shipped in one-tonne bags to a store where they were sampled to check specific weight and moisture content. Sub-samples were shipped to the Cambridge laboratory of the National Institute of Agricultural Botany for confirmation of cultivar. The method used was acid polyacrylamide gel electrophoresis (Acid-PAGE) which separates the wheat storage proteins, gliadin and glutenin, by their charge:mass ratios. The presence and molecular form of the proteins are largely functions of variety, and acid-PAGE is employed routinely as an independent test in the assessment of varietal identity and purity.

In total 89 samples of wheat were obtained, however, in the event only 16 of these samples were used, and of those, three were obtained by gravity separation because the appropriate specific weight could not be obtained directly from a farm.

There were several reasons for the large wastage of samples. First and most important was that on re-assessing specific weight at the store, several months after harvest, and subsequently again in the laboratory at Leeds University, a significant proportion of the samples had specific weights which were more than 5 units higher than that indicated on the merchants' database. Others were a mixture of cultivars or were a different cultivar to that indicated originally.

The determination of specific weight on the farm of origin at or shortly after harvest was an unreliable assessment.

Despite considerable efforts by major merchants and following appeals through the trade press direct to farmers, it proved impossible to source the full matrix of samples as specified at the outset of the project of 6 cultivars each at 5 specific weights ranging from 60 to 80 kg/hl.

2.2 Characteristics of the samples of wheat used in the feeding experiments.

The matrix of the 16 samples of wheat used in the feeding experiments is in Table 2.1 and the origin of each sample is in Table 2.2.

Table 2.1 Cultivars and specific weights of the 16 samples of winter wheat used in the feeding experiments

Cultivar	**Endosperm**	**Specific Weight Code**			
		1	2	3	4
		Specific weight[1] (kg/hl)			
Riband	Soft	64	69	73	78
Buster	Hard	67	71	73	78
Consort	Soft	69	71	73	78
Haven	Hard	60	66	71	76
Average		**65**	**69.25**	**72.5**	**77.5**

[1]Determined by the University of Leeds laboratory.

Table 2.2 Origin of each wheat sample

Cultivar	Specific weight	Bag No. /bulk	Sample No.	Year of harvest	Origin
RIBAND	64	Bulk	79	1999	J D Martin Ltd
	69	Bagged from bulk	55	1998	KW (Swiers)
	73	Bulk	58	1998	KW (Wright)
	78	Bulk	82	1999	J D Martin Ltd
BUSTER	67	41 + 42	41	1998	Wells
	71	35 + 36	35	1998	Ezard
	73	75 + 76	75	1998	Jackson
	78	Bagged, no number	84	1999	Pears
CONSORT	69	Bagged, no number	80	1998	Roslin
	71	Bagged, no number	87	1999	J D Martin Ltd (gravity separation)
	73	45 + 46	45	1998	Hardwick
	78	Bagged, no number	81	1999	J D Martin Ltd
HAVEN	60	47 + 48	47	1998	Sluggate
	66	52 + 53	52	1998	Sluggate
	71	Bagged, no number	88	1999	J D Martin Ltd (gravity separation)
	76	Bagged, no number	89	1999	J D Martin Ltd (gravity separation)

Three samples were prepared by gravity separation. Six samples were obtained from the 1999 harvest and ten from the 1998 harvest. The samples of Haven at 60 and 66 kg/hl were sourced

from a farm near Truro, Cornwall and the other two were produced by gravity separation from two lots of 74 and 75 kg/hl sourced from farms near Hull, Yorkshire.

The data for physical and compositional characteristics of the 16 wheat samples were subjected to ANOVA and linear regression using a General Linear Model in Minitab 12.1.

The physical characteristics of the 16 samples are shown in Table 2.3 as main effects of cultivar and specific weight. There were significant differences between both cultivar ($P<0.001$) and specific weight ($P<0.05$) with respect to dry matter (DM) concentration, though the magnitude of the differences between the means was small and there was no evidence of a consistent trend in DM with change in relative specific weight. There were no significant differences between cultivar with respect to density or thousand grain weight. Pour density, tap density and thousand grain weight increased with increasing relative specific weight ($P<0.001$, $P=0.001$ and $P=0.029$, respectively).

Table 2.3 Physical characteristics of the wheat samples (n = 16)

	Cultivar				**Specific weight**[1]				**SED**
	Riband	**Buster**	**Consort**	**Haven**	**1**	**2**	**3**	**4**	
DM (g/kg fresh weight)	883	897	905	897	896	893	892	897	1.44
Pour density[2] (kg/hl)	57.8	59.2	60.3	57.0	54.0	54.1	61.5	64.7	2.26
Tap density[2] (kg/hl)	67.8	69.0	72.1	66.7	63.5	64.6	71.1	76.3	2.62
Thousand grain weight (g)	35.3	39.1	37.4	39.5	31.8	37.2	38.9	43.4	3.02
Viscosity *in vitro*	12.1	12.3	10.3	29.5	13.8	14.9	19.8	15.7	7.07

[1] 1 = Lowest, 4 = Highest specific weight.

[2] Pour and tap density were performed on the whole grain by the method of CIPAC (1995).

Although there was no effect of relative specific weight on viscosity *in vitro*, it was markedly higher for Haven than for the other cultivars ($P=0.037$).

Compositional characteristics of the wheat samples are shown in Table 2.4. There were no significant differences between cultivar or relative specific weight in terms of Hagberg Falling Number or starch concentration, though there was a trend for starch to be lower in the samples of lower specific weight (588 g/kg DM for the lowest relative specific weigh compared to 632 g/kg DM at the two higher relative specific weights, P=0.073). There were no effects of cultivar or of relative specific weight on crude protein concentration, although there was a trend for Consort to have lower crude protein content than Riband or Haven (P=0.082). There was an effect of cultivar (P=0.002) on the concentration of neutral detergent fibre (NDF), with Riband having the highest, Buster the lowest and Haven and Consort having intermediate concentrations.

In contrast, differences between cultivars in concentrations of modified acid detergent fibre (MADF) were small, suggesting that the differences noted above in NDF were associated with differences between cultivars in hemicellulose. The concentration of MADF decreased with increasing relative specific weight (P=0.034). Haven had the lowest concentration of oil, whilst Consort had the highest (P=0.028), with Buster and Riband intermediate. There were no differences in oil due to relative specific weight.

Table 2.4 Compositional characteristics of the wheat samples. (n=16)

	Cultivar				**Specific weight**[1]				**SED**
	Riband	**Buster**	**Consort**	**Haven**	**1**	**2**	**3**	**4**	
Hagberg Falling Number	292	262	234	187	229	258	255	234	39.6
Starch (g/kg DM)	605	619	644	608	588	623	632	632	19.1
Crude protein (g/kg DM)	121	114	105	120	119	114	116	111	5.75
Neutral detergent fibre (g/kg DM)	208	126	174	141	171	162	169	147	14.7
Modified acid detergent fibre (g/kg DM)	31.4	30.1	32.4	29.8	33.1	33.0	30.7	27.0	1.90
Oil-B (g/kg DM)	28.1	24.1	30.5	22.5	27.5	27.0	25.4	25.2	2.34

[1] 1 = Lowest, 4 = Highest specific weight.

The above ANOVA did not take account of differences in actual specific weight between cultivars (Tables 2.1 and 2.2), so linear regressions were performed on the data.

Significant positive relationships were found between specific weight and pour density (R^2 = 70.3%, Figure 2.1), tap density (R^2 = 62.2%, Figure 2.2), thousand grain weight (R^2 = 43.8%, Figure 2.3) and starch (R^2 = 40.0%, Figure 2.4). We were particularly interested in the measures of pour density and tap density as these involve grinding the wheat samples before assessing density and hence removing any morphological differences that might affect packing properties of the whole grain. However these two density measures remained closely correlated to specific weight.

A significant negative relationship was found between specific weight and MADF (R^2 = 27.6%, Figure 2.5) and there was also a trend towards a negative relationship between specific weight and crude protein content (R^2 = 21.0%, Figure 2.6). In the latter regression of specific weight against crude protein content Consort 71 is a clear outlier with a crude protein value of only 90.1 g/kg, when this value is removed the regression becomes significant (R^2 = 38.2%, P=0.011).

The complementary changes in starch and MADF content with changing specific weight indicate a shift in the composition of the complex carbohydrate fraction of the grain. Such changes in composition with changing specific weight have been reported elsewhere (Sibbald and Price, 1976; Batterham et al., 1980; Hickling, 1994).

In addition to the matrix of wheat samples described above which were used in all trials, we were extremely fortunate to obtain an additional 42 wheat samples from the Department of Agriculture and Rural development, Northern Ireland. Relatively small quantities of these wheats were available so that they could only be used in some of the poultry trials. The characteristics of these wheats are described in Chapters 3 and 5.

CHAPTER 3

RELATIONSHIP BETWEEN NUTRITIVE VALUE OF WHEAT FOR BROILERS AND WHEAT SPECIFIC WEIGHT USING HIGH WHEAT/CASEIN DIETS

Introduction

Wheat is widely used as a major ingredient for poultry feed and is normally traded on the basis of specific weight (SW). The minimum for feed grade wheat is internationally accepted as 72 kg/hl. A recent review of nutritional value of low specific weight (SW) wheat (Miller and Wilkinson, 1998) highlighted the lack of definitive information on this important subject and the need for reliable, rapid methods of assessing the nutritive value of samples prior to diet formulation. One major problem with previous studies such as that of Hickling (1994) is that factors such as variety and location of production were confounded with SW. *In vitro* viscosity has been implicated as an important factor in determining wheat feeding quality for broilers (Bedford and Morgan, 1996) and some reports (eg Classen *et al*., 1995; McCracken *et al.* 2001) have suggested that this may provide a more satisfactory basis for assessment of nutritive value than SW. Varieties containing the 1B1R rye translocation tend to have higher *in vitro* viscosity than non 1B1R and there is some evidence that insertion of the 1B1R translocation causes reduced nutrient digestibility (Short *et al.*, 2000). However, in the studies of McCracken *et al*. (1999; 2001), there were no differences in performance of broilers given 1B1R or non-1B1R varieties. The 1998 harvest at three sites in Northern Ireland (Crossnacreevy, Downpatrick, Limavady) yielded a good range of SW for a number of varieties. Ten wheats (5 1B1R, 5 non-1B1R) were selected giving a total of 30 samples (10 wheats * 3 sites) for study with a view to (a) determining the effects of SW with variety effects controlled (b) examining alternative methods of assessment such as *in vitro* viscosity and (c) further examining the nutritive value of varieties containing the 1B1R translocation.

Materials and Methods

Diets

The 10 varieties selected and their characteristics are summarised in Table 3.1. Specific weight ranged from 59-75 kg/hl with the mean values at the three sites being respectively 63.6, 69.2, 72.2 for Crossnacreevy (C), Downpatrick (D) and Limavady (L). Wheat was ground in a hammer-mill using a 5 mm screen. The diet formulation (Table 3.2) was based on a modification of the Australian protocol (Choct *et al.,* 1994) using high wheat inclusion but incorporating 50 g/kg of a

typical fat blend to mirror the commercial situation. The fatty acid profile of the fat blend (%) was: C12:0, 5.8; C14:0, 2.4; C16:0, 26.5; C18:0, 5.7; C18:1, 32.3; C18:2, 20.5; C18:3, 3.2; C20:1, 2.8. The diets were heat-treated to 80°C (direct low pressure steam for 90 sec), pelleted (3 mm die), floor-cooled and crumbled.

Experimental design

The 10 wheats by 3 sites gave rise to 30 diets. 60 birds were used in each of five consecutive time replicates with 2 blocks of 30 in each replicate, effectively giving a total of 10 blocks of 30 birds. In each block birds were ranked in terms of weight. The 10 wheats were randomly allocated in a 10 x 10 latin square to groups of three birds of similar weight. Within each group of 3, birds were randomly allocated to sites. This gave rise to a split-plot design with wheat as the main plot and sites as the sub-plot factor.

Birds and Management

Male Ross broiler chicks were obtained at hatching and kept in a commercial brooder for 1 week with *ad libitum* access to a crumbled starter diet and water. At 7 d, all birds (approximately 90) were weighed. The lightest and heaviest birds were discarded and 60 allocated to experiment according to the randomisation. Birds were placed in individual cages in a room at an initial temperature of 32°C and reduced 1°C per 2 d down to 24°C. The light:dark cycle was 18:6 and relative humidity was set for 50%.

Birds were fed *ad libitum* from 7-28d, with feed intake and weight being recorded on a weekly basis. A total excreta collection was made from 14-21d for determination of apparent metabolisible energy (AME) content. At 28d, birds were humanely killed and the contents of the proximal ileum (end of duodenum to Meckel's Diverticulum) removed for determination of supernatant viscosity. Empty bird weight was recorded and the carcasses were retained for later measurement of total carcass energy (McCracken and Clements, 2000).

Analysis of diets, excreta and ileal digesta

The wheat samples were analysed for crude protein (Nx5.83), neutral detergent fibre (NDF), non-starch polysaccharides (NSP, total and soluble), starch, amino acid content and gross energy. Specific weight, thousand grain weight and *in vitro* viscosity were also recorded. The diets were analysed for DM, crude protein (Nx6.25), crude fat (acid hydrolysis), ash, NDF, and gross energy. Starch and NSP concentrations in diets were calculated from the values for the individual wheats. The excreta samples were oven-dried for 24 h at 85ºC, milled and analysed for crude protein (N x

6.25), crude fat, ash, starch and gross energy. All analyses were carried out in duplicate and results reported on a dry matter (DM) basis. DM was determined by oven drying at 100^{o}C for 24h and ash content was determined by ashing samples in a muffle furnace at 450^{o}C for 16h (AOAC, 1990). Crude fat was extracted with petroleum ether (40-60 BP) in a Soxtec System, after 3M-HCl hydrolysis (Stoldt, 1952), NDF according to Van Soest (1963) and crude protein (CP) by the Kjeldahl method (AOAC, 1990) and also using an automated nitrogen analyser (Leco FP2000, Leco Instruments, UK Ltd.). Total starch was determined using a commercial enzyme assay kit (Megazyme International Ireland Ltd) as described by McCleary *et al.* (1997). Non starch polysaccharide (NSP) content of the wheat samples was determined using a commercial enzyme assay kit as described by Englyst *et al.* (1994). *In vitro* viscosity of wheats was determined using a modification of the method described by Bedford and Classen (1993) with the resulting sample supernatant viscosity being measured with a Brookfield Viscometer. Gross energy of diet and excreta samples was determined using an isothermal automated bomb calorimeter (PARR, Model 1271).

Determination of True Metabolisable Energy (TME)

TME/TMEn were determined using adult cockerels. Ground samples (50g) of wheat were tube-fed to starved (48h) birds and the excreta collected over the subsequent 48h were dried, weighed and homogenised. TME/TMEn values were derived according to McNab and Blair (1988).

Statistical analysis

The results of the main study were subjected to analysis of variance taking account of the split-plot design and with wheat variety as the main plot factor and site (specific weight) as the sub-plot factor. For growth parameters initial weight was used as a co-variate. The TME results were subjected to one-way ANOVA. Regression relationships between various parameters were established with variety effects being taken into account where appropriate.

Near Infrared Reflectance Spectroscopy (NIRS)

Milled wheat samples were scanned at 2nm intervals over the range 1100 to 2500 nm using a Technicon Infralyser 500 (Bran and Luebbe). Triplicate packings were done on each sample. Data acquisition, manipulation and analysis were carried out using the IDAS software. Calibrations were done by the Stepwise Multiple Linear Regression (SMLR) technique using a maximum of 9 wavelengths. The thirty wheat samples were used initially for calibration and the 12 samples from the study of McCracken *et al* (2001) were used as a validation set. In addition a set of 20 or 25 samples was selected from the 30 as a calibration set and the remaining 10 or 5 used in a further

validation exercise (Table 3.10). The varieties and mean AME concentrations for the 12 sample validation set are given in Table 3.8 and the values for the 30 samples in the present study are given in Table 3.9.

Results

There was quite a narrow range of crude protein content (Nx5.83) across the 30 wheat samples, the means for Crossnacreevy, Downpatrick and Limavady respectively being 112, 121, 122 g/kg (Table 3.3). Starch contents ranged from 604 to 679 g/kg with the mean value at Limavady (659) tending to be higher than those observed at Crossnacreevy and Downpatrick. The range of measured CP (228-262 g/kg) in the diets (Table 3.4) was greater than would have been calculated from the wheat values. Gross energy values of all diets were similar, ranging from 19.3 to 19.6 MJ/kg DM.

There were no significant variety effects for dry matter intake, liveweight gain (LWG) or gain:feed (Table 3.5). However all three parameters tended to be least for the variety Chaucer and greatest for Harrier. There were significant variety* site interactions (P= 0.02) for DM intake and LWG due to values for Brigadier and Riband being highest at Limavady and those for Chaucer and Madrigal being lowest at Limavady. Apparent metabolisability of energy (ME:GE) ranged from 0.738 (Hussar) to 0.778 (Harrier) the effect being significant (P<0.05). Calculated wheat AME ranged from 13.05 to 14.03 MJ/kg DM (P>0.05). ME:gain was not significantly affected by variety, averaging 19.8 MJ/kg gain. TME values ranged from 16.3 to 16.6 MJ/kg DM (NS).

In vivo viscosity ranged from 12.3 (Ritmo) to 23.7 cps (Hussar), the varietal effects being significant (P<0.001). Viscosity was significantly higher for the 1B1R varieties than for the non-1B1R (22.7 vs 16.3 cps) but there were no significant effects on DM intake, LWG, gain:food, ME:GE, calculated wheat AME , ME:gain or TME (Table 3.6).

DM intake was similar for all 3 sites and there was no significant effect on LWG (Table 3.7). Gain:feed was 2 per cent lower at Crossnacreevy and the effect just failed to attain significance (P=0.054). ME:GE was significantly lower at Crossnacreevy than at Limavady (P<0.05), the means being, respectively, 0.755, 0.762, 0.777 for C, D, L sites but ME:gain was highest at Limavady (P=0.01). Calculated wheat AME increased from 13.4 MJ/kg DM at Crossnacreevy to 13.9 MJ/kg DM at Limavady (P<0.05). TME values for C, D, L were 16.3, 16.5, 16.5 MJ/kg (NS). Ileal digesta viscosity was similar across all three sites. However, there was a significant variety

*site interaction (P<0.001) with values for 2 varieties (Cantata and Chaucer) being higher for Limavady than for Crossnacreevy and the reverse being true for the varieties Hussar and Equinox.

Taking the values for the 30 wheats there was a weak positive relationship between starch content and specific weight (Figure 3.1). There was no significant relationship between SW and DM intake, LWG or gain:feed (Figures 3.2 - 3.4). There was a weak (P<0.05) positive relationship between ME:GE and SW (Figure 3.5) and between calculated wheat AME content and specific weight (Figure 3.6). There was also a weak positive relationship between wheat TME and SW (Figure 3.6) but the slope was even lower than for AME. Neither calculated wheat AME nor wheat TME correlated with starch content (Figure 3.7). Wheat AME was negatively correlated (P<0.05) with total NSP (slope -0.035) but was significantly affected by variety, constants ranging from 16.74 to 17.79 (Figure 3.8). For wheat TME there were significant variety* total NSP interactions with slopes ranging from 0.29 to -0.07. There was no significant relationship between wheat AME and soluble NSP and there were significant variety* soluble NSP interactions for TME with slopes ranging from 0.09 to -0.14 (Figure 3.10). Despite the relatively wide range of *in vitro* viscosity there was no significant correlation of either calculated wheat AME or wheat TME with *in vitro* viscosity (Figure 3.11). For TME there were significant variety* viscosity interactions with slopes ranging from 0.21 to -0.13 (P<0.001).

NIRS calibration and validation statistics for AME are shown in Table 3.10. AME values for the calibration set varied from 12.71 to 14.54 MJ/kg and averaged 13.63 MJ/kg, whereas for the validation set the values ranged from 13.01 to 15.13 MJ/kg with the mean value being 13.74 MJ/kg. The best correlation coefficient (r^2) of 0.90 was obtained when the calibration sample set was subjected to SMLR using the second order derivatized data (Figure 3.15). Using the same set for self-prediction, an identical r^2 (0.90) value was obtained. However, despite the high correlation coefficient obtained for the calibration and a low standard error of calibration (SEC) = 0.175, r^2 for the validation set was poor, being 0.12 with standard error of prediction (SEP) = 2.346 (Figure 3.16). Splitting the main set into a subset of 20 samples resulted in an improvement, with r^2 being 0.98 (Figure 3.17); however the correlation coefficient for the residual validation set of 10 samples (Figure 3.18) was poorer (1-VR = 0.09).

Discussion

Despite the wide range of SW the ranges of concentration of crude protein, starch and total NSP were quite narrow. For crude protein (CP) the range (105-131 g/kg DM) was similar to that seen

for the N. Ireland variety samples in 1996, 1997 and 1998 (George, 2000), narrower than that reported by Nicol *et al.* (1993) and (correcting to N x 5.83) similar to that reported by Choct *et al.* (1999). In agreement with the report of Hickling (1994) there was a poor relationship between CP and SW. The range of starch concentrations (604 to 679 g/kg DM) was almost identical to that reported by George (2000) for all N. Ireland wheats during the period 1997-1999 and similar to other reports (Annison, 1991; Classen *et al.,* 1995). The relationship between starch and SW was much poorer ($r^2 = 0.10$) than that reported by Hickling (1994) and the slope was less (0.17 vs 0.55) but similar to that observed (0.21) by McCracken *et al.* (2001).

Although there were no statistically significant variety effects (Table 3.5) for DM intake, LWG or gain:feed it is important to note that the differences between the lowest and highest values were, for DM intake, LWG and gain:feed respectively 4, 8 and 4 per cent with all three values being least for Chaucer and best for Harrier. Such differences, if real, would be of considerable commercial importance. Significant variety differences did occur in ME:GE and, although differences in calculated wheat AME did not attain significance, the range of values was approximately 1MJ i.e. a 7 per cent difference, similar to that observed by Stewart (1998) and McCracken *et al.* (2001). Furthermore there was excellent agreement between the results for the 3 varieties which were common to the study of McCracken *et al.* (2001) values being for Brigadier, Chaucer, Reaper respectively 13.8, 13.7, 13.5, MJ/kg DM for the present samples and 13.5, 13.7, 13.4 MJ/kg DM for the previous year. Variety differences have been reported in other studies (e.g. Rose *et al.*, 1993; Stewart, 1998; McCracken *et al,* 2001) but it is difficult to determine specific varieties which consistently perform well or badly. Furthermore, the present results highlighted variety * site interactions suggesting that specific environmental or soil-related factors may play a part in the observed variability.

The range of TME values was small (NS) and there was a poor correlation between wheat AME and TME values. The actual TME values were considerably higher than those reported by Wiseman and McNab (1995) but the lack of difference due to variety accords with their results.

The lack of difference in performance between the varieties with or without the 1B1R translocation (Table 3.6) is notable. This accords with previous observations from this laboratory (McCracken *et al,* 1998) and provides further evidence that the 1B1R translocation is not detrimental to the nutritive value of wheat. Indeed, the variety Harrier which gave the best performance in terms of DM intake, LWG, gain:feed and calculated wheat AME is a 1B1R variety.

In terms of the main objective of the study, the performance results (Figures 3.2 to 3.4) show a poor correlation with SW which was not improved by seeking to take account of variety effects. Similarly, calculated wheat AME and TME were poorly correlated (r^2=0.16) with SW. The equation for wheat AME is very similar to that found by McCracken *et al.* (2001) and the regression was significant (P<0.05).

If one accepts the slopes of these relationships at face value then a 10kg/hl increase in SW would correspond respectively to an improvement of 1.6, 1.4 and 3.3 per cent in gain:feed, TME or calculated wheat AME respectively. The value for TME is similar to that calculated from the data of McNab (1991). The effect for calculated wheat AME is probably a worst-case scenario, bearing in mind the high level of wheat inclusion in the present study and the fact that *in vivo* viscosity values are higher with the wheat/casein diets used here than with more typical commercial formulations (Stewart, 1998).

In view of the poor relationships established with SW a number of other chemical and physical attributes of the wheats were studied. There was no significant correlation for either TME or wheat AME with starch concentration (Figure 3.7). This is in agreement with the results of McCracken *et al.* (2001) and previous reports (Mollah *et al.* 1983; Rogel *et al.* 1987; Hickling, 1994).

For TME there was no significant relationship with total NSP but there was a weak negative relationship (P<0.05) between wheat AME and total NSP (Figure 3.8) the slope of which corresponded to a 4 per cent change in AME with 20 g/kg change in total NSP. This is a much smaller effect than that reported by Choct and Annison (1990) on addition of water insoluble pentosans to a sorghum-based diet.

There are conflicting reports in the literature as to the role of soluble NSP but in general it is concluded that higher levels of soluble NSP result in higher *in vivo* viscosity and consequent reductions in nutritive value. In the present study there was no significant relationship between *in vivo* viscosity and soluble NSP concentration (Figure 3.9) and no significant relationship between either wheat AME or TME and soluble NSP (Figure 3.10).

Previous studies (Classen and Scott, 1995; Dusel *et al.* 1997) have suggested that *in vitro* viscosity (IVV) may provide a suitable basis for the rapid estimation of energy value and this is being used commercially (Bedford and Morgan, 1996). The study of McCracken *et al.* (2001) established a strong relationship between calculated wheat AME and *in vitro* viscosity (r^2 = 0.64) and it was

concluded that IVV appeared to be a better measure of nutritive value than SW. In contrast, despite a similar range of IVV in the present study, there was no significant relationship between either wheat AME or TME and IVV (Figure 3.11).

Thousand grain weight (TGW) is another physical parameter which potentially could be used as a measure of nutritive value although published results are inconsistent. In the present study there was a fair spread of TGW and reasonable correlation between TGW and SW (Figure 3.12). When wheat AME was regressed against TGW there was no overall significant relationship but when variety was included as a factor in the analysis the regression was significant ($P<0.05$), the equation being $Y = 9.65 + 0.076$ TGW, for Cantata and the constant ranging from 9.65 to 10.94 (Figure 3.13). The slope corresponds to a 6 per cent increase in wheat AME for a 10g increase in TGW. The major effect of variety on this relationship could explain why previous studies have given inconsistent results. From a practical point of view this effect undermines any potential usefulness of the relationship since it would be difficult, under commercial conditions, to establish the variety.

Part of the problem for any correlation lies in the extent of bird variation on any one treatment. This aspect has been discussed at some length by McCracken and Clements (2001) using the data from this study. Variation was high for all wheat varieties and this was not due to random error as shown by the good correlation between gain: feed and ME:GE (Figure 3.14).

The NIRS calibration set consisting of 30 wheats from the present study gave correlation coefficients ≥ 0.90; however, moving to validation, the outcome was extremely poor with 1-VR values being 0.12 and 0.09. This was surprising as the second validation set (1-VR = 0.09) was a subset of the 30 samples, chosen at random, and it was expected that results would have improved in comparison to the validation set (12 samples) from the study of McCracken et al (2001).

Valdes and co-workers have reported a number of studies (Valdes et al, 1985; Valdes and Leeson, 1992, 1994) on the application of NIRS to the analyses of poultry feeds, AME of poultry feed ingredients and of feed grade fats in test diets for poultry. 28 samples were used for calibration, each being either a different type of cereal, by-product, meal or plant ingredient (corn, barley, wheat, oats, test bakery by-product, soybean, canola meal, cotton meal, etc.) (Valdes and Leeson, 1992). Though an r^2 of 0.93 was obtained for AME_n of ingredients, the equation failed to predict the AME_n of linseed, full-fat soybeans, soybean meal and wheat. A universal calibration developed for complete feeds attained an r^2 of 0.78. However, the authors cited lack of samples for the non-validation of the calibration work.

The only other known NIRS study on wheat is that of Wiseman and McNab (1995) who, despite having a much wider range of determined AME values than in the present study, reported that "extensive assessments of spectra obtained did not allow for meaningful relationships between them and AME to be derived."

In summary, the following conclusions can be drawn.

1. None of the production characteristics showed a good correlation with specific weight. Using the linear estimates for wheat AME and TME the effect of a 10 kg/hl change in SW equates to a 3 or 1.4 per cent change respectively. The estimate for AME is likely to be a worst-case value due to the high inclusion level of wheat.
2. The range of calculated wheat AME (approximately 1MJ) across the 30 wheat samples is similar to that seen in previous studies for wheat grown in N.Ireland and much lower than in some other studies.
3. None of the other parameters examined gave any better relationship with nutritive value (assessed as AME or TME) than SW. This is a disappointing outcome, particularly in view of some previous studies which suggested that *in vitro* viscosity provides a good prediction of nutritive value.
4. The NIRS calibration was encouraging, particularly considering the small range of AME values. However the prediction of values for the separate validation set and even for the randomly selected subset suggests that NIRS is not likely to provide a solution although further work on this is warranted.

Table 3.1 Specific weight (SW), thousand grain weight (TG), *in vitro* viscosity (VIS) values and 1B1R status of selected wheats

		Crossnacreevy			Downpatrick			Limavady		
Variety	1B1R	SW	TG	VIS	SW	TG	VIS	SW	TG	VIS
Cantata	-	66	46.8	10.6	71	47.9	12.4	76	49.9	15.9
Ritmo	-	62	42.5	10.8	67	43.9	11.5	71	43.9	11.9
Riband	-	66	40.4	13.0	69	44.4	15.2	72	46.2	13.1
Chaucer	-	61	37.6	15.9	68	40.1	14.2	70	44.1	12.3
Reaper	-	65	41.8	25.0	69	42.9	22.2	72	46.1	20.8
Brigadier	+	65	37.5	22.2	68	38.1	15.3	72	43.8	24.8
Madrigal	+	62	35.8	14.3	70	40.3	14.4	73	42.2	19.6
Hussar	+	65	40.0	24.2	69	37.6	21.5	75	43.5	26.3
Harrier	+	65	39.7	16.6	71	42.8	15.3	73	44.9	19.9
Equinox	+	59	40.1	16.1	70	42.6	18.3	68	45.4	22.7

Table 3.2 Composition of diets (g/kg)

Wheat	744
Casein	142
Poultry fat blend*	50
Dicalcium phosphate	22
Potassium carbonate	10.8
Sodium bicarbonate	7.5
Binder**	8.0
Minerals/vitamins***	7.2
Arginine HCl	5.0
Methionine	2.0
Titanium dioxide	1.5

* Composition (g/kg): C12:0, 58; C14:0, 24; C16:0, 265; C18:0, 57; C18:1, 323; C18:2, 205; C18:3, 32; C20:1, 28.

** Lava dust (Exal-H, Talsa, Spain)

***The mineral /vitamin mixture supplied (per kg final feed): retinol 3.6 mg, cholecalciferol 0.125 mg, tocopherol 80 mg, thiamin 3 mg, riboflavin 8 mg, vitamin K 8 mg, pyridoxine 5 mg, nicotinic acid 80 mg, calcium pantothenate 20 mg, folic acid 3 mg, biotin 0.25 mg, cobalamin 30 µg, betaine 350 mg, manganese 100 mg, iron 60 mg, zinc 60 mg, copper 20 mg, iodine 2 mg, cobalt 0.5 mg, selenium 0.25 mg.

Table 3.3 Chemical composition (g/kg DM) and gross energy (GE) content (MJ/kg DM) of wheat samples

Variety	Site*	CP (Nx5.83)	NDF	Starch	Total NSP	Sol NSP	Lysine	Threonine	GE
Cantata	C	110.9	117	604	101.5	21.9	3.6	3.7	18.43
	D	123.5	124	642	101.1	27.0	3.3	3.5	18.44
	L	120.0	121	679	92.1	20.6	3.0	3.2	18.39
Ritmo	C	112.1	129	633	106.5	22.2	3.2	3.1	18.27
	D	114.7	133	631	107.0	19.7	3.1	3.2	18.32
	L	125.6	121	664	99.4	19.8	3.0	2.9	18.44
Riband	C	105.4	131	659	97.3	18.8	3.3	3.2	18.37
	D	112.1	131	654	102.1	23.8	3.2	3.2	18.25
	L	115.9	122	664	96.7	18.3	3.3	3.1	18.32
Chaucer	C	110.9	134	651	100.6	26.7	3.9	3.5	18.31
	D	121.8	132	613	101.4	22.9	3.5	3.3	18.32
	L	119.5	125	654	99.8	24.2	3.9	3.6	18.31
Reaper	C	117.5	121	672	97.0	18.9	2.9	3.6	18.37
	D	127.5	149	651	97.8	27.8	3.5	3.6	18.37
	L	126.7	135	672	97.5	30.1	3.0	3.4	18.38
Brigadier	C	110.4	139	646	122.6	27.0	3.4	3.3	18.27
	D	127.5	138	615	117.7	28.0	3.6	3.5	18.35
	L	114.4	134	658	100.7	22.9	3.4	3.5	18.29
Madrigal	C	114.7	125	633	108.3	17.6	3.3	3.0	18.29
	D	131.3	132	627	107.4	24.0	3.6	3.5	18.34
	L	125.5	121	665	100.7	24.2	3.3	3.3	18.39
Hussar	C	111.1	151	613	111.6	19.8	3.2	2.9	18.30
	D	130.3	153	616	121.1	30.1	3.4	3.3	18.43
	L	119.2	148	677	106.5	24.1	3.6	3.1	18.37
Harrier	C	111.6	137	612	111.8	24.1	3.3	3.2	18.33
	D	114.0	133	612	108.0	24.3	3.3	3.2	18.26
	L	119.0	130	621	100.0	21.7	3.6	3.3	18.40
Equinox	C	116.3	144	649	114.6	26.9	3.1	3.0	18.34
	D	112.4	137	620	107.3	26.9	3.5	3.4	18.28
	L	129.3	134	636	105.8	32.6	3.4	3.1	18.46

*C, Crossnacreevy; D, Downpatrick; L, Limavady.

Table 3. 4 Composition of diets (g/kg DM).

Diet	Variety	Site	CP (Nx6.25)	Oil	NDF	Ash	Calc Total NSP	Calc sol NSP	Calc Starch	Gross energy MJ/kg DM
3	Cantata	C	247.8	67.0	128.5	63.0	75.5	16.3	449	19.47
2		D	246.5	61.3	122.0	59.0	75.2	20.1	478	19.31
1		L	228.5	62.0	119.2	55.8	68.5	15.3	505	19.31
6	Ritmo	C	248.5	66.4	125.0	63.0	79.2	16.5	471	19.38
5		D	243.0	67.3	116.6	62.7	79.6	14.7	469	19.32
4		L	256.0	67.9	117.9	62.4	74.0	14.7	494	19.45
9	Riband	C	237.9	68.8	109.8	64.0	72.4	14.0	490	19.39
8		D	244.7	67.2	114.7	63.1	76.0	17.7	487	19.38
7		L	241.9	64.3	116.4	60.3	71.9	13.6	494	19.37
18	Chaucer	C	238.7	69.3	124.7	62.6	74.8	19.9	484	19.36
17		D	239.2	67.3	141.6	61.5	75.4	17.0	456	19.45
16		L	236.6	66.1	147.4	60.2	74.3	18.0	487	19.32
21	Reaper	C	237.3	64.6	111.2	63.2	72.2	14.12	500	19.41
20		D	239.5	64.4	130.2	59.6	72.8	0.7	484	19.38
19		L	236.0	69.3	102.6	60.8	72.5	22.4	500	19.50
12	Brigadier	C	230.5	65.2	114.3	60.2	91.2	20.1	481	19.27
11		D	253.0	68.8	112.5	64.7	87.6	20.8	458	19.45
10		L	243.9	70.0	131.0	60.5	74.9	17.0	490	19.28
15	Madrigal	C	241.5	69.6	115.8	63.3	80.6	13.1	469	19.46
14		D	249.3	67.1	124.8	62.6	79.9	17.9	466	19.50
13		L	250.9	66.4	114.8	61.9	74.9	18.0	495	19.46
24	Hussar	C	244.7	69.0	124.2	62.6	83.0	14.7	456	19.60
23		D	262.4	68.3	130.4	61.3	90.1	22.4	458	19.63
22		L	247.5	67.4	114.4	64.5	79.2	17.9	504	19.42
27	Harrier	C	240.4	68.9	135.8	60.3	83.2	17.9	455	19.48
26		D	241.2	67.0	132.9	61.1	80.4	18.1	455	19.44
25		L	243.8	64.3	126.1	58.8	74.4	16.1	462	19.42
30	Equinox	C	249.7	67.9	123.0	63.5	85.3	20.0	483	19.48
29		D	239.7	67.8	128.6	60.1	79.8	20.0	461	19.43
28		L	242.2	69.4	143.3	58.9	78.7	24.3	473	19.51

Table 3.5 Effects of variety on performance and energy metabolism (df 261)

	Cantata	Ritmo	Riband	Chaucer	Reaper	Brigadier	Madrigal	Hussar	Harrier	Equinox	SED	P=
Initial weight (g)	136.3	135.0	134.0	133.1	133.0	133.5	133.9	135.2	134.4	132.9	3.51	NS
DM intake (g/d)	69.3	69.0	68.3	66.5	68.6	66.8	68.4	69.1	69.3	68.4	1.30	NS
LWG (g/d)	51.8	52.0	51.7	49.1	51.3	50.1	51.9	51.2	53.1	51.4	1.09	NS
Gain:feed	0.747	0.755	0.757	0.739	0.750	0.751	0.759	0.743	0.768	0.755	0.0107	NS
ME : GE	0.754	0.770	0.770	0.769	0.759	0.775	0.774	0.738	0.778	0.757	0.0119	0.047
ME : gain	19.6	19.8	19.8	20.2	19.7	19.9	19.9	19.5	19.7	19.6	0.30	NS
Calc wheat AME†	13.31	13.73	13.74	13.71	13.52	13.81	13.93	13.05	14.03	13.49	0.311	NS
TME(MJ/kg DM)	16.45	16.33	16.54	16.60	16.33	16.42	16.44	16.48	16.54	16.28	0.256	NS
Gizzard/EBW	17.2	17.3	17.9	17.2	16.8	18.1	18.1	18.1	18.5	17.9	0.81	NS
Viscosity *	14.2	11.3	13.2	14.5	20.5	21.0	19.9	21.1	21.1	18.6	-	<0.001
Viscosity (cps)	15.7	12.3	14.1	17.3	21.7	22.9	22.0	23.7	23.6	21.1	2.40	<0.001

† MJ / kg DM * Data log transformed and recalculated NS, $P > 0.05$

Table 3.6 Effects of 1B1R translocation on performance and energy metabolism

	1B1R	Non 1B1R	SED	P=
Initial wieght (g)	134.0	134.3	1.68	NS
Final weight (g)	1217	1209	11.6	NS
DM intake (g/d)	68.4	68.3	0.62	NS
LWG (g/d)	51.5	51.2	0.55	NS
Gain:food	0.755	0.750	0.0055	NS
ME:GE	0.764	0.764	0.0059	NS
ME:gain	19.7	19.8	0.61	NS
Calc wheat AME †	13.7	13.6	0.16	NS
TME (MJ/kg DM)	16.4	16.4	0.17	NS
Gizzard/EBW	18.1	17.3	0.28	0.003
Viscosity (cps)	22.7	16.3	1.02	<0.001

† MJ/kg DM NS, P > 0.05

Table 3.7 Effects of site (specific weight) on performance and energy metabolism (df 261)

	Crossnacreevy	Downpatrick	Limavady	SED	P=
Initial weight (g)	134.4	133.9	134.1	2.09	NS
Final weight (g)	1196	1226	1216	14.4	NS
DM intake (g/d)	68.2	68.6	68.3	0.76	NS
LWG (g/d)	50.6	52.0	51.5	0.69	NS
Gain:feed	0.743	0.758	0.756	0.0069	0.054
ME : GE	0.755	0.762	0.777	0.0074	0.009
ME : Gain	19.7	19.6	20.0	0.16	0.011
Calc. Wheat AME †	13.4	13.6	13.9	0.18	0.012
TME (MJ/kg DM)	16.3	16.5	16.5	0.21	NS
Gizzard:EBW	17.6	17.7	17.8	0.34	NS
Viscosity *	17.5	17.3	16.6	-	NS
Viscosity (cps)	20.0	19.7	18.6	1.23	NS

† MJ/ kg DM * Data log transformed and recalculated NS, P > 0.05

Table 3.8. AME (MJ/kg DM) of wheat samples (McCracken et al 2001) (Validation set)

Variety	1B1R gene	C (AME)	D (AME)	L (AME)
Consort	-	14.19	14.01	15.13
Brigadier	+	13.30	13.50	13.68
Reaper	-	13.04	13.53	13.50
Chaucer	-	13.18	13.81	13.98

Table 3.9. Calculated AME (MJ/kg DM) of wheat samples (Calibration set)

Variety	1B1R gene	C (AME)	D (AME)	L (AME)
Cantata	-	12.85	13.10	13.99
Ritmo	-	13.43	13.62	14.14
Riband	-	13.56	13.50	14.17
Chaucer	-	13.39	13.82	13.91
Reaper	-	13.52	13.45	13.58
Brigadier	+	13.46	13.97	13.99
Madrigal	+	13.53	14.13	14.12
Hussar	+	12.71	13.26	13.19
Harrier	+	14.54	13.14	14.41
Equinox	+	12.87	13.72	13.87

Table 3.10. NIRS calibration and validation statistics for wheat AME (MJ/kg DM) using SMLR

Site/Year	Nc	D	Range	Mean	SD	R^2	SEE	nv	SEP	1-VR	Wavelengths
CDL 98	30	2	12.71 - 14.54	13.63	0.45	0.90	0.175	12	2.35	0.12	224, 1256, 1264, 1272, 1280, 548, 2216, 2452, 2468
CDL 98	20	2	12.71 - 14.54	13.72	0.44	0.98	0.071	10	0.99	0.09	268, 1280, 1344, 1420, 1480, 548, 1844, 2336, 2444
CDL 98	25	1	12.71 - 14.54	13.68	0.45	0.97	0.102	5	0.41	0.63	383, 1735, 1867, 1883, 1899, 2119, 2431, 2459, 2471
CDL97/98	42	2	12.71 - 15.13	13.66	0.49	0.70	0.30	42	0.26		180, 1232, 1444, 1740, 2192, 2228, 2444, 2448

D = Derivative
nc = number of samples in calibration set
nv = number of samples in validation set
SD = standard deviation
SEE = standard error of estimate
SEP = standard error of prediction for validation set
1-VR = validation regression coefficient

CHAPTER 4

THE NUTRITIVE VALUE (METABOLISABLE ENERGY AND AMINO ACID DIGESTIBILITY) OF WHEATS OF DIFFERENT VARIETY AND DENSITY

4.1 Quality statement

Roslin Nutrition Ltd (RNL) throughout this trial was working to ISO 9002 standards. This covered all areas (feed manufacture, farm facilities and analytical laboratory). Accreditation has now been gained (November 2000).

4.2 Summary

The true metabolisable energy values (TME and TMEN) and the digestible amino acid contents of 16 samples of wheat grown in the UK (4 varieties x 4 densities) were derived and compared against each other. Simultaneously the same parameters were derived on 16 samples of wheat grown in Northern Ireland (8 varieties x 2 sites) and these were also compared against each other.

4.3 Study objective 1

The objective of this trial was to derive the true metabolisable energy values (TME and TMEN) and digestible amino acid contents of 16 samples of wheat grown in the UK. The wheats consisted of 4 varieties (Buster, Consort, Haven and Riband) each of which was selected from a larger number of samples to provide 4 densities with the widest range.

4.3 Study objective 2

The objective of this trial was to derive the true metabolisable energy values (TME and TMEN) and digestible amino acid contents of 16 samples of wheat grown at 2 sites in Northern Ireland (Downpatrick and Limavady, 8 from each site).

4.4 Materials 1

4.4.1 Test articles

The test articles were the 16 whole wheat samples grown in the UK and sourced by Leeds University. They were delivered to Roslin Nutrition Ltd where they were ground through a 5 mm screen before feeding. Before grinding the samples were visually assessed by the Mill Manager for quality and his assessment and comments are given in Table 25**.**

4.4.2 Target species

Adult ISA brown dubbed cockerels were the target species for this trial. The birds were not acclimatised to any of the diets.

4.4.3 Animals and maintenance conditions

Before the start of the trial the animals were examined for signs of ill-health and injury. Only birds appearing to be in good condition were used for the study.

The birds were assigned to their treatment groups using a recognised randomisation technique.

The cages housing the animals were uniquely labelled.

4.4.4 Environment

The birds were kept in suitable cages at Roslin Nutrition Ltd under the following environmental conditions

Temperature	21^{o}C
Light	16 h/day
Air changes	10-15 per h
NB: Daily records were kept of the environmental temperatures.	

4.4.5 Water supply

Water was available *ad libitum* throughout the test periods.

4.4 Materials 2

4.4.6 Test articles

The test articles were the 16 whole wheat samples sourced by Queens University Belfast (Dr Kelvin McCracken) and delivered to Roslin Nutrition Ltd. The wheats were ground through a 5 mm screen before feeding.

4.4.7 Target species

Adult ISA brown dubbed cockerels were the target species for this trial. The birds were not acclimatised to any of the diets.

4.4.8 Animals and maintenance conditions

Before the start of the trial the animals were examined for signs of ill-health and injury. Only birds appearing to be in good condition were used for the study.

The birds were assigned to their treatment groups using a recognised randomisation technique.

The cages housing the animals were uniquely labelled.

4.4.9 Environment

The birds were kept in suitable cages at Roslin Nutrition Ltd under the following environmental conditions

Temperature	21^{o}C
Light	16 h/day
Air changes	10-15 per h
NB: Daily records were kept of the environmental temperatures.	

4.4.10 Water supply

Water was available *ad libitum* throughout the test period.

4.5 Experimental design

4.5.1 Assignment of treatment groups

Each of the 32 wheats was allocated to 2 cages (32 wheats x 2 replicates) using a standard randomisation technique. This design was applied to 3 experiments in which the allocation of treatments are shown in Tables 1, 2 and 3.

4.5.2 Administration of test articles and duration of treatment

The ground wheat samples (50 g) were fed by tube to the birds.

4.6 Methods

4.6.1 Allocation of birds and feeding

On 3 separate occasions 70 adult ISA brown cockerels were allocated to individual cages according to plans described in Tables 1-3 and were starved of food for 48 hours. They were then fed 50 g aliquots of the wheats by tube and returned to the same cages equipped with clean trays for the quantitative collection of droppings for 48 hours (the full TME protocol is shown in Table 4). 6 of these birds received 50 g of glucose and acted as negative controls for the determination of endogenous excretions (energy, nitrogen and amino acids). All birds had free access to water at all times. The wheats were analysed for dry matter, gross energy and nitrogen (Tables 5 and 6).

4.6.2 Collection of droppings

Precisely 48 hours after feeding the birds the trays were removed and the droppings quantitatively collected, frozen, freeze-dried, equlibrated to atmospheric moisture level, weighed and ground through a 1 mm screen before analyses.

4.6.3 Analyses of droppings

Aliquots of each of the 32 ground wheat samples and each of the droppings samples were analysed for gross energy and nitrogen according to standard procedures.

4.6.4 Amino acid analyses

Aliquots of each of the 32 wheat samples and 2 of the droppings samples from each of the 6 birds fed on the different wheats were analysed for their amino acid contents. The 2 droppings samples from each treatment were chosen on the basis of their median TMEN values.

Samples were hydrolysed i) in 6 N hydrochloric acid for 24 hours in a heating block at 110^{o}C, and ii) after pretreatment with performic acid in 6 N hydrochloric acid for 23 hours in a heating block at 110^{o}C (for cystine and methionine). After work-up all samples were analysed on a Beckman 6300 HPLC amino acid analyser using nor-leucine as an internal standard.

4.7 Results

4.7.1 Analyses of wheats

Tables 5 & 6

4.7.2 TMEN of the UK grown wheats

Tables 7, 8, 9, 10 & 11

4.7.3 TMEN of the Northern Ireland grown wheats

Tables 17, 18, 19 & 20

4.7.4 Amino acid digestibility of UK grown wheats

Table 12, 13, 14, 15 & 16

4.7.5 Amino acid digestibility of Northern Ireland grown wheats

Tables 21, 22, 23 & 24

4.7.6 Visual assessment of the quality of the UK grown wheats

Table 25

4.8 Discussion 1

UK Wheats

The 16 wheats were compared against each other, within and between varieties and the main features are described below:

Comparison of all wheats (4 varieties x 4 densities)

- The TME_N value of Haven 66 was significantly higher than those of Busters 67, 71 and 73, Consorts 69 and 71, Havens 60 and 76 and Ribands 64, 69 and 73
- The TME_N value of Buster 78 was significantly higher than those of Busters 67, 71 and 73, Consorts 69 and 71, Haven 60 and Ribands 64, 69 and 73
- The TME_N values of Haven 71 and Riband 78 were significantly higher than those of Busters 67, 71 and 73, Haven 60 and Ribands 64, 69 and 73
- The TME_N value of Consort 73 was significantly higher than those of Busters 67, 71, and 73, Haven 60 and Ribands 64 and 69
- The TME_N value of Consort 78 was significantly higher than those of Buster 73, Haven 60 and Ribands 64 and 69
- The TME_N value of Haven 76 was significantly higher than those of Haven 60 and Riband 64
- The TME_N values of Busters 67 and 71, Consorts 69 and 71 and Riband 73 were significantly higher than that of Riband 64

- The digestibility coefficient of the total amino acids contained in Consort 71 was significantly higher than those in Busters 73 and 78, Consort 69, Havens 60, 71 and 76 and Riband 78
- The digestibility coefficients of the total amino acids contained in Busters 67 and 71, Consorts 73 and 78, Haven 66 and Ribands 64, 69 and 73 were all significantly higher than that in Haven 60
- The digestibility coefficients of the total amino acids contained in Buster 78, Consort 69 and Haven 71 were all significantly higher than that in Haven 60
- The digestibility coefficient of cystine in Haven 71 was significantly higher than those in Busters 67, 71 and 78, Consorts 69, 71, 73 and 78, Havens 66 and 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficient of cystine in Buster 73 was significantly higher than those in Busters 67, 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficient of cystine in Haven 60 was significantly higher than those in Busters 67, 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 69 and 78
- The digestibility coefficients of cystine in Haven 66 and Ribands 64 and 73 were significantly higher than those in Buster 67 and Consorts 69 and 71
- The digestibility coefficients of cystine in Busters 71 and 78 and Riband 78 were significantly higher than that in Consort 69
- The digestibility coefficients of lysine in Buster 73 and Haven 66 were significantly higher than those in Busters 67, 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficients of lysine in Havens 60 and 71 were significantly higher than those in Busters 71 and 78, Consorts 69, 71 and 78, Haven 76 and Ribands 69, 73 and 78
- The digestibility coefficient of methionine in Haven 66 was significantly higher than those in Busters 67, 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficient of methionine in Buster 73 was significantly higher than those in Busters 67, 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 64, 69 and 78
- The digestibility coefficient of methionine in Haven 60 was significantly higher than those in Busters 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Riband 64
- The digestibility coefficient of methionine in Haven 71 was significantly higher than those in Consorts 69, 71 and 78
- The digestibility coefficient of methionine in Riband 73 was significantly higher than that in Consort 71

- The digestibility coefficient of threonine in Buster 73 was significantly higher than those in Busters 71 and 78, Consorts 69, 71, 73 and 78, Havens 60 and 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficient of threonine in Haven 66 was significantly higher than those in Busters 71 and 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficients of threonine in Buster 67 and Haven 71 were significantly higher than those in Buster 78, Consorts 69, 71, 73 and 78, Haven 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficient of threonine in Haven 60 was significantly higher than those in Buster 78, Consorts 69, 73 and 78, Haven 76 and Ribands 64, 69, 73 and 78
- The digestibility coefficient of threonine in Buster 71 was significantly higher than those in Buster 78, Consorts 69 and 78, Haven 76 and Riband 78

Comparison across wheat varieties (all densities combined within a variety)

- The TME_N values of Consort and Haven were significantly higher than that of Riband
- The digestibility coefficients of the total amino acids contained in the 4 wheats did not differ significantly
- The digestibility coefficients of both cystine and methionine in Buster, Haven and Riband were significantly higher than those in Consort
- The digestibility coefficients of lysine in Haven was significantly higher than those in Consort and Riband
- The digestibility coefficients of threonine in Buster and Riband were significantly higher than that in Consort

Comparison of densities within varieties

Buster

- The TME_N of 78 was significantly higher than those of 67, 71 and 73
- The digestibility coefficients of the total amino acids contained in the 4 densities did not differ significantly
- The digestibility coefficients of cystine, lysine and methionine in 73 were significantly higher than those in the other 3 densities
- The digestibility coefficients of threonine in 73 was significantly higher than those in 71 and 78 and those in 67 and 71 were significantly higher than that in 78

Consort

- The TME_N values of all densities did not differ significantly
- The digestibility coefficients of the total amino acids contained in all 4 densities also did not differ significantly
- The digestibility coefficients of both cystine, lysine and methionine in all 4 densities did not differ significantly
- The digestibility coefficient of threonine in 73 was significantly higher than that in 71

Haven

- The TME_N of 66 was significantly higher than those of 60 and 76 while those of 71 and 76 were significantly higher than that of 60
- The digestibility coefficient of the total amino acids contained in 66 was significantly higher than that of 60
- The digestibility coefficients of cystine in 60 and 71 were significantly higher than those in 66 and 76 while that in 66 was significantly higher than that in 76
- The digestibility coefficient of lysine in 76 was significantly lower than those in 60, 66 and 71
- The digestibility coefficient of methionine in 66 was significantly higher than those in 71 and 76 while that in 60 was significantly higher than that in 76
- The digestibility coefficient of threonine in 76 was significantly lower than those in 60, 66 and 71

Riband

- The TME_N of 78 was significantly higher than those of 64 and 69 while that of 73 was significantly higher than that of 64
- The digestibility coefficients of the total amino acids contained in 64, 69 and 73 were significantly higher than that in 78
- The digestibility coefficients of cystine, lysine and methionine in all 4 densities did not differ
- The digestibility coefficients of threonine in 64 and 73 were significantly higher than that in 78

4.8 Discussion 2

Northern Ireland Wheats

The 16 wheat varieties were compared against each other, and between and within sites. The main features are described below:

Comparison of all wheats (2 sites, Downpatrick (D) and Limavady (L), x 8 varieties)

- The TME_N value of variety A/G grown at L was significantly higher than those of varieties A/B, A/D, A/E, A/G, A/P, A/R, A/V and B/D grown at D and A/D and A/E grown at L
- The TME_N values of varieties A/P and A/V grown at L were significantly higher than those of varieties A/E, A/R and A/V grown at D
- The TME_N values of varieties A/B, A/D, A/G, A/P and B/D grown at D and A/B, A/D, A/E, A/R and B/D grown at L were significantly higher than those of varieties A/E and A/V grown at D

- The digestibility coefficient of the total amino acids contained in the variety A/P grown at D was significantly higher than those in varieties A/D, A/G, A/R and B/D grown at D and A/D, A/E, A/G, A/R and A/V grown at L
- The digestibility coefficient of the total amino acids contained in the variety A/B grown at D was significantly higher than those in varieties A/R grown at D and A/E and A/V grown at L
- The digestibility coefficient of the total amino acids contained in the variety A/P grown at L was significantly higher than those in varieties A/R grown at D and A/V grown at L
- The digestibility coefficients of the total amino acids contained in the varieties A/E, A/G, A/V and B/D grown at D and A/B, A/D, A/R and B/D grown at L were all significantly higher than that in variety A/R grown at D
- The digestibility coefficient of cystine in variety A/R grown at D was significantly higher than those in varieties A/B, A/D, A/E, A/G, A/P, A/V and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L
- The digestibility coefficient of cystine in variety A/V grown at L was significantly higher than those in varieties A/B, A/D, A/E, A/P, A/V and B/D grown at D and A/E, A/G, A/P, A/R and B/D grown at L
- The digestibility coefficient of lysine in variety A/V grown at L was significantly higher than those in varieties A/B, A/D, A/E, A/G, A/P, A/V and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L

- The digestibility coefficient of lysine in variety A/R grown at D was significantly higher than those in varieties A/D, A/E, A/G and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L
- The digestibility coefficients of methionine in varieties A/R grown at D and A/V grown at L were significantly higher than those in all other varieties grown at both D and L
- The digestibility coefficients of methionine in varieties A/B, A/E, A/G, A/P, A/V and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L were significantly higher than that in variety A/D grown at D
- The digestibility coefficient of threonine in variety A/R grown at D was significantly higher than those in varieties A/B, A/E, A/G, A/P and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L
- The digestibility coefficient of threonine in variety A/V grown at D was significantly higher than those in varieties A/B, A/E and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L
- The digestibility coefficients of threonine in varieties A/G grown at D and A/V grown at L were significantly higher than those in varieties A/E and B/D grown at D and A/B, A/D, A/E, A/G, A/P, A/R and B/D grown at L
- The digestibility coefficient of threonine in variety A/P grown at D was significantly higher than those in varieties B/D grown at D and A/E, A/G, A/P, A/R and B/D grown at L

Comparison of wheats between sites D and L

- The TME_N value of the wheats from L was significantly higher than that of the wheats from D
- The digestibility coefficients of the total amino acids contained in the wheats from D and L did not differ significantly although those from D were numerically higher
- The digestibility coefficients of cystine in the wheats from D and L did not differ significantly; the same was true for the digestibility coefficients of lysine and methionine
- The digestibility coefficient of threonine in the wheats from D was significantly higher than that in the wheats from L

Comparison of wheats within sites

Downpatrick:

- The TME_N values of the varieties A/B, A/D and B/D were significantly higher than those of A/E and A/V

- The digestibility coefficient of the total amino acids contained in A/P was significantly higher than those in A/D, A/G, A/R, A/V and B/D while those in A/B, A/D, A/E, A/G, A/V and B/D were all significantly higher than that in A/R
- The digestibility coefficient of cystine in A/R was significantly higher than those in all other samples while those in A/B, A/E, A/G and A/V were all significantly higher than that in A/D
- The digestibility coefficient of lysine in A/R was significantly higher than those in all other samples
- The digestibility coefficient of methionine in A/R was also significantly higher than those in all other samples while those in A/B, A/E, A/G, A/V and B/D were significantly higher than that in A/D
- The digestibility coefficient of threonine in A/R was significantly higher than those in A/B, A/E, A/G, A/P and B/D while those in A/D and A/V were significantly higher than those in A/B, A/E and B/D; furthermore those in A/G and A/P were significantly higher than that in B/D

Limavady:

- The TME_N value of the variety A/G was significantly higher than those of A/D and A/E
- The digestibility coefficient of the total amino acids contained in A/P was significantly higher than that in A/V
- The digestibility coefficient of cystine in A/V was significantly higher than those in all other varieties except A/B and A/D
- The digestibility coefficient of lysine in A/V was significantly higher than those in all other varieties
- The digestibility coefficient of methionine in A/V was also significantly higher than those in all other varieties while that in A/B was significantly higher than that in A/G
- The digestibility coefficient of threonine in A/V was significantly higher than those in all other varieties except A/B

4.9 Conclusions

UK wheats

Apart from the conclusions highlighted in the discussion we also compared the relationship between the biological properties of the wheats and their densities and have the following observations to make. It can be seen that a weak relationship ($r^2 = 0.31$) existed between the TMEN of the wheats (all samples) and their densities (Figure 1), although when examined by individual variety (Figures 2-5)

the relationship was very strong for Riband ($r^2 = 0.98$), intermediate for Buster ($r^2 = 0.62$) and Consort ($r^2 = 0.48$) and poor for Haven ($r^2 = 0.18$). Interestingly, if the TMEN value for Haven 66 (the wheat with the third lowest density in the data set but with the highest TMEN value) was omitted from the analyses (Figure 6) the correlation coefficient of the linear relationship was improved substantially ($r^2 = 0.64$). This means that for every increase in density of
1 kg/hl the TMEN of wheat might be expected to increase by 0.03 MJ/kg or by using a 76 wheat rather than a 66 wheat the TMEN value would be 0.30 MJ/kg higher.

Both the content of the amino acids in the wheats and their digestibility was very variable, for example, the total amino acid content of the wheat varied from 82.4 g/kg (Riband 78) to 117.2 g/kg (Buster 67) and their overall digestibility from 79.7% (Haven 60) to 86.9% (Consort 71). This inevitably meant that the digestible amino acid content of wheat was also very variable, from 62.9 g/kg (Riband 78) to 95.1 g/kg (Buster 67).

We also examined whether the density of the wheats was related to their total amino acid content (sum of all the amino acids less tryptophan) and those of cystine, lysine and methionine (Figures 7-11). None of the relationships examined gave a significant correlation coefficient although in every case the parameter involving amino acids declined as the density of the wheat increased. The highest correlation coefficient ($r^2 = 0.24$) was given by the relationship between total digestible amino acids and density ($y = 14.31 – 0.091x$). This means that as the density of the wheat increases by 10 (say from 66 to 76) then its total digestible amino acid content is reduced by 9.1 g/kg or by about 10%.

It is therefore perhaps not surprising that as the density of the wheat increases the responses in TMEN and amino acids are in the opposite direction. It is well known that the concentration of starch in cereals (the principal source of energy) is negatively correlated with the protein content.

CHAPTER 5

FURTHER STUDIES ON THE RELATIONSHIP BETWEEN NUTRITIVE VALUE OF WHEAT FOR BROILERS AND WHEAT SPECIFIC WEIGHT

Introduction

The study of McCracken et al (2001) and that reported in Chapter 3, using 4 and 10 wheat varieties respectively, have determined weak relationships between calculated wheat apparent metabolisable energy (AME) or determined true metabolisable energy (TME) and specific weight corresponding respectively to 3 and 1.5 per cent increases for a 10 kg/hl increase in SW. However, the diets were based on high wheat content (740 g/kg) with casein as the protein supplement and it is known that such diets give higher *in vivo* viscosity than commercial cereal/soya diets (McCracken and Bedford, 2000) which may have exacerbated any differences between wheat samples. *In vitro* viscosity has been implicated as an important factor in determining wheat feeding quality for broilers (Bedford and Morgan, 1996) and some reports (eg Classen et al, 1995; McCracken et al 2001) have suggested that this may provide a more satisfactory basis for assessment of nutritive value than SW. However, the results in the previous chapter indicated a poor relationship between measures of nutritive value and *in vitro* viscosity. It was intended that this present study would further test the effects of SW on nutritive value using a wide range of SW from a small number of varieties and using a typical commercial formulation. Unfortunately it proved much more difficult than expected to obtain a suitable range of samples within GB and only 4 samples from each of 4 varieties were eventually available. The 1999 harvest at two sites in Northern Ireland (Downpatrick, Limavady) yielded a good range of specific weight for a number of varieties. In addition to the GB wheats eight of these (4 IBIR, 4 non-IBIR) were selected giving a total of 32 samples (4 wheats * 4 SW plus 8 wheats * 2 SW) for study.

Materials and Methods

Diets

The 12 varieties selected and their characteristics are summarised in Table 5.1(a) and (b). Those designated D, L are the 8 Northern Ireland varieties and the GB varieties are Buster, Consort, Riband and Haven. Specific weight ranged from 60-78 kg/hl with the mean values for the GB and Northern Ireland samples being 71.1 and 68.5. Seventeen of the samples were below the feed wheat minimum of 72 kg/hl. Wheat was ground in a hammer-mill using a 5 mm screen. The diet

formulation (Table 5.2) was a typical UK starter / grower with a small inclusion of maize starch to permit adjustment of the levels of inclusion of lysine, threonine and methionine to equalize these across all diets based on amino acid analysis of the wheat samples. The diets were mixed, heat-treated (70^0C, 15 sec) and pelleted (3mm die) in the commercial mill at Roslin and transported to Belfast and Harper Adams at the beginning of the experiment. Samples of the pellets were tested at a commercial feed mill for hardness (Holman, Table 5.5).

Experimental design -- Belfast Trial

The 4 wheats by 4 SW plus 8 wheats by 2 SW gave rise to 32 diets. Sixty four birds were used in each of five consecutive time replicates with 2 weight blocks of 32 in each replicate. All 32 treatments were randomly allocated within a weight block of 32 birds.

Experimental design -- Harper Adams (HAUC) Trial

The same 32 treatments were allocated to one cage of birds within each of the three positional blocks (96 cages). Two birds were allocated per cage. This experimental procedure was repeated four times with four different batches of broiler chickens to give a total of twelve cage replicates for each dietary treatment.

Birds and Management – Belfast Trial

Male Ross broiler chicks were obtained at hatching and kept in a commercial brooder for 1 week with *ad libitum* access to a crumbled starter and water. At 7 d, all birds (approximately 90) were weighed. The lightest and heaviest birds were discarded and 64 allocated to experiment according to the randomisation. Birds were placed in individual cages in a room at an initial temperature of 32°C and reduced 1°C per 2 d down to 24°C. The light:dark cycle was 18:6 and relative humidity was set for 50%.

Birds were fed *ad libitum* from 7-28d, with feed intake and weight being recorded on a weekly basis. A total excreta collection was made from 14-21d for determination of apparent metabolisible energy (AME) content. At 28d, birds were humanely killed and the contents of the proximal ileum (end of duodenum to Meckel's Diverticulum) removed for determination of supernatant viscosity. Empty bird weight and gizzard weight were recorded.

Birds and Management – Harper Adams (HAUC) Trial

Female Ross broiler chicks were obtained at hatching and kept in a floor pen for 5 d with *ad libitum* access to a crumbled starter and water and then moved into cages with access to the same feed. At

7 d, all birds (approximately 220) were weighed. The lightest and heaviest birds were discarded and 192 were randomly allocated to one of 96 cages that were distributed on three positional tier blocks within the same environmentally-controlled room. Two birds were placed in each cage. The initial temperature of 32°C was reduced 1°C per 2 d down to 24°C. One hour of darkness was given each day. Each of the 32 diets was given to one cage of birds within each of the three positional blocks. The experimental diet and water were given *ad libitum*. The weight gain and feed intakes of the birds were recorded over a 21 d feeding period.

Analysis of wheats and diets

The wheat samples were analysed for crude protein (Nx5.83), neutral detergent fibre (NDF), non-starch polysaccharides (NSP, total and soluble), starch, amino acid content and gross energy. Specific weight, thousand grain weight and *in vitro* viscosity were also recorded and wheats were assayed for hardness using NIR. The diets were analysed for DM, crude protein (Nx6.25), crude fat (acid hydrolysis), starch, ash, NDF, and gross energy. All analyses were carried out in duplicate and results reported on a dry matter (DM) basis. DM was determined by oven drying at 100^{o}C for 24h and ash content was determined by ashing samples in a muffle furnace at 450^{o}C for 16h (AOAC, 1990). Crude fat was extracted with petroleum ether (40-60 BP) in a Soxtec System, after 3M-HCl hydrolysis (Stoldt, 1952), NDF according to Van Soest (1963) and crude protein (CP) by the Kjeldahl method (AOAC, 1990) and also using an automated nitrogen analyser (Leco FP2000, Leco Instruments, UK Ltd.). Total starch was determined using a commercial enzyme assay kit (Megazyme International Ireland Ltd) as described by McCleary et al (1997). Non starch polysaccharide (NSP) content of the wheat samples was determined using a commercial enzyme assay kit as described by Englyst et al (1994). *In vitro* viscosity of wheats was determined using a modification of the method described by Bedford and Classen (1993) with the resulting sample supernatant viscosity being measured with a Brookfield Viscometer. Gross energy of diet and excreta samples was determined using an isothermal automated bomb calorimeter (PARR, Model 1271).

Calculation of wheat AME content

Wheat AME content was calculated from the diet AME concentration assuming a value of 5.0 MJ for the residual components of the diet. Thus wheat AME = (Diet AME - 5.0) / 0.65.

Determination of True Metabolisable Energy (TME)

TME/TMEn were determined using adult cockerels. Ground samples (50g) of wheat were tube-fed to starved (48h) birds and the excreta collected over the subsequent 48h were dried, weighed and homogenised. TME/TMEn values were derived according to McNab and Blair (1988).

Statistical analysis

The results of the both trials were subjected to analysis of variance treating the two factorial designs (4*4 and 8*2) as two sub-experiments within the one study and with wheat variety and specific weight as the main factors. For growth parameters initial weight was used as a co-variate. For the Belfast trial the 32 treatments were also tested for linear and quadratic trends against SW. The TME results were subjected to one-way ANOVA. Regression relationships between various parameters were established and a number of multiple regressions was examined using the data from the Belfast trial.

Near Infrared Reflectance Spectroscopy (NIRS)

Wheat samples and diets were scanned at 2nm intervals over the range 1100 to 2500 nm using a FOSS6500 instrument. Duplicate packings were done on each sample. Calibrations were done using MPLS, first and second derivative, plus 3 scatter corrections (SNVD, NMSC and WMSC). The 32 wheat samples were used initially for calibration and back prediction of wheat AME and TME and then a random set of 16 samples was used for calibration and the other 16 samples for validation. The diet scans were used only for prediction of wheat AME.

Results

Thousand grain weights ranged from 29 to 59.5 (Table 5.1), the mean values for the two Northern Ireland (NI) sites being similar (53.4 and 52.9) and the mean for the GB samples being considerably lower (40.8). *In vitro* viscosity values ranged from 8 to 44, the means for Downpatrick, Limavady and GB respectively being 12.6, 13.9 and 15.9 cps.

There was quite a narrow range of crude protein content (Nx5.83) across the 32 wheat samples (Table 5.3), though the mean for Downpatrick (130 g/kg DM) tended to be higher than those for Limavady and GB (111 and 115 respectively). Starch contents ranged from 630 to 719 g/kg and NDF ranged from 101 to 154 g/kg. Gross energy values of all wheat samples were similar, ranging from 18.2 to 18.6 MJ/kg DM. There was a very weak positive relationship between starch content and SW (Table 5.4) which was complicated by an interaction between the NI and GB samples, the

slope being greater (3.4) for GB samples. Crude protein was negatively correlated with SW (r^2 = 0.41) whilst there were negligible relationships for either NDF or total NSP.

The range of measured CP (213-259 g/kg) in the diets (Table 5.5) was somewhat greater than would have been calculated from the wheat values. Starch content ranged from 375 to 428 g/kg DM and NDF from 102 to 153 g/kg DM. Gross energy concentrations of all diets, except Equinox (Downpatrick) were similar, ranging from 18.7 to 19.1 MJ/kg DM. The low value for Equinox (18.4) appeared to have been due to addition of extra minerals during mixing.

Growth rates and feed conversion efficiency were higher in the Belfast trials probably because male birds were used in this study. Similar treatment effects were evident in both trials (Tables 5.6, 5.7, 5.8). AME and viscosity data are available for the Belfast trial data so these results are discussed in further detail.

There were no differences in mean DM intake or liveweight gain (LWG) between the means for NI and GB samples (Table 6) but gain:feed was higher for NI (P = 0.053, Belfast trial and P=0.037, HAUC trial). Apparent metabolisable energy (AME) to gross energy ratio (ME:GE) and calculated wheat AME were higher (P<0.001) for NI wheats but TME was slightly higher (P = 0.032) for GB wheats, mainly due to the very high value recorded for Haven 66. *In vivo* viscosity was higher (P = 0.011) for GB samples due mainly to the high value (10.2) observed for Haven 76.

The effects of variety are summarised in Table 5.7 with separate statistical analyses for NI and GB samples. There were no significant variety differences for DM intake, LWG or gain:feed in the HAUC trial. In the Belfast trial mean DM intake ranged from 74.1 g/d (Equinox) to 80.0 (Buster), the effects for GB being significant (P<0.001), but associated with a significant variety* sample interaction (P<0.05) due to a very high intake for Buster 71 (Figure 1). LWG ranged from 56.9 (Equinox) to 60.7 (Aardvark). The differences were statistically significant for the GB samples (P<.05) but there was a significant variety * sample interaction corresponding to the DM pattern (Figure 5.2). Gain:feed ranged from 0.748 (Savannah) to (0.788) Hereward (NS). ME:GE ranged from 0.693 (Buster) to 0.734 (Hereward) and the variety differences were significant (P<0.05, P = 0.001 for NI and GB). However, there were significant variety* site interactions (P<0.05, P = 0.001) for both data sets, with individual sample values ranging from 0.671 (Buster 67) to 0.744 (Hereward, L). The same pattern of variety* site interactions was seen for calculated wheat AME (P<0.05, P<0.001 for NI, GB) with values ranging from 11.8 (Buster 67) to 13.9 (Hereward L). Wheat TME values ranged (NS) from 15.9 MJ/kg DM (Savannah) to 16.2 (Hereward, Haven).

In vivo viscosity values ranged from 3.9 (Hereward) to 6.6 (Haven). Within GB samples variety differences were significant ($P<0.001$) but there was a variety* site interaction ($P<0.001$) due to the high value (10.2) for Haven 76.

In view of the limitations of the factorial analysis, due to differences in SW of samples within varieties, the Belfast results were tested for linear and quadratic trends using SW as the X variate. There was no significant relationship between DM intake or LWG and SW (Figures 5.1, 5.2). There was a significant quadratic relationship ($P<0.01$) between gain:feed and specific weight ($r^2 = 0.35$) (Figure 5.3). Similarly, there were significant ($P = 0.011$, $P<0.01$) quadratic relationships between diet ME:GE or calculated wheat AME and SW ($r^2 = 0.27$ and 0.31 respectively), (Figures 5.4, 5.5). In contrast, there were significant linear relationships between wheat TME and SW ($r^2 = 0.21$, Figure 5.6) and between wheat TMEn and SW ($r^2 = 0.33$, Figure 5.7), the slopes corresponding respectively to 1.2 or 1.7 per cent increases for a 10 kg/hl increase in SW.

There was quite a strong relationship between gain:feed and ME:GE (Figures 5.8 and 5.9) though 4 of the GB samples (2 Buster, 2 Riband) gave higher total gain:feed values than predicted on the basis of ME:GE (Figure 5. 9).

When variety effects were tested there were significant variety * site interactions for all relationships between gain:feed and individual chemical or physical parameters. There was a weak linear relationship ($P<0.05$) between ME:GE and starch concentration ($r^2 = 0.13$) and the slope was negligible (Figure 5.10), corresponding to a 3 per cent increase in ME:GE for 100g/kg change in starch content. ME:GE was not significantly correlated with NDF content but there was a highly significant ($P = 0.001$) quadratic relationship between ME:GE and total NSP (Figure 5.11). Wheat AME and TME relationships with starch, NDF and total NSP were not significant but there was a weak linear relationship ($P<0.05$) between TMEn and total NSP (Figure 5.12), the slope corresponding to a 1 per cent reduction in TMEn for 20g/kg increase in total NSP.

Thousand grain weight (TGW) correlated well with SW ($r^2 = 0.74$) when variety effects were accounted for (Figure 5.13). ME:GE showed a weak ($P<0.05$) linear relationship with TGW ($r^2 = 0.14$) with the slope corresponding to 1 per cent increase in ME:GE for a 10g increase in TGW (Figure 5.14). However, neither calculated wheat AME nor TME were significantly related to TGW.

There was no correlation between either gain:feed (Figure 5.15) or ME:GE (Figure 5.16) and *in vivo* viscosity. However, when variety effects were taken into account there was a significant relationship ($P<0.05$) between ME:GE and *in vitro* viscosity ($r^2 = 0.62$), (Figure 5.17). Calculated wheat AME showed a similar pattern ($r^2= 0.55$) but there were some variety * sample interactions (Figure 5.18).

Stepwise multiple linear regression using SW, TGW, starch and IVV yielded significant relationships for ME:GE and wheat AME which involved only SW and starch, the equations being:

ME:GE = 0.604 – 0.0011 SW + 0.0003 starch P = 0.011 $r^2 = 0.27$
Wheat AME = 10.39 – 0.038 SW + 0.0085 starch P = 0.004 $r^2 = 0.32$

NIR, using the wheat samples, yielded calibrations with r^2 of 0.89 and 0.43 respectively for wheat AME and TME (Table 5. 9). However the error of cross validation (SECV) increased in both cases and the 1-VR were low. On back prediction for AME one major outlier (Hereward, Limavady) was seen (Figure 5.19). Excluding it there was an excellent fit ($r^2 = 0.93$) and the correlation for TME was also reasonable (Figure 5.20). Calibration for AME using NIR of the diets was less sensitive than for the wheat calibration (Table 5. 9) and the r^2 of the back prediction (0.59) was weaker (Figure 5.21). For both AME and TME the samples were split 50/50, either on the basis of origin (NI, GB) or randomly, and the resulting calibrations were validated using the remaining 16 samples. In all cases the validations gave low r^2. The validation based on the random selected sample (Figure 5.22) is typical of all the validation sets.

Discussion

The study differed from the previous one (Chapter 3) in a number of respects. The level of wheat inclusion was lower, the main protein source was soya and a major attempt was made to ensure that the leading essential amino acids were balanced across diets and at a level which would not be limiting. A less satisfactory aspect was that half of the samples were from GB across 2 harvest years and the rest from N. Ireland and that, while the range of SW was similar for the two locations, the TGW of the GB samples was much lower. This could not be attributed solely to variety though, inevitably, it became associated with variety in the statistical analysis. Despite the observed differences in samples from the two locations (GB, NI) the mean performance values were similar and, in fact, the growth rates of the birds in the Belfast trial were among the highest recorded in the laboratory over several years. Furthermore, despite lower dietary ME concentrations than in the previous study, total gain:feed were marginally higher with the result that ME:gain values were

lower (17.7 cf 19.7 MJ/kg). This excellent performance may be partly attributable to the care taken in balancing amino-acid contents but is also thought to have been related to the quality of the pellets and to the care taken to ensure that birds started to eat soon after transfer to individual cages.

As with the previous study, whilst there were significant variety effects, there were also significant variety * site (sample) interactions indicating that differences were related more to specific samples than to variety *per se*. In relation to calculated wheat AME the range of values (11.8 to 13.9 MJ/kg DM) was somewhat greater than previously observed and absolute values tended to be lower. However, the latter observation should be interpreted with care since the calculation of wheat AME is by difference between the diet value and the assumed contribution from the other ingredients (in this case 35% of the diet) and so absolute values may be in error.

One of the most striking aspects of the present results is that, despite the range of *in vitro* viscosity being greater than in the previous study, the *in vivo* values were much lower (4.8 vs 19.5) which agrees with previous comparisons of "commercial" vs "high wheat/casein" diets (McCracken & Bedford, 2000). It would be expected therefore, that *in vivo* viscosity would have little impact on performance and the lack of relationship between either gain:feed or ME:GE is clearly demonstrated in Figures 5.15 and 5.16.

The lack of significant relationships between DM intake or LWG and SW concurs with the previous study. In contrast the excellent gain:feed observed with a number of the low SW wheats led to a significant quadratic relationship for gain:feed which was also observed for ME:GE. Third order relationships were also tested but were not significant. This study therefore has failed to establish any significant linear relationships between the main determinants of nutritive value (AME and performance) and SW. Indeed the linear relationships for ME:GE and gain:feed gave negative slopes with SW. The significant positive linear relationships between TME or TMEn and SW are similar to those observed in the previous study. Taking all of the results together (including those in Chapter 3) it would seem that a reduction of 10kg/hl in SW corresponds to an average reduction of approximately 1.5 per cent in TME/TMEn value. With respect to wheat AME it would seem that, depending on the other dietary ingredients, the effect of a 10kg/hl change in SW would be between zero and 3 per cent. There is certainly no evidence in favour of an arbitrary cut-off of 72kg/hl. In fact, in both the Belfast and HAUC trials, the mean values for the main performance parameters were similar for the 17 samples below 72kg/hl and the 15 above (Table 5. 8).

In relation to other chemical and physical parameters there were no strong relationships. TMEn was linearly related ($P<0.05$) to total NSP (Figure 5.12) but the correlation was poor ($r^2 = 0.13$) and the slope corresponded to a 1 per cent reduction for 20g/kg increase in NSP. Thousand grain weight (TGW) only correlated well with SW when variety effects were considered (Figure 5.13) and although ME:GE was linearly correlated with TGW ($P<0.05$) the correlation was poor ($r^2 = 0.14$) and the slope corresponded to a 1 per cent change in ME:GE per 10g change in TGW. The calculated wheat AME vs TGW relationship was not significant ($P = 0.078$) and when variety was taken into account there were significant variety * sample interactions.

In contrast to the previous study where *in vitro* viscosity showed no significant relationship, and perhaps surprisingly in view of the low observed *in vivo* viscosity values, there was a significant relationship ($P<0.05$) between diet ME:GE and *in vitro* viscosity ($r^2 = 0.62$) when variety effects were taken into account. However, the slope was low and it would normally be impracticable to seek to correct for variety. Furthermore, the performance of the GB variety (Haven) which showed high *in vitro* viscosity (Figure 5.17) was better than that of the Buster and Riband samples which were lower viscosity wheats. A further complication was that, if the NI and GB wheats were considered separately there was an excellent linear relationship with the NI samples but none whatsoever for the GB samples. Clearly there is a need for further study of the factors affecting *in vitro* and *in vivo* viscosity and their relevance to nutritive value.

Attempts to establish multiple regression relationships using easily measured parameters (SW, TGW, *in vitro* viscosity, starch) were not particularly successful. The relationships for ME:GE and wheat AME involved SW and starch and only achieved r^2 of 0.27 and 0.32 respectively.

The NIR calibrations, based on the 32 samples, for both AME and TME were initially encouraging. However the cross validations were less so and, as with the results from the previous study, attempts to use a smaller sample for validation and the rest for validation were highly disappointing eg Figure 5.22. Unfortunately it was not possible use the previous results for validation purposes since they had been scanned in a different instrument. It is normally accepted that a larger calibration set than that available here is required for NIR and it may be worth while to consider ways of obtaining further appropriate data sets on which to further develop the use of NIR for estimation of wheat AME.

In conclusion, this study has further demonstrated a significant degree of variability between wheat samples, some of which may be related to variety. However, none of the chemical or physical

parameters measured provided a consistent basis on which to predict nutritive value. Under the experimental conditions used here, which would be similar to commercial production, SW was unsatisfactory as a basis for evaluation apart from TME and TMEn. Furthermore the results for gain:feed and calculated wheat AME would suggest that TME is not a suitable basis for assessing the value of wheat in practical diets. The use of NIR may be worth further study.

Table 5.1a. Specific weight (SW), thousand grain weight (TG) and *in vitro* viscosity (VIS) of selected Northern Ireland wheats

Variety	**1B1R**	Downpatrick			Limavady		
		SW	**TG**	VIS	**SW**	**TG**	**VIS**
Aardvark	-	62.8	51.8	14.2	72.5	55.6	16.7
Charger	-	62.4	43.3	10.8	73.2	46.9	10.5
Hereward	-	63.8	49.8	9.0	75.7	46.8	9.0
Reaper	-	65.8	58.5	14.0	75.3	58.0	13.5
Equinox	+	60.1	57.4	10.5	72.4	54.0	13.7
Napier	+	64.7	57.4	13.8	73.8	56.2	12.0
Rialto	+	61.7	49.8	13.4	73.4	53.3	18.5
Savannah	+	64.4	59.5	15.3	74.7	52.7	14.1

Table 5.1b. Specific weight (SW), thousand grain weight (TG) and *in vitro* viscosity (VIS) of GB wheats

Variety	**1B1R**	**SW**	**TG**	**VIS**	**SW**	**TG**	**VIS**	**SW**	**TG**	**VIS**	**SW**	**TG**	**VIS**
Buster	-	67	29.0	13.0	71	36.8	12.5	73	44.7	10.2	78	46.3	10.4
Consort	-	69	35.3	14.0	71	38.7	8.5	73	40.0	10.0	78	49.7	8.5
Riband	-	64	28.7	15.5	69	33.6	15.8	73	40.7	9.2	78	53.2	8.0
Haven	+	60	37.8	13.0	66	47.7	25.0	71	38.7	44.0	76	51.4	36.0

Table 5.2. Composition of diets (g/kg)

Wheat	650
Hipro soya meal	200.5
Full fat soya	40
Fish meal	40
Soya/tallow blend	25
Limestone	8
Dicdeum phosphate	14
Trace minerals/vitamins†	5
Sodium bicarbonate	2
Salt	2
Choline chloride	0.5
Lysine††	2.5
Methionine††	4.7
Threonine ††	2.8
Maize starch ††	3.0

† The trace mineral/vitamin mixture supplied (per kg feed): retinol 3.6 mg, cholecalciferol 0.125 mg, ά -tocopherol 50 mg, thiamin 2mg, riboflavin 7 mg, vitamin K 3mg, pyridoxine 5 mg, nicotinic acid 50 mg, calcium pantothenate 15 mg, folic acid 1 mg, biotin 0.2 mg, cobalamin 15 µg, manganese 100 mg, iron 80 mg, zinc 80 mg, copper 10 mg, iodine 1 mg, cobalt 0.5 mg, selenium 0.2 mg, molybdenum 0.5 mg.

†† For each wheat sample inclusions of lysine, methionine, threonine and maize starch were adjusted on the basis of the determined amino acid analysis of the wheat to equalise total concentrations across all diets.

Table 5.3. Chemical composition (g/kg DM) and gross energy (GE) contents (MJ/kg DM) of wheat samples

Variety	Site/SW	CP (Nx5.83)	NDF	Starch	Total NSP	Sol NSP	Lysine	Threonine	GE
Aardvark	D	116.0	144.4	658.5	126.7	33.2	3.1	4.2	18.41
	L	114.2	122.0	668.4	127.9	28.3	3.3	3.4	18.39
Charger	D	130.2	131.0	663.4	114.4	22.1	3.7	4.3	18.36
	L	96.0	139.2	702.1	111.6	24.8	2.9	2.9	18.35
Hereward	D	131.0	139.7	674.4	118.0	29.5	3.7	4.5	18.37
	L	127.7	127.4	668.4	115.6	14.7	3.1	4.0	18.53
Reaper	D	127.5	120.7	671.0	102.5	23.4	3.3	4.4	18.36
	L	110.6	117.1	678.1	100.1	14.4	2.9	3.4	18.38
Equinox	D	126.7	120.3	687.9	115.7	29.0	3.4	4.9	18.37
	L	101.7	132.6	683.8	113.8	22.0	3.1	3.1	18.31
Napier	D	121.4	123.8	666.6	126.9	30.4	3.4	4.1	18.27
	L	106.0	130.2	685.0	131.6	28.6	3.1	3.4	18.31
Rialto	D	140.1	122.4	660.1	127.7	32.1	4.0	4.7	18.44
	L	121.5	136.4	670.7	138.8	35.7	3.5	4.1	18.46
Savannah	D	123.7	140.9	667.1	126.6	32.7	3.5	4.6	18.35
	L	106.3	131.7	692.7	117.7	20.4	3.2	3.5	18.36
Buster	67	131.5	150.7	632.3	137.4	32.8	4.0	4.2	18.52
	71	123.0	154.2	642.2	130.3	30.2	3.4	3.9	18.48
	73	114.2	133.0	665.5	123.6	23.6	3.4	3.6	18.40
	78	114.0	139.3	672.0	121.7	24.6	3.5	3.2	18.41
Consort	69	105.5	114.3	687.4	115.5	23.1	2.9	3.5	18.35
	71	88.3	113.7	687.1	105.2	27.1	2.6	3.0	18.25
	73	100.6	111.2	711.3	99.4	28.8	3.0	3.6	18.41
	78	108.1	101.3	718.7	101.9	23.5	3.0	3.5	18.31
Riband	64	129.6	137.5	629.7	108.5	21.9	3.9	3.8	18.55
	69	121.6	130.0	669.6	110.4	21.6	3.7	4.2	18.49
	73	125.5	130.0	667.5	98.4	17.7	3.5	4.1	18.58
	78	94.6	137.5	713.7	110.0	24.6	3.0	2.9	18.27
Haven	60	129.4	142.0	654.2	123.0	38.0	3.9	4.6	18.49
	66	122.9	135.0	663.5	107.9	33.4	3.3	4.3	18.46
	71	117.4	145.3	654.9	106.3	28.4	3.5	4.0	18.47
	76	116.6	147.1	664.0	117.7	32.4	3.5	3.6	18.44

Table 5.4. Linear relationships between chemical parameters of wheat and specific weight

	Constant	**Slope**	**r^2**
Crude protein	222.2	-1.50	0.41
Starch	546	+1.12	0.09
NDF	149.1	-0.23	0.01
Total NSP	146.3	-0.43	0.04

Table 5.5. Chemical analysis (g/kg DM), pellet hardness (H) and gross energy (GE) values (MJ/kg DM) of diets

Variety	Site/SW	CP	Oil B	NDF	Starch	Ash	H	GE MJ/kg
Aardvark	D	247.2	53.5	117.3	382.6	67.1	81.6	18.94
	L	239.5	52.1	127.3	404.9	64.6	80.5	18.84
Charger	D	239.8	55.1	115.7	387.6	65.1	88.0.	18.90
	L	228.2	55.0	116.1	408.0	66.7	83.3	18.73
Hereward	D	246.4	56.4	128.5	399.7	66.2	88.6	18.90
	L	249.5	53.2	123.2	361.4	67.1	80.5	18.86
Reaper	D	248.2	52.1	102.0	410.3	67.9	77.8	18.92
	L	228.5	54.0	108.4	411.9	66.0	81.9	18.78
Equinox	D	237.7	48.4	102.4	412.7	64.6	87.5	18.88
	L	212.7	51.9	117.1	417.2	77.7	82.1	18.43
Napier	D	237.3	53.0	111.6	408.2	65.5	86.8	18.89
	L	224.2	56.3	133.0	411.6	66.1	79.5	18.84
Rialto	D	248.2	52.7	126.3	391.6	65.7	79.7	18.88
	L	241.2	50.3	126.3	397.7	64.5	89.3	18.85
Savannah	D	243.4	50.1	120.9	388.5	65.3	83.6	18.91
	L	233.0	49.3	126.1	395.7	65.9	85.6	18.74
Consort	69	258.6	54.5	124.7	368.9	67.1	89.1	18.98
	71	232.7	56.2	118.1	414.5	67.3	80.6	18.83
	73	231.5	54.4	115.1	417.2	66.6	80.3	18.92
	78	238.7	54.1	108.5	427.6	68.0	52.5	18.82
Buster	67	244.6	53.5	153.3	375.0	68.1	78.6	18.90
	71	244.3	55.5	139.5	394.1	66.6	93.1	18.89
	73	249.6	57.1	113.6	386.4	72.7	83.9	18.94
	78	242.4	54.5	135.1	410.1	68.8	75.6	18.90
Haven	60	247.9	60.0	117.0	408.7	69.4	78.8	18.85
	66	245.8	55.4	112.2	402.1	67.2	80.9	18.88
	71	245.6	56.7	119.2	414.2	70.0	77.2	18.86
	76	235.0	55.6	117.4	419.0	66.2	83.3	18.85
Riband	64	252.1	59.7	124.9	392.4	72.5	77.9	18.97
	69	247.6	53.8	131.9	395.4	68.7	71.8	18.87
	73	246.3	61.3	111.0	409.4	69.8	68.4	19.11
	78	233.0	55.6	107.8	427.9	70.3	64.3	18.76

Table 5.6. Comparison of mean values for NI and GB samples

	NI	**GB**	**P =**	**SED**
Belfast Trial				
DM intake (g/d)	76.6	77.1	NS	0.68
LWG (g/d)	58.5	58.1	NS	0.52
Gain:feed	0.766	0.756	0.053	0.0045
ME:GE	0.721	0.707	<0.001	0.0030
ME:gain	17.7	17.7	NS	0.08
TME (MJ/kg DM)	16.0	16.1	0.032	0.04
Calc AME (MJ/kg DM)	13.2	12.9	<0.001	0.08
Viscosity (cps)	4.50	5.16	0.011	0.245
HAUC Trial				
DM intake (g/d)	74.1	75.2	NS	0.95
LWG (g/d)	53.1	53.0	NS	0.54
Gain:feed	0.717	0.706	0.037	0.0049

NS , P>0.05

Table 5.7. Effects of variety on performance parameters and wheat energy values

	Aardvark	Charger	Hereward	Reaper	Equinox	Napier	Rialto	Savannah	Buster	Consort	Haven	Riband	P = W1*	P = W2*	SED W1	SED W2
Belfast Trial																
DMI (g/d)	78.5	76.2	75.2	79.0	74.1	77.1	76.4	76.2	80.0	77.5	76.1	74.6	NS	0.001	1.92	1.36
LWG (g/d)	60.7	58.4	59.1	59.5	56.9	58.0	58.2	57.1	59.8	58.3	57.6	56.8	NS	0.042	1.48	1.05
Gain:Feed	0.775	0.768	0.788	0.753	0.768	0.761	0.763	0.748	0.750	0.753	0.757	0.765	NS	NS	0.0129	0.0090
ME:GE	0.724	0.721	0.734	0.712	0.729	0.722	0.708	0.715	0.693	0.712	0.717	0.706	0.044	0.001	0.0085	0.0061
ME:GAIN	17.7	17.7	17.7	17.8	17.7	18.0	17.5	17.8	17.5	17.9	17.8	17.5	NS	0.017	0.23	0.16
TME †	16.0	16.1	16.2	16.1	16.0	16.1	16.0	15.9	16.1	16.1	16.2	16.1	NS	NS	0.11	0.08
Wheat AME †	13.3	13.2	13.6	12.9	13.2	13.2	12.8	13.0	12.5	13.0	13.1	12.9	NS	0.003	0.25	0.18
Viscosity (cps)	4.7	4.8	3.9	4.0	4.5	4.3	5.5	4.4	4.7	4.0	6.6	5.3	NS	<0.001	0.68	0.48
HAUC Trial																
DMI (g/d)	74.8	73.4	73.7	74.3	74.8	72.4	75.7	73.6	76.4	75.7	74.5	74.0	NS	NS	2.86	1.89
LWG (g/d)	53.0	53.1	53.1	53.5	53.5	52.0	53.3	53.5	52.8	53.2	53.2	52.8	NS	NS	0.98	1.07
Gain:Feed	0.708	0.723	0.721	0.720	0.715	0.719	0.704	0.727	0.692	0.703	0.714	0.716	NS	NS	0.0157	0.0098

* W1 refers to the 8 wheat varieties from N. Ireland; W2 refers to the 4 GB varieties

† MJ /kg DM NS, P>0.05

Table 5.8. Mean values for performance of 17 samples (<72 kg/hl) and

15 samples (>72kg/hl)

	<72	**>72**
Belfast Trial		
DM intake (g/d)	76.7	77.0
LWG (g/d)	58.4	58.2
Gain:feed	0.764	0.758
ME:GE	0.714	0.714
ME:gain	17.7	17.8
HAUC Trial		
DM intake (g/d)	74.6	74.6
LWG (g/d)	53.2	52.7
Gain:feed	0.713	0.706

Table 5.9. Calibration statistics for the HGCA Wheats

	n	**Mean**	**SEC**	**RSQ**	**SECV**	**1-VR**	**λ**
AME	61	13.02	0.13	0.89	0.25	0.63	676
TME	64	16.08	0.15	0.43	0.18	0.18	676

CHAPTER 6

THE EFFECT OF DIFFERENCES IN SPECIFIC WEIGHT OF FOUR WHEAT CULTIVARS ON THEIR NUTRITIVE VALUE FOR GROWING BROILER CHICKENS

Introduction

Sixteen wheat samples were obtained as part of the HGCA-funded project. Four wheat samples that differed in their specific weights were obtained each for four wheat cultivars; Consort, Buster, Riband and Haven. All of the samples were independently grown, either in the 1998 or 1999 harvest years, except for the two samples of Haven (specific weights of 71 and 76 kg/hl) that were produced by grain density separation of a single sample of Haven.

The objectives of this study were to compare the growth performance of broiler chickens when fed each of these wheat samples as part of nutritionally complete pelleted diets. Three separate experiments were performed.

1. A floor-pen experiment was conducted in which small groups (25 birds/replicate) of broiler chickens were fed a two-stage programme of wheat diets from day-old to slaughter. 16 treatments were compared.

2. A cage experiment was conducted in which two birds per cage were fed a single wheat-based diet (First stage diet of the floor pen experiment) from 7 to 28 days of age. 16 treatments were compared.

3. Large quantities of the Riband samples were available. A further floor-pen experiment was performed in which pens of birds (100 birds/replicate) were fed wheat-based diets comparing the four Riband wheat samples with specific weights of 64, 69, 73 and 78 kg/hl. Four treatments were compared.

Materials and Methods

Diets

Practical dietary formulations were produced for starter and finisher broiler chickens. Each diet met or exceeded the calculated nutrient specifications for that age of bird. The formulations both

contained 650g/kg of wheat (Table 1). Each formulation contained a small proportion of maize starch that was replaced with varying amounts of lysine, methionine and threonine to maintain a constant dietary concentration for each of these nutrients. The feeds were steam pelleted using a 3mm die. Sixteen wheat samples that comprised four cultivars (Buster, Consort, Haven and Riband) each at four different specific weights (Table 2) were used in each of the starter and finisher diet formulations.

Birds

Experiment 1:

A batch of 1200 Ross hybrid male broiler chicks was housed at day old. Twenty-five birds were randomly placed into one of 48 pens (floor area of 2.6m^2) within a controlled environment house. The pens each had a electric radiant-heat brooder, two hanging tube feeders and one hanging bell drinker. For the first week of the feeding period, small low-sided feed trays and font drinkers were added to each pen. The initial background temperature of the house was 26^oC and the localized heater provided an approximate 32^oC in one area of each pen. The temperatures were reduced each second day until the overall house temperature reached 21^oC, with no localized heating, at 26 days of age. One hour of darkness was given each day.

The birds were given *ad libitum* access to food and water throughout the 38d feeding period. Each pen of birds was randomly allocated to one of the 16 experimental feeds within each of three positional blocks. The starter feed was given until 28 d of age and the finisher/withdrawal feed was given to the end of the feeding period. Feed intakes were recorded for 0 to 28d and 28 to 38 d. All the birds in each pen were weighed on arrival and at 28d and 38 d of age. All mortalities were recorded and a pen feed weigh-back was conducted on any bird death after 10 d to correct the mean bird feed intake data.

On the completion of this feeding trial, another batch of 1200 birds was housed and the experimental procedures were repeated in a second time replicate. The positions of the dietary treatments within the house were re-randomized. The experiment thus used six replicates of each of the 16 wheats.

Experiment 2:

Female Ross broiler chicks were obtained at hatching and kept in a floor pen for 5 d with *ad libitum* access to a proprietary crumbled starter feed. They were then moved into cages with access to the same feed and water *ad libitum*. At 7 d, all birds (approximately 220) were weighed. The lightest and heaviest birds were discarded and 192 were randomly allocated to one of 96 cages that were distributed on three positional tier blocks within the same environmentally-controlled room. Two birds were placed in each cage. The initial temperature of 32°C was reduced 1°C per 2 d down to 24°C. One hour of darkness was given each day. Each of the 16 diets was given to one cage of birds within each of the three positional blocks. The experimental diet and water were given *ad libitum*. The weight gain and feed intakes of the birds were recorded over a 21 d feeding period. This experimental procedure was repeated four times with four different batches of broiler chickens to give a total of twelve cage replicates of each dietary treatment.

Experiment 3:

A batch of 3200 Ross hybrid male broiler chicks were housed at day old. On hundred birds were randomly placed into one of 32 pens (floor area of 2.6m^2) in three positional blocks within a controlled environment house. The pens each had two electric radiant-heat brooders, two hanging tube feeders and one hanging bell drinker. For the first week of the feeding period, small low-sided feed trays and font drinkers were added to each pen. The initial background temperature of the house was 26^oC and the localized heater provided an approximate 32^oC in one area of each pen. The temperatures were reduced each second day until the overall house temperature reached 21^oC, with no localized heating, at 26 days of age. One hour of darkness was given each day.

The birds were given *ad libitum* access to food and water throughout the 38d feeding period. Each pen of birds was allocated to one of the four Riband wheat samples. The starter feed was given until 21 d of age and the finisher/withdrawal feed was given to the end of the feeding period. Feed intakes were recorded for 0 to 21d and 21 to 37 d. All the birds in each pen were weighed on arrival and at 28d and 37 d of age. All mortalities were recorded and a pen feed weigh-back was conducted on any bird death after 10 d to correct the mean bird feed intake data.

Statistical Methods

A randomised block analysis of variance was used to compare the treatment means in all three experiments. In experiments 1 and 2, a factorial treatment structure was used that partitioned the main effects of cultivar and specific weight rank (as detailed in Table 2) and their interactions. There were six blocks (two time replicates x three positional blocks) used in experiment 1 and there were twelve blocks (four time replicates x three positional blocks) used in experiment 2. Comparisons between different cultivars were made by partitioning the treatment sums of squares into orthogonal contrasts. The four quantitative specific weight treatments of experiment 3 were compared by partitioning the treatment sums of squares into their linear, quadratic and cubic effects. Three positional blocks within the house were included in this randomised block design.

The feeds used in experiment 1 and 2 were made in two separate batches. Inspection of the initial results of both experiments indicated that all the broiler chickens fed the second batch of the starter diet of the Riband cultivar, specific weight 78 treatment had a very poor growth performance compared to all other treatment groups. The growth performance of the birds fed the first batch of feed that was produced for this dietary treatment was entirely different, and comparable to the other fifteen treatments. Birds given a third batch of this starter feed in experiment 3 also had a similar growth performance compared to the other dietary treatments. A proximate nutrient analysis of the second batch of feed was undertaken but no omission of a major feed ingredient was detected. However, we concluded that some factor had been inadvertently introduced or omitted from the feed and that any data produced from this batch of feed would be unreliable. We therefore excluded all data from birds that had been fed this batch of experimental feed from the statistical analysis of the experimental data. Data from three pens of broilers were thus excluded from experiment 1 and data from six cages of broilers were excluded from experiment 2. The excluded data were considered to be missing values in the ANOVA designs.

Experiment 2 used only two birds in each cage. If any bird within a cage died during the feeding period, or otherwise needed to be removed, all data for the cage unit were removed from the data set and considered to be missing values in the ANOVA. Ten cages out of the original 192 were withdrawn for this reason. In summary, experiment 1 had three missing values, experiment 2 had 16 missing values and there were no missing values in experiment 3.

Results and Discussion

Experiment 1

Birds fed the Riband and Buster samples had significantly (P=0.002) improved overall (0 to 38 d) growth rates compared to those fed Consort and Haven (Table 3). These differences in growth rates were also evident (P=0.027) in the first 28 days of growth (Table 4). The birds fed Buster samples had high feed intakes in the 28 to 38 days period and consequently their overall (0 to 38 d) FCRs were also poorer (P=0.002) compared to the birds fed Riband (Table 5). There were differences in the means of the specific weights of the four cultivar samples, also there was no information on the source of the samples. Therefore the data cannot be reliably used to indicate any general differences between the four cultivars in their nutritive value for broiler chickens.

Increasing specific weight within each set of cultivar samples was not consistently related to a change in growth performance, however this was primarily due to a cultivar x specific weight interaction. Increasing specific weight in the Haven samples gave an increasing FCR whereas increasing specific weight had no effect on the FCR in the other three cultivars. The 71 and 76 kg/hl Haven samples gave the biggest increase in FCR and these samples were derived from density partitioning of a single sample of grain. This technique could have given atypical sample characteristics.

The experimental data indicate that there were economically important differences in broiler growth performance that resulted from feeding different wheat samples. However, the differences were not solely related to the specific weight of the wheat sample. The differences in growth performance were similarly not related to the starch contents, endosperm hardness or proximate nutrient contents of the wheat samples. Agronomic differences in the crop growth or storage of the wheat samples thus appear to affect nutritive value, but these affects cannot be detected by conventional nutrient analysis or other common wheat quality tests.

Differences in specific weight rank gave differences ($P<0.001$) in overall mortality levels, particularly in the second part (28 to 38 d) of the feeding period. The lowest specific weight wheat sample of each cultivar gave high bird mortalities. It is possible that low specific weight wheats had higher mycotoxin contaminations that caused these effects. However, only small bird numbers were used in this experiment so the high variability of these data could have given misleading results.

Experiment 2

No significant treatment differences were detected in the cage experiment (Table 6). However, the numerical differences were very similar to the treatment differences observed in the floor pen experiment.

Experiment 3

The large floor pen experiment that compared only the four Riband samples also gave expected results. Although there were no significant effects of specific weight on overall (0 to 37 d) growth performance (Table 7), increasing specific weights gave increased broiler weight gains ($P=0.019$) and feed intakes ($P=0.004$) from 0 to 21 days of age (Table 8), although the significant ($P<0.001$ and $P=0.016$ respectively) cubic effects indicated a large amount of variation in this response. Interestingly, there were no ($P>0.05$) treatment differences in mortality.

Summary

- Two broiler growth experiments have quantified the nutritive differences between wheat samples that differed in their specific weight for four separate cultivars.

- There were significant differences between the four cultivars in broiler growth performance. Birds fed the Riband and Buster samples had significantly ($P=0.002$) improved overall growth rates compared to those fed Consort and Haven. Broilers fed Buster samples had high feed intakes in the 28 to 38 days growth period and consequently their overall FCRs were also poorer ($P=0.002$) compared to the birds fed Riband.

- Increasing specific weight did not affect FCR in three cultivars (Consort, Riband and Buster) but gave a decrease in FCR in the Haven samples. Some Haven samples were generated from one sample by a density separation technique and this may have been a cause of the spurious response in this cultivar. Low specific weight samples in all of the four wheat cultivars gave higher amounts of late bird mortality in the feeding period.

- A third experiment examined the effect of increasing specific weight in four Riband wheat samples using large bird numbers. Increasing specific weight gave a linear increase in weight gain ($P=0.019$) and feed intake ($P=0.004$) although there was a large amount of variation in this response. There was no ($P>0.5$) effect of specific weight on bird mortaility.

Table 6.1. Ingredient composition of experimental diets (kg/tonne)

Ingredient	Starter/Grower diet	Finisher/Withdrawal diet
Wheat sample	650	650
Hipro soya meal	200.5	180
Full fat soya	40	45
Fish meal	40	-
Sunflower seed meal	-	30
Soya/tallow blend	25	45
Limestone	8	10
Dicalcium phosphate	14	18
Trace minerals/vitamins†	5	5
Sodium bicarbonate	2	2
Salt	2	1.5
Choline chloride	0.5	0.5
Lysine††	2.5	3.6
Methionine††	4.7	3.2
Threonine ††	2.8	3.2
Maize starch ††	3.0	3.0
Calculated composition		
ME (MJ/kg)	12.8	13.0
Crude protein (g/kg)	216	190
Lysine (g/kg)	12.8	11.4
Methionine plus cystine (g/kg)	10.6	8.2
Calcium (g/kg)	10.1	10.3
Phosphorus (g/kg)	7.3	7.2

† The trace mineral/vitamin mixture supplied (per kg feed): retinol 3.6 mg, cholecalciferol 0.125 mg, ά -tocopherol 50 mg, thiamin 2mg, riboflavin 7 mg, vitamin K 3mg, pyridoxine 5 mg, nicotinic acid 50 mg, calcium pantothenate 15 mg, folic acid 1 mg, biotin 0.2 mg, cobalamin 15 µg, manganese 100 mg, iron 80 mg, zinc 80 mg, copper 10 mg, iodine 1 mg, cobalt 0.5 mg, selenium 0.2 mg, molybdenum 0.5 mg.

†† For each wheat sample inclusions of lysine, methionine, threonine and maize starch were adjusted on the basis of the determined amino acid analysis of the wheat to equalise total concentrations across all diets.

Table 6.2. Wheat samples used in the broiler chicken experiments

Cultivar	Specific weight ranked in order from lowest to highest			
	1	2	3	4
Buster	**71**	**73**	**75**	**78**
Consort	**69**	**71**	**73**	**78**
Haven	**60**	**66**	**71**	**76**
Riband	**64**	**69**	**73**	**78**

Table 6.3. Specific weights of four wheat cultivars and the growth performance of broilers

Pen Trials: Overall growth performance (0 to 38 days of age)

Wheat cultivar	*Specific weight (kg/hl)*	*Final body weight (kg)*	*Weight gain (kg/bird)*	*Feed intake (kg/bird)*	*FCR*	*Mort-ality (%)*
Consort						
	69	2.249	2.212	3.996	1.8056	4.0
	71	2.262	2.225	3.880	1.7444	2.7
	73	2.217	2.180	3.847	1.7658	2.0
	78	2.272	2.235	3.918	1.7537	6.0
	Mea	*2.250*	*2.213*	*3.910*	*1.7674*	*3.7*
Buster						
	67	2.291	2.252	4.017	1.7828	7.3
	71	2.235	2.196	3.988	1.8214	0.7
	73	2.333	2.296	4.160	1.8139	4.0
	78	2.313	2.275	4.002	1.7609	6.7
	Mea	*2.293*	*2.255*	*4.042*	*1.7947*	*4.7*
Riband						
	64	2.276	2.238	3.987	1.7856	6.7
	69	2.303	2.266	3.873	1.7099	2.0
	73	2.428	2.390	4.063	1.7015	2.0
	78	2.268	2.230	3.919	1.7574	1.5
	Mea	*2.319*	*2.281*	*3.961*	*1.7386*	*3.1*
Haven						
	60	2.301	2.263	3.886	1.7161	9.3
	66	2.264	2.225	3.759	1.6913	3.3
	71	2.183	2.145	3.884	1.8104	2.7
	76	2.181	2.143	3.924	1.8327	3.3
	Mea	*2.232*	*2.194*	*3.863*	*1.7626*	*4.7*
Treatment effects (P=)						
Cultivar		0.015	0.015	0.006	0.019	0.364
Specific weight		0.695	0.696	0.131	0.168	<0.001
Cultivar * Specific weight		0.037	0.035	0.609	<0.001	0.188
SED (72df) for comparing main factors		0.0288	0.0288	0.0507	0.01735	1.086
SED (72df) for comparing C *SpWt		0.0577	0.0576	0.1015	0.03469	2.173

Table 6.4. Specific weights of four wheat cultivars and the growth performance of broilers

Pen Trials: Early growth performance (0 to 28 days of age)

Wheat cultivar	Specific weight (kg/hl)	28d body weight (kg)	Weight gain (kg/bird)	Feed intake (kg/bird)	FCR	Mort-ality (%)
Consort						
	69	1.397	1.359	2.154	1.5867	2.7
	71	1.523	1.486	2.255	1.5220	1.3
	73	1.482	1.445	2.305	1.6011	0.7
	78	1.527	1.490	2.259	1.5204	2.0
	Mean	1.482	1.445	2.243	1.558	1.7
Buster						
	67	1.494	1.456	2.288	1.5722	2.7
	71	1.513	1.475	2.163	1.4702	0.7
	73	1.515	1.477	2.304	1.5619	3.3
	78	1.525	1.488	2.268	1.5309	3.3
	Mean	1.512	1.474	2.256	1.534	2.5
Riband						
	64	1.519	1.481	2.295	1.5529	2.7
	69	1.534	1.496	2.245	1.5026	0.0
	73	1.597	1.559	2.323	1.4926	1.3
	78	1.493	1.455	2.204	1.5180	0.9
	Mean	1.536	1.498	2.267	1.5170	1.2
Haven						
	60	1.543	1.505	2.265	1.5046	4.0
	66	1.510	1.472	2.199	1.4946	2.7
	71	1.503	1.465	2.252	1.5397	1.3
	76	1.414	1.376	2.223	1.6205	1.3
	Mean	1.493	1.454	2.235	1.5400	2.3
Treatment effects (P=)						
Cultivar		0.100	0.102	0.860	0.426	0.348
Specific weight		0.240	0.240	0.238	0.084	0.141
Cultivar * Specific weight		0.020	0.020	0.655	0.214	0.679
SED (72df) for comparing main factors		0.02266	0.02266	0.0398	0.02470	0.80
SED (72df) for comparing C *SpWt		0.04533	0.04533	0.0796	0.04941	1.60

Table 6.5. Specific weights of four wheat cultivars and the growth performance of broilers

Pen Trials: Finisher growth performance (28 to 38 days of age)

Wheat cultivar	*Specific weight (kg/hl)*	*Weight gain (kg/bird)*	*Feed intake (kg/bird)*	*FCR*	*Mort-ality (%)*
Consort					
	69	0.852	1.842	2.169	1.4
	71	0.739	1.626	2.209	1.4
	73	0.735	1.542	2.115	1.3
	78	0.745	1.658	2.240	4.1
	Mean	*0.768*	*1.667*	*2.183*	*2.1*
Buster					
	67	0.796	1.728	2.173	4.7
	71	0.722	1.825	2.529	0.0
	73	0.818	1.856	2.268	0.7
	78	0.788	1.734	2.206	3.4
	Mean	*0.781*	*1.786*	*2.294*	*2.2*
Riband					
	64	0.757	1.692	2.252	4.1
	69	0.770	1.627	2.151	2.0
	73	0.831	1.740	2.094	0.7
	78	0.775	1.716	2.222	0.7
	Mean	*0.783*	*1.694*	*2.180*	*1.9*
Haven					
	60	0.758	1.622	2.139	5.6
	66	0.753	1.560	2.103	0.7
	71	0.680	1.632	2.415	1.3
	76	0.767	1.701	2.218	2.0
	Mean	*0.740*	*1.629*	*2.219*	*2.4*
Treatment effects (P=)					
Cultivar		0.073	0.002	0.197	0.929
Specific weight		0.115	0.498	0.748	<0.001
Cultivar * Specific weight		0.003	0.023	0.019	0.158
SED (72df) for comparing main factors		0.01817	0.0408	0.0592	0.827
SED (72df) for comparing C *SpWt		0.03634	0.0816	0.1183	1.654

Table 6.6. Specific weights of four wheat cultivars and the growth performance of broilers

Cage Trials: Growth performance (7 to 28 days of age)

Wheat cultivar	*Specific weight (kg/hl)*	*Weight gain (kg/bird)*	*Feed intake (kg/bird)*	*FCR*
Consort				
	69	1.1456	1.8510	1.6172
	71	1.0609	1.7183	1.6245
	73	1.1142	1.8576	1.6699
	78	1.1434	1.8300	1.6011
	Mean	*1.1160*	*1.8142*	*1.6282*
Buster				
	67	1.0765	1.8226	1.6927
	71	1.1563	1.8800	1.6270
	73	1.1100	1.8014	1.6247
	78	1.0969	1.8228	1.6627
	Mean	*1.1099*	*1.8317*	*1.6518*
Riband				
	64	1.0522	1.7560	1.6690
	69	1.1250	1.7829	1.5863
	73	1.1173	1.7889	1.6023
	78	1.1099	1.7688	1.5956
	Mean	*1.1011*	*1.7865*	*1.6133*
Haven				
	60	1.1464	1.7951	1.5679
	66	1.1556	1.8040	1.5611
	71	1.1191	1.8158	1.6239
	76	1.0429	1.7247	1.6498
	Mean	*1.1160*	*1.7849*	*1.6007*
Treatment effects (P=)				
Cultivar		0.678	0.044	0.006
Specific weight		0.263	0.595	0.074
Cultivar * Specific weight		<0.001	0.026	0.002
SED (149df) for comparing main factors		0.01400	0.02248	0.01500
SED (149df) for comparing C *SpWt		0.02799	0.04496	0.03000

Table 6.7. Specific weights of four wheat cultivars and the growth performance of broilers

Large growth trial – examining four Riband samples only

Pen Trials: Overall growth performance (0 to 37 days of age)

Wheat cultivar		*Final body weight (kg)*	*Weight gain (kg/bird)*	*Feed intake (kg/bird)*	*FCR*	*Mort-ality (%)*
Riband						
		1.966	1.957	3.656	1.869	5.0
		1.936	1.896	3.580	1.890	5.5
		1.987	1.947	3.680	1.897	3.5
		1.966	1.927	3.598	1.870	4.8
SED (15df)		0.0424	0.0423	0.0461	0.0416	1.24
Probability of treatment differences						
Main treatment effects		0.518	0.517	0.139	0.872	0.442
Polynomial contrasts of Specific weight:						
Linear effect		0.740	0.738	0.543	0.954	0.575
Quadratic effect		0.528	0.514	0.926	0.425	0.641
Cubic effect		0.195	0.198	0.027	0.876	0.151

Table 6.8. Specific weights of four wheat cultivars and the growth performance of broilers

Large growth trial – examining four Riband samples only

Pen Trials: Early growth performance (0 to 21 days of age)

Wheat cultivar		*21d body weight (kg)*	*Weight gain (kg/bird)*	*Feed intake (kg/bird)*	*FCR*	*Mort-ality (%)*
Riband						
		0.8236	0.7844	1.1593	1.481	2.83
		0.7854	0.7459	1.1598	1.556	3.17
		0.8724	0.8324	1.5158	1.462	1.33
		0.8504	0.8113	1.1997	1.481	2.17
SED (15df)		0.01885	0.01879	0.01576	0.0310	0.888
Probability of treatment differences						
Main treatment effects		0.002	0.002	0.005	0.037	0.217
Polynomial contrasts of Specific weight:						
Linear effect		0.019	0.018	0.004	0.419	0.217
Quadratic effect		0.552	0.521	0.467	0.215	0.696
Cubic effect		<0.001	<0.001	0.016	0.010	0.095

Table 6.9. Specific weights of four wheat cultivars and the growth performance of broilers

Large growth trial – examining four Riband samples only

Pen Trials: Late growth performance (21 to 37 days of age)

Wheat cultivar		*Weight gain (kg/bird)*	*Feed intake (kg/bird)*	*FCR*	*Mort-ality (%)*
Riband					
		1.172	2.497	2.132	2.22
		1.150	2.420	2.110	2.42
		1.1150	2.465	2.231	2.19
		1.116	2.398	2.163	2.73
SED (15df)		0.0409	0.108	0.437	0.954
Probability of treatment differences					
Main treatment effects		0.445	0.108	0.437	0.691
Polynomial contrasts of Specific weight:					
Linear effect		0.138	0.059	0.419	0.691
Quadratic effect		0.701	0.857	0.680	0.826
Cubic effect		0.652	0.103	0.176	0.743

CHAPTER 7

RELATIONSHIP BETWEEN SPECIFIC WEIGHT OF WHEAT AND ITS NUTRITIVE VALUE FOR GROWER PIGS

7.1 Introduction

Specific weight of wheat is the trading standard used by the feed industry to determine purchase price and is therefore assumed to be an indicator of nutritive value. However evidence suggests that specific weight is not an appropriate measure of wheat quality (see review by Miller and Wilkinson, 1998). Work investigating the effects of low specific weight wheat on its nutritive value for pigs is limited and generally confounded with variety. In this experiment we investigated the effect of different specific weights of wheat within four known varieties on pig performance between 15 and 27 kg live weight to establish whether specific weight is an adequate indicator of nutritional value of wheat for grower pigs. Earlier work has indicated that the energy value of wheat for pigs declines below about 68 kg/hl (Batterham *et al*. 1980, de Lange *et al*. 1993). One of the four varieties chosen was Buster which has been specifically developed as a feed wheat and which therefore should perform better than the other varieties of wheat tested. Wiseman (2000) has demonstrated that varietal differences do exist for DE In growing pigs. In addition diet digestibility was measured for each diet by incorporating titanium dioxide into all the diets as an external marker and digestible energy (DE) was calculated for each diet.

The aims of this experiment were:
To determine whether specific weight was an indicator of the nutritional value of wheat or whether there was a critical point below which nutritional value of wheat would be predictable reduced.
To determine whether Buster was a superior wheat variety for young growing pigs compared to Riband, Haven and Consort.

We hypothesised that nutritional value of wheat would decline with declining specific weight and that Buster would outperform the other three wheat varieties.

7.2 Materials and Methods

7.2.1 Diets

Sixteen wheat samples comprising four varieties (Riband, Buster, Consort and Haven), each at 4 different specific weights (see Table 1) were processed into pelleted diets according to the formulation shown in Table 2. Details of the individual wheats are described in Chapter 2. All diets contained 67% wheat and no other wheat products. All other ingredients were included at the same level in each diet with the exception that diets were balanced for lysine, methionine plus cysteine, threonine and tryptophan by the inclusion of appropriate amounts of L-lysine HCl, DL-methionine, L-threonine and L-tryptophan.

Table 7.1 Wheat samples used in the grower pig trial

Variety	Specific weight ranked in order from lowest to highest			
	1	2	3	4
Buster	71	73	75	78
Consort	69	71	73	78
Haven	60	66	71	76
Riband	64	69	73	78

Table 7.2 Diet composition for grower pig trial

Raw material	%
Wheat	67.00
Full fat soyabean	7.50
Soya hipro	12.50
South American fishmeal	8.50
Soya oil	1.70
D.C.P. 40	1.30
Salt	0.26
Limestone flour	0.26
Chromic oxide	0.30
L - lysine HCl	0.32
DL methionine	0.08
L threonine	0.14
Premix	0.25

Estimated Nutrient Composition (%, unless otherwise stated)	
Digestible energy (MJ/kg)	14.72
Crude protein	22.15
Fibre	2.48
Lysine	1.45
Methionine	0.48
Methionine & cysteine	0.82
Threonine	0.94
Tryptophan	0.27
Calcium	0.85
Phosphorus (total)	0.75
Sodium	0.19

Titanium dioxide was included in all the diets at 3g/kg fresh weight to provide an external marker for the estimation of digestibility and hence digestible energy (DE) content.

7.2.2 Animals and management

Nine hundred and forty four pigs (JSR hybrid - Duragilt x Yorker) were used in the trial comprising 144 pens of 6 pigs and 16 pens of 5 pigs (one pen of 5 pigs per treatment). Pigs were accommodated in conventional plastic slatted second stage flat deck pens. The accommodation comprised three similar rooms, each containing eight pens, four on each side of a central passageway. The pens measured 1.5 x 2.3m and each was fitted with a single space feeder at the front of the pen and two nipple drinkers at the rear of the pen. House temperature was thermostatically controlled. The temperature was set at 24°C at the start of the trial and reduced on a pre-set scale to 20°C by day 20.

The pigs started the trial at an average of 50 days of age (sd= 2.1) at a mean weight of 15.7 kg (sd = 1.92). Nine replicates of Riband, ten replicates of Buster and Haven and 11 replicates of Consort were placed on trial. Within each room piglets were allocated to pens on the basis of weight, sex, previous history and litter of origin. One pen within each room was randomly allocated to each of the four specific weights for two of the wheat varieties. The two wheat varieties compared at any one time were rotated so that each variety was fed in combination with each other variety during the course of the trial. The pigs were on treatment for 20 days.

Pigs were moved into the second stage flat deck accommodation 6 days before the trial started and the trial diet was gradually introduced during this period. Pigs were individually identified by ear tag were each weighed at the start and end of the trial period. Feed was supplied *ad libitum* throughout the trial. Total feed intake per pen was recorded over the trial period.

Faecal samples were taken from at least 4 animals in each pen on day 20 of the trial for replicates one to six. For each pen samples were bulked, thoroughly mixed and then frozen for subsequent analysis.

7.2.3 Analysis of diets and faeces

The wheat samples were analysed for crude protein, amino acid profile, NDF, non-starch polysaccharides (NSP, total and soluble), starch and GE. Hagberg falling number, thousand grain weight, in vitro viscosity, pour density and tap density were also recorded (see Chapter ???). The diets were analysed for DM, crude protein (N x 6.25), oil-B, ash, NDF, GE, titanium dioxide, phosphorus and calcium.

Faecal material was analysed for DM, ash, N, titanium dioxide and GE. Digestibility of DM, organic matter (OM), ash and N were calculated from the equation:

Digestibility = 100 - (100 x
%TiO2 in feed DM/%TiO2 in faeces DM x %X in faeces/%X in feed)

Digestible energy content of each diet was also calculated.

7.2.4 Statistics

Data were analysed using the REML procedure of Genstat to take account of variation between replicate and room. Wheat by relative specific weight were the main effects blocked by replicate and room. For growth parameters initial weight was used as a covariate. Regression analysis was also performed between various characteristics of the diets or the wheats themselves and the pig performance data to establish whether any characteristics of the wheat could be used to predict its nutritive value for grower pigs. In particular, because of the difference in specific weight between varieties, regression of pig performance parameters against specific weight both within and across varieties was performed.

7.3 Results

7.3.1 Diet composition

The chemical composition of each diet is given in Table 7.3. There was a difference in crude protein content between the diets with Riband 78 and Consort 71 having the lowest values at 24.3 and 23.6 %DM respectively. Riband 73 had the highest crude protein content at 26.9 %DM. However all diets contained more crude protein than had been allowed for in the diet formulation and therefore were not considered to be limiting in protein content. Diets were similar for all other measured parameters.

Table 7.3 Analysed composition of Grower Pig diets

Wheat variety	SW	DM %	CP %w/w DM	Ash %w/w DM	Oil -B %w/w DM	ND-fibre %w/w DM	P %w/w DM	Ca %w/w DM
Riband	**64**	88.3	26.4	7.0	5.0	15.6	1.03	1.27
	69	88.4	26.0	6.3	4.5	15.1	0.88	1.06
	73	88.2	26.9	6.2	4.5	12.8	0.94	1.13
	78	89.1	24.3	5.7	4.9	11.0	0.81	0.93
Buster	**71**	88.3	26.1	6.2	4.8	13.3	0.92	1.04
	73	87.8	26.0	6.1	4.4	13.1	0.92	1.05
	75	88.4	25.0	6.1	4.3	14.7	0.92	1.10
	78	88.5	25.0	6.2	4.5	13.6	0.92	1.07
Consort	**69**	88.6	25.2	6.0	4.5	15.5	0.93	1.05
	71	88.4	23.6	6.4	4.1	13.9	0.88	1.10
	73	87.9	24.7	6.0	4.0	14.9	0.84	1.01
	78	88.4	24.7	5.6	3.9	13.8	0.89	1.02
Haven	**60**	88.0	26.2	6.3	4.2	14.6	0.94	1.03
	66	88.3	25.7	6.0	4.2	13.7	0.87	1.00
	71	88.8	25.8	6.3	4.3	12.3	0.95	1.13
	76	88.5	25.5	6.2	4.2	13.0	0.89	1.04

7.3.2 Pig performance

Least square means for start weight, end weight, average daily gain, average daily feed intake and feed conversion ratio are shown in Tables 7.4 to 7.6. The effect of wheat variety is shown in Table 7.4, the effect of specific weight is shown in Table 7.5 and a comparison of all diets is shown in Table 7.6.

Effect of wheat variety

Pig growth rates and end of trial weights were not affected by wheat variety. Pigs grew from 15.7 kg (sd= 1.92) to 27.1 kg (sd =2.86) with an average growth rate of 567 g/day (sd=100.9).

Daily feed intakes were higher for Buster and Consort than for Haven (P= 0.021) with Riband intermediate in value. There were no significant differences between wheat varieties for FCR.

Table 7.4 Grower pig performance - wheat variety means

Wheat variety	Start weight (kg)	End weight (kg)	Average daily gain (g/pig/d)	Average daily FI (g/pig/d)	Feed conversion ratio
Buster	15.9	27.6	595	1019	1.74
Consort	15.9	27.1	572	1012	1.82
Haven	15.7	27.1	567	939	1.74
Riband	15.8	27.7	596	964	1.65
SED	*0.17*	*0.37*	*17.7*	*29.5*	*0.075*
	P=0.77	P=0.23	P=0.22	P=0.021	P=0.17
	N.S.	N.S.	N.S.	*	N.S.

Overall effect of relative specific weight

Relative specific weight had no effect on any aspect of pig performance.

Table 7.5 Grower pig performance - specific weight means

Relative specific weight		Start weight (kg)	End weight (kg)	Average daily gain (g/pig/d)	Average daily FI (g/pig/d)	Feed conversion ratio
High	**4**	15.9	27.5	587	982	1.74
	3	15.9	27.2	577	977	1.74
	2	15.7	27.3	581	988	1.73
Low	**1**	15.8	27.4	584	986	1.74
SED		*0.14*	*0.30*	*14.3*	*23.5*	*0.059*
		P=0.33	P=0.76	P=0.92	P=0.97	P=1.0
		N.S.	N.S.	N.S.	N.S.	N.S.

Effect of specific weight within variety

Growth performance

There were no differences in growth rate or end weight for specific weights within any of the four varieties. Overall the best growth performance occurred in pigs that had received Riband 64, these pigs averaged 624 g/pig/day to reach an end weight of 28.2kg. The worst growth performance occurred in pigs which had received Haven 60, these pigs averaged 529 g/pig/day to end the trial weighing 26.4 kg.

Feed intake and feed conversion ratio

There were no differences in feed intake or feed conversion ratio (FCR) for specific weights within variety for pigs which had received Buster or Riband. For Consort, pigs which received specific weight 78 tended to have eaten less than pigs which received specific weight 73 and had correspondingly better FCR; 1.69 versus 1.95, respectively (P=0.018). Pigs that received specific weights 71 and 69 had intermediate intakes and FCRs. For Haven, pigs which received specific weight 76, tended to have eaten more than pigs which received specific weight 71, 66 or 60. Specific weight 71 pigs had better FCR than pigs that had received specific weight 76 or 60 with 66 intermediate.

Overall the highest feed intake was recorded for pigs that had received Consort 73 and this corresponded to the worst FCR: 1070 g/pig/day and 1.95, respectively. The lowest feed intake was achieved by pigs receiving Haven 71 which corresponded with the best FCR: 887 g/pig/day and 1.51, respectively (P=0.018). The second best FCR was achieved by pigs with the highest growth rate ie Riband 64, with a FCR of 1.57.

Table 7.6 Grower pig performance - wheat by specific weight means

Wheat variety	SW	Start weight (kg)	End weight (kg)	Average daily gain (g/pig/d)	Average daily FI (g/pig/d)	Feed conversion ratio
Buster	**78**	16.2	27.8	594	1033	1.79
	75	15.9	27.4	582	986	1.71
	73	15.7	27.5	593	1025	1.76
	71	15.6	27.9	609	1032	1.70
Consort	**78**	15.9	27.4	584	958	1.69
	73	16.0	26.5	554	1070	1.95
	71	15.7	27.2	574	1011	1.82
	69	15.9	27.2	576	1008	1.82
Haven	**76**	15.8	27.3	578	1009	1.86
	71	15.7	28.0	607	887	1.51
	66	15.6	26.8	554	921	1.70
	60	15.7	26.4	529	939	1.86
Riband	**78**	15.6	27.6	592	930	1.62
	73	15.8	27.0	566	967	1.75
	69	15.7	27.8	604	996	1.66
	64	16.1	28.2	624	964	1.57
SED		0.29	0.62	30.0	49.6	0.13
		P=0.48	P=0.12	P=0.12	P=0.06	P=0.018
		N.S.	N.S.	N.S.	N.S.	*

Regression analysis with performance data

Regression analysis found no relationship between specific weight and any aspect of piglet performance, either across all diets (Figures 7.1 to 7.3) or within variety (Table 7.7).

Table 7.7 Adjusted R^2 values for regressions between specific weight and average daily gain (ADG), average daily feed intake (ADFI) or feed conversion ratio (FCR) within each wheat variety

Wheat variety	Adjusted R^2 (%)		
	ADG	ADFI	FCR
Buster	0.0	0.0	0.0
Consort	0.0	0.0	0.0
Haven	1.2	0.0	0.0
Riband	0.0	0.0	0.0

7.3.3 Digestibility and digestible energy

Least square means for digestibilities of DM, OM, ash, and N and DE are shown in Tables 7.8 to 7.10. The effect of wheat variety is shown in Table 7.8, the effect of specific weight is shown in Table 7.9 and a comparison of all diets is shown in Table 7.10.

Effect of wheat variety

DM digestibility

There was no difference in DM digestibility between any of the wheat varieties. DM digestibility averaged 84.5 % (sd = 2.37).

OM digestibility

There was no difference in OM digestibility between any of the wheat varieties. OM digestibility averaged 86.7 % (sd = 0.68).

N digestibility

There were no significant differences in N digestibility between varieties. Values ranged between 81.8 % for Riband and 78.8 % for Consort.

Ash digestibility

Ash digestibility of Haven was significantly lower than that of Consort ($P<0.05$), 49.3 versus 53.6 %, respectively, Buster and Riband were intermediate in value.

Digestible energy

Haven contained significantly more DE than any other wheat variety (P<0.001) at 16.2 MJ/kg DM.

Table 7.8 Digestibility and Digestible Energy of grower diets - wheat variety means

Wheat variety	Digestiblity (%) DM	OM	N	Ash	Digestible Energy (MJ/kg DM)
Buster	84.4	86.5	80.1	51.6	15.8
Consort	85.1	87.1	78.8	53.6	15.7
Haven	84.3	86.7	79.5	49.3	16.2
Riband	84.3	86.5	81.8	51.7	15.9
SED	*0.61*	*0.62*	*1.28*	*1.41*	*0.11*
	P=0.49	P=0.51	P=0.08	P=0.02	P<0.001
	N.S.	N.S.	N.S.	*	***

Overall effect of relative specific weight

DM digestibility

There was no difference in DM digestibility between any of the relative specific weights.

OM digestibility

OM digestibility was lower for the lowest specific weight than for the higher specific weights (P<0.05).

N digestibility

The second from lowest ranked specific weight had the highest N digestibility whilst the lowest had the lowest N digestibility (P<0.001).

Ash digestibility

Ash digestibility was highest for the lowest relative specific weight and lowest for the second highest 52.8 versus 50.1 %, respectively (P<0.05).

Digestible energy

The highest specific weight had significantly lower DE in DM than the second highest specific weight (P<0.05). There were no other differences.

Table 7.9 Digestibility and Digestible Energy of grower diets - specific weight means

Relative Specific weight		Digestiblity (%) DM	OM	N	Ash	Digestible Energy (MJ/kg DM)
High	**4**	84.9	87.1	79.5	51.8	15.8
	3	84.9	87.3	80.2	50.1	16.0
	2	84.4	86.6	81.7	51.5	15.9
Low	**1**	83.8	85.9	78.8	52.8	15.9
SED		*0.56*	*0.57*	*1.18*	*1.23*	*0.10*
		P=0.13	N.S.	P=0.08	P=0.168	P=0.574
		N.S.				

Effect of specific weight within variety

DM digestibility

There was no difference in DM digestibility between specific weights for Haven or Riband. For Buster DM digestibility at 78 was higher than at 73 with 71 and 75 intermediate (P<0.05). For Consort DM digestibility at 78 was lower than that at 73 (P<0.05), 71 and 69 were intermediate.

OM digestibility

There was no difference in OM digestibility between specific weights for Haven or Riband. For Buster OM digestibility at 78 was higher than at 73 with 71 and 75 intermediate (P<0.05). For Consort OM digestibility at 78 was lower than that at 73 (P<0.05), 71 and 69 were intermediate.

N digestibility

There was no difference in N digestibility between specific weights for Buster. For Consort, N digestibilities of 78 and 69 were lower than those of 73 and 71 (P<0.05). For Haven, 66 had the highest digestibility at 83.9 %, followed by 76 at 79.6 % (P<0.05) with 71 and 60 significantly lower than both of these (P<0.001 and P<0.05, respectively). For Riband, 64 had the highest N digestibility and 69 the lowest (P<0.001) with 73 and 78 intermediate in value.

Ash digestibility

There was no difference in ash digestibility between specific weights for Buster, Consort or Haven. Ash digestibility of Riband was significantly higher for 64 and 69 than for 73 and 78 ($P<0.05$).

Digestible energy

There was no difference in DE in DM for Haven. The other three varieties all had significant differences in DE between specific weights ($P<0.001$). For Buster, 71 and 78 produced higher DE values than 73 and 75; for Consort, 73 was highest followed by 71 and 78 was lowest, 69 was intermediate between 71 and 78; for Riband, 69 was higher than 78 or 64 with 73 intermediate.

Table 7.10 Digestibility and Digestible Energy of grower diets - means by wheat and specific weight

Wheat Variety	SW	Digestiblity (%) DM	OM	N	Ash	Digestible Energy (MJ/kg DM)
Buster	**78**	85.8	87.9	79.8	53.2	15.9
	75	84.3	86.7	80.1	49.6	15.5
	73	83.3	85.5	80.6	50.3	15.5
	71	84.0	86.1	80.1	53.2	16.1
Consort	**78**	83.8	85.8	75.3	53.1	15.3
	73	86.3	88.4	82.5	54.1	16.1
	71	85.7	87.9	82.4	51.8	15.7
	69	84.5	86.4	75.2	55.5	15.6
Haven	**76**	84.9	87.2	80.3	50.9	16.3
	71	84.2	86.5	77.3	49.8	16.2
	66	85.1	87.6	84.5	49.6	16.3
	60	82.9	85.5	75.7	47.0	16.2
Riband	**78**	85.2	87.5	82.8	50.0	15.8
	73	84.9	87.4	81.0	46.8	16.0
	69	83.5	85.5	79.3	54.5	16.2
	64	83.6	85.7	84.1	55.6	15.7
SED		*1.14*	*1.16*	*2.40*	*2.53*	*0.20*
		P=0.12	P<0.05	P<0.001	P=0.016	P<0.001
		N.S.		***	*	

Digestibility parameters and pig performance

There was a significant but extremely weak negative correlation (R^2 =0.056, P=0.02) between DE and specific weight (see Figure 7.4). There was no correlation between any digestibility measurement and specific weight, although there was a trend for DM digestibility to show a weak and non-meaningful regression (R^2 =0.036, P=0.063).

There was no correlation between any of the digestibility values, including DE, and any aspect of pig performance. Even parameters that varied significantly between diets, such as DE and N digestibility, were not correlated with performance. Adjusted R^2 values for correlations between DE, CP and N digestibility and performance characteristics are shown in Table 7.11.

Table 7.11 Adjusted R^2 values for regressions between DE, CP or N digestibility and average daily gain (ADG), average daily feed intake (ADFI) or feed conversion ratio (FCR) across all diets.

	Adjusted R^2 (%)		
	ADG	**ADFI**	**FCR**
CP	0.0	0.0	0.0
DE	0.0	1.6	1.6
N digestibility	0.0	0.0	0.0

Wheat characteristics and pig performance

There were no correlations between any measured wheat characteristics and pig performance.

7.4 Discussion

7.4.1 Specific weight as a predictor of nutritional value of wheat in pigs

The main aim of this experiment was to assess whether specific weight can be considered a reliable measure of nutritional value of wheat. With this end in view four varieties of wheat were tested, each at four different bushel weights. If specific weight were an indicator of nutritional value there should be a decline in at least some aspect of pig performance with declining specific weight of wheat in the diet. It is clear from the results that such a decline was not demonstrated. There were no differences in pig performance as specific weight declined across wheat varieties (Table 7.5 and Figures 7.1 to 7.3).

A second hypothesis is that specific weight only becomes an indicator of limiting nutritional value below a particular point which should be 72 kg/hl since this is the industry standard below which a price penalty is applied. For all varieties studied here we had samples both below and above 72 kg/hl and it is apparent from the results that there is no sudden decline in performance when wheat specific weight falls below this value. In practice the feed industry will still purchase wheat for use as first grade feed wheat down to values of 68 kg/hl (Miller and Wilkinson, 1998). Unfortunately only two wheat samples fell below this value in the present experiment, Riband 64 and Haven 60. Nevertheless these comprise half of the observations within the lowest relative specific weight category and have not caused reduced pig performance. When these two samples are compared to the whole data set (Table 7.6) it is apparent that Riband 64 has the best overall performance (+57 g/pig/day above the overall average) whilst Haven 60 has the worst (-38 g/pig/day below the overall average)! Whilst it might be tempting to assume that Haven 60 produced the worst performance because it has the lowest specific weight this cannot be supported by the data set as a whole. Such emphasis on one individual value could equally inappropriately be placed on the excellent Riband 64 result and a conclusion drawn that low specific weight wheat has higher nutritional value! Both conclusions would be equally wrong. It is clear that there is substantial variation in the nutritional value of individual wheats for growing pigs which is not related to specific weight. This is further demonstrated by the failure to develop any meaningful regression equations between specific weight and any aspect of pig performance (Table 7.7, Figures 7.1 to 7.3). This data supports that of Miller *et al*. (2000 and 2001) who fed known varieties varying in specific weight between 66 and 72.5 kg/hl (Miller *et al*. 2000) and between 64 and 78 kg/hl (Miller *et al*. 2001) to weaned piglets and found no difference in performance. Likewise, Stewart *et al*. (1997) found no difference in performance when pigs between 30 and 74 kg were fed diets containing wheats with specific weights between 60 and 72 kg/hl. Unfortunately variety was not considered in their experiment.

Relative specific weight of wheat did affect DE and some aspects of diet digestibility, but with the exception of OM digestibility these were not sequentially related to changes in specific weight (Table 7.9). When DE and digestibility were compared across specific weights within variety, a number of significant differences were observed but again these were largely irrelevant of sequential specific weight (Table 7.10). This is further demonstrated by the inability to generate any sensible regression relationships between specific weight and DE or digestibility (Table 7.11). Relative uniformity in DE value has been recognised by other authors (Wiseman et al. 1979, Fuller et al. 1989 and Wiseman 2000). Although it has been suggested by Hickling (1994) that

differences in energy value may only become apparent at specific weights below 60 kg/hl, which lie beyond the scope of this study.

It is interesting to note that both N and ash digestibilities are highest for Riband 64 and lowest for Haven 60 in parallel with their respective growth performances.

7.4.2 Variety as a predictor of nutritional value of wheat in pigs

The main aim of this trial was to assess the value of wheat specific weight. The value of wheat variety as an indicator of the nutritional value of wheat was only of secondary interest. However, one of the varieties tested was Buster which was developed specifically as a feed wheat and it is therefore interesting to note how Buster performed compared to the other wheat varieties tested.

It is clear from the results that there was no significant improvement in any aspect of pig performance as a result of feeding Buster. Likewise digestibility and DE value were not significantly better for Buster than for any other wheat variety tested here. Buster should not therefore be regarded as a superior variety of feed wheat for pigs up to 30 kg liveweight. This conclusion is supported by the work of Miller *et al*. (2000) who found no improvement in performance when weaned piglets were fed Buster in comparison to Riband.

7.4.3. Wheat characteristics as predictors of nutritional value of wheat in pigs

Unfortunately there was no correlation between any wheat characteristic described in Chapter 2 and pig performance so that although specific weight was not a good indicator of nutritive value, no better alternative was indicated by this work.

7.5 Conclusions

- **Specific weight did not indicate nutritive value of wheat in this experiment.**
- **No reliable indicator of nutritive value was identified.**
- **Buster was no better feed wheat than the other three varieties.**

CHAPTER 8

EFFECT OF SPECIFIC WEIGHT ON ENERGY VALUE OF WINTER WHEAT GRAIN TO SHEEP

8.1 Executive summary

Sixteen samples of winter wheat grain, comprising four cultivars (Riband, Buster, Consort and Haven each at four specific weights ranging from 60 to 78 kg/hl were given in a pelleted concentrate (wheat = 0.69 of total) to housed mature sheep at 0.6 of total daily dry matter (DM) intake. Chopped winter wheat straw comprised 0.4 of total daily DM intake.

There was no overall effect of specific weight on digestibility of whole diet DM or on whole diet metabolisable energy (ME) value. With regard to the main effect of cultivar, values for digestibility were lower ($P<0.05$) for Buster and Consort than for Riband and Haven. Values for ME were also lower ($P<0.05$) for Buster than for Riband and Haven.

It is concluded that there is considerable flexibility in the use of winter wheat of different specific weights in diets for ruminants.

8.2 Materials and methods

8.2.1 Feeds

16 samples of winter wheat comprising four cultivars (Riband, Buster, Consort, Haven), each of four different specific weights (Tables 8.1 and 8.2), were processed at the experimental feed mill at the Roslin Institute into ground pellets according to the formulation shown in Table 8.3.

Table 8.1 Cultivars and specific weights of the 16 samples of winter wheat used in the Leeds HGCA sheep digestibility experiment

Cultivar	Endosperm	Cultivar code	Specific Weight Code			
			1	2	3	4
			Specific weight[1] (kg/hl)			
Riband	Soft	A	64	69	73	78
Buster	Hard	B	67	71	73	78
Consort	Soft	C	69	71	73	78
Haven	Hard	D	60	66	71	76

[1]Determined by the University of Leeds laboratory.

The varietal purity of each sample of wheat was confirmed by electrophoresis at the National Institute of Agricultural Botany, Cambridge. The origin of the wheat samples (Table 8.2) shows that three samples were prepared by gravity separation. Six samples were obtained from the 1999 harvest and ten from the 1998 harvest.

The formulation of the concentrates is shown in Table 8.3. Titanium dioxide (TiO_2) was added to all diets at 3 g/kg fresh weight a marker for the estimation of faecal output. The proportion of wheat in the total concentrate dry matter (DM) was fixed at 686g/kg fresh weight, thus there were small differences between the 16 feeds in the total crude protein (Table 8.4), With the exception of Consort, the lower concentrations of crude protein in the concentrates were generally associated with wheats of higher specific weight. The estimated metabolisable energy concentration of the concentrate was 12.9 MJ/kg DM (MAFF, 1992).

Table 8.2 Origin of each wheat sample

Cultivar	Specific weight	Bag No. /bulk	Sample No.	Year of harvest	Origin
RIBAND	64	Bulk	79	1999	J D Martin Ltd
	69	Bagged from bulk	55	1998	KW (Swiers)
	73	Bulk	58	1998	KW (Wright)
	78	Bulk	82	1999	J D Martin Ltd
BUSTER	67	41 + 42	41	1998	Wells
	71	35 + 36	35	1998	Ezard
	73	75 + 76	75	1998	Jackson
	78	Bagged, no number	84	1999	Pears
CONSORT	69	Bagged, no number	80	1998	Roslin
	71	Bagged, no number	87	1999	J D Martin Ltd (gravity separation)
	73	45 + 46	45	1998	Hardwick
	78	Bagged, no number	81	1999	J D Martin Ltd
HAVEN	60	47 + 48	47	1998	Sluggate
	66	52 + 53	52	1998	Sluggate
	71	Bagged, no number	88	1999	J D Martin Ltd (gravity separation)
	76	Bagged, no number	89	1999	J D Martin Ltd (gravity separation)

Table 8.3 Formulation of the 16 pelleted ground wheat concentrates used in the Leeds HGCA sheep digestibility experiment

Ingredient	**g/kg fresh weight**
Wheat	686.4
Molassed sugar beet pulp	175
Hipro soyabean meal	100
Minerals	34.5
Titanium dioxide (marker)	3.0
Amino acids	1.6
Total	**1000.5**

Table 8.4 Crude protein[1] concentration of the 16 pelleted ground wheat concentrates used in the Leeds HGCA sheep digestibility experiment

Cultivar	**Specific Weight Code (Table 8.1)**			
	1 (lowest)	2	3	4 (highest)
	Crude protein (g/kg fresh weight)			
Riband	146.0	140.5	139.5	128.0
Buster	147.0	140.0	140.0	134.0
Consort	131.0	134.0	129.0	136.0
Haven	144.0	141.0	140.0	136.0

[1] Determined at the Roslin Institute laboratory

8.2.2. Animals

Fourteen mule (Blue-faced Leicester x Swaledale) ewes, approximately four years old were selected from the University of Leeds flock on 19 July 2000 on the basis of their live weight (target 70 kg). The flock had been sheared 35 days previously. The sheep were immediately transported to the Large Metabolism House at Spen Farm. On the day of transfer, each animal was examined visually to ensure that it was not lame or lacking in teeth and dosed with an anthelmintic drench (Panacur, Hoechst Roussel Vet Ltd).

Two sheep were housed in a room adjacent to the Large Metabolism House as potential replacements, if required, during the course of the experiment. These replacement sheep were given a diet of 700 g daily of high-temperature dried grass pellets and bedded on winter wheat straw.

The live weight of each sheep was determined at weekly intervals throughout the experiment.

8.2.3 Housing

The sheep were installed in twelve individual pens (average size 4.5 m^2) comprising steel gates mounted on rubber mats. The pens were bedded with "Drybed" (Fosse Ltd, Whetstone Magna, Lutterworth Road, Whetstone, Leics LE8 6NB), an inert high absorbency material manufactured from re-processed newspaper. The bedding was added to each pen daily to ensure that each pen remained relatively dry throughout the experiment. The material was unpalatable to the animals and was not observed being eaten at any stage during the experiment. Wet material was removed daily.

Each pen was equipped with containers to hold the pelleted concentrate, chopped winter wheat straw (chopped to 60 mm average particle length by a mechanical straw chopper), and water which was offered *ad libitum* in polythene buckets which were replenished twice daily.

The sheep remained in the same pens throughout the experiment.

8.2.4 Experimental design

The design of the experiment was balanced incomplete Latin Square with four periods and three replications of each individual diet (Table 8.5).

Table 8.5 Design of the Leeds HGCA sheep digestibility experiment

Sheep No.	1	2	3	4	5	6	7	8	9	10	11	12
Period						Diet						
1	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
(Roslin	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Diet No.)												
2	B3	B1	B4	B2	D4	D3	D1	D2	A4	A3	A1	A2
(Roslin					(16)	(15)	(13)	(14)				
Diet No.)												
3	C4	C3	C2	C1	A2	A1	A4	A3	D2	D1	D4	D3
4	D2	D4	D1	D3	C3	C4	C2	C1	B3	B4	B2	B1

Cultivar: A= Riband, B= Buster, C=Consort, D = Haven
Specific weight rank: 1=Lowest specific weight, 4 = highest (Table 8.1)

8.2.5 Procedures

The sheep were given an 11-day pre-experimental acclimatisation period, during which time their diet was gradually changed from one of dried grass to one of concentrate and chopped straw (Table 8.6). Dried grass was reduced and concentrate was increased daily in increments of 100g per head per day, up to a maximum of 700 g per head per day. Chopped straw was offered *ad libitum* during this acclimatisation period, and the amount eaten increased steadily during this period from 150 g per head per day to 700 g per head per day.

Each experimental period (Table 8.5) was of 14 days duration, with two sub-periods. The first sub-period was of 9 days and was an adjustment period to the new wheat diet. The second sub-period

was of 5 days, during which faeces samples were taken daily from each animal at 09.30h. Data for intake of concentrate and straw for the second sub-period of each period were used to calculate digestibility and metabolisable energy values for each diet.

The dates of each complete period are shown in Table 8.6.

Table 8.6 Dates of each complete period of the Leeds HGCA sheep digestibility experiment

Period	Date
1	28 July to 10 August 2000
2	11 August to 24 August 2000
3	25 August to 7 September 2000
4	8 September to 21 September 2000

Each diet was given to the sheep once daily at 09.00 h at a restricted level designed to maintain the live weight of the sheep during the experiment. The daily quantity of pelleted concentrate was calculated to be 700 g fresh weight per head per day, based on an estimated requirement of 7.75 MJ metabolisable energy (ME)/day for the maintenance of mature, non-pregnant sheep weighing 70 kg live weight (AFRC, 1993). The daily quantity of straw offered was calculated to be slightly less than that consumed when offered *ad libitum*, so that the amount refused the following morning was minimal.

Samples of each concentrate feed were taken daily and bulked for each 5-day sub-period during which the faeces samples were being taken, for subsequent analysis. One sample of straw was taken during each period for analysis.

Water was offered *ad libitum* and the water buckets were re-filled daily to ensure that a clean supply of water was available at all times.

Faeces were sampled *per rectum* from each sheep at 07.30 h daily on the 5 final days of each period. On the few occasions when it proved impossible to obtain a sample at the appointed hour, a sample was obtained when the sheep were checked the following afternoon (at 15.30 h). If a defaecation was observed during or after feeding, a sample was obtained immediately from the pen

floor. Daily samples were frozen immediately after collection and bulked over the five-day collection period for subsequent analysis. Two samples of bedding were also taken for analysis.

The sheep were weighed each Friday (i.e. on the middle and final day of each period) using a portable weigh crush placed at one corner of the room at 08.30 h, i.e. before being fed. Each sheep was led in turn from its pen to the crush, weighed and then returned to its pen immediately.

8.2.6 Analyses of samples

Samples of feed and faeces were analysed for dry matter (DM) by oven drying, for TiO_2 (by a method supplied by the Roslin Institute) and for gross energy by adiabatic bomb calorimetry.

8.2.7 Statistical analyses

The data for intake of concentrate DM, straw DM, digestibility of whole diet DM and whole diet metabolisable energy (ME) value were analysed using a linear mixed model (Genstat 5 Release 3.1) using Restricted Estimate Maximum Likelihood (REML) to allow for the unbalanced nature of the design. The blocking factors, sheep and period with their interaction, were considered as random effects, and the treatment factors, cultivar and ranked specific weight and their interaction as fixed effects.

8.3 Results

8.3.1 Animal health

The health of all the animals except one remained good throughout the experiment. One sheep (in pen 3) died suddenly on 30 August. Post-mortem examination revealed no apparent cause of death other than the observation that the pH of the rumen contents was relatively low at 4.5, indicating possible ruminal lactic acidosis (Ryan, 1964). This condition could have created stasis of the rumen, failure to eructate the gases produced by the fermentation, bloat and death as a result of heart failure.

The feeding of the ground and pelleted wheat in a single daily feed was recognised as a potential health risk, especially as the animals were given the concentrate at a restricted level. However, it was evident at the outset that the sheep normally took several hours to consume the concentrate. The level of intake of chopped straw was considered to be adequate to promote sufficient rumination and associated secretion of salivary bicarbonate to buffer the accumulation of acids in the rumen. The sheep which died had consumed an average of 426 g of straw per day over the 5

days prior to its death (range 404 g to 441 g per day), which was relatively constant and close to the mean for the whole group (473 s.d.93.4 g fresh weight per day).

There were no further cases of acidosis and the feeding protocol remained unchanged for the remainder of the experiment.

One of the two spare sheep was immediately used to replace the dead sheep in pen 3, and it completed Period 3 when the rest of the sheep were on Period 4, and completed its own Period 4 between 22 September and 5 October 2000.

8.3.2 Live weight

The live weight of each sheep at each weighing is shown in Table 8.7. The mean initial weight of the group on 3 August was 66.7 kg (s.d.3.71 kg) and the mean final live weight on 22 September was 68.4 kg (s.d. 3.73 kg). It is evident that the diet was a maintenance diet since there was very little change in the weight of the sheep as the experiment progressed.

Table 8.7 Live weight of each sheep at each weighing

Date / **Sheep**	**3 Aug**	**7 Aug**	**11 Aug**	**21 Aug**	**25 Aug**	**4 Sept**	**8 Sept**	**17 Sept**	**22 Sept**
1	69	68	68	69	71	71	69	69	69.5
2	67	69	67	67	69	71.5	71	70	69
3	67	65	67	69	71	71	New	70	67.5
4	65	66.5	67.5	65	68	67	65.5	66	65
5	57	60.5	61	59	62	62.5	61.5	62.5	62
6	68.5	70	70.5	68	72	71	72	72	69
7	71.5	74.5	74	72.5	77.5	75	75	75	75.5
8	65.5	68.5	67	63	67.5	67	66.5	68	66.5
9	66	67	69	65.5	72	70	69	70	68.5
10	69	68	67	66.5	72	70	69.5	72.5	74
11	70	70.5	72	71	73	71.5	71	72	69.5
12	64.5	65	64	63	66.5	65	68.5	66	65
Mean	**66.7**	**67.7**	**67.8**	**66.5**	**70.1**	**69.4**	**69.0**	**69.4**	**68.4**
s.d.	3.71	3.44	3.41	3.76	3.89	3.40	3.58	3.42	3.73

8.3.3 Food intake

The sheep usually consumed their daily allowance of 700 g of concentrate fresh weight completely, with the exception of three sheep in Period 1, which rejected some of their daily allowance. These sheep were receiving the Buster diet at the highest specific weight (Rank 4), and Consort at the two lowest specific weights (Ranks 1 and 2, Table 8.8). Voluntary intake of wheat straw was variable since this feed was offered *ad libitum*.

Mean intakes of concentrate dry matter (DM) are shown in Table 8.8. There were no significant effects of specific weight or of cultivar on intake of concentrate DM. However, a trend of decreasing intake of concentrate DM with increasing specific weight was apparent in the case of Buster.

Mean intakes of straw DM (offered *ad libitum*) are in Table 8.9. There were no significant effects of specific weight or of cultivar on intake of straw DM.

The mean intakes of concentrate and straw DM were 607 g and 426 g per head per day, respectively. Thus the mean concentrate DM intake was 0.59 of total DM intake.

Table 8.8 Mean intake of concentrate DM, g/day (n=3)

		Relative specific weight					
		Low	**Quite Low**	**Quite High**	**High**	**Mean**	**s.e.d.**
Cultivar	**Buster**	618.7	616.9	582.9	528.7	586.8	18.72 (NS)
	Consort	620.0	560.6	620.0	622.3	605.7	
	Haven	612.9	613.6	612.2	612.9	612.9	
	Riband	622.6	622.3	619.5	620.8	621.3	
	Mean	**618.6**	**603.4**	**608.7**	**596.2**	**606.7**	
	s.e.d.	18.08 (NS)					

The s.e.d. for comparison of within-table means = 36.39 (NS).

Table 8.9 Mean intake of straw DM, g/day (n=3)

		Relative specific weight					
		Low	**Quite Low**	**Quite High**	**High**	**Mean**	**s.e.d.**
Cultivar	**Buster**	453.3	395.6	368.0	511.8	**432.2**	23.61 (NS)
	Consort	439.0	465.5	427.2	359.4	**422.8**	
	Haven	425.5	448.6	369.2	373.8	**404.3**	
	Riband	360.6	468.9	505.8	441.8	**444.3**	
	Mean	**419.6**	**444.7**	**417.6**	**421.7**		
	s.e.d.	22.37 (NS)					

The s.e.d. for comparison of within-table means = 54.56 (NS).

8.3.4 Digestibility of whole diet

The pelleted concentrate diet contained titanium dioxide (TiO_2), added as an indigestible marker for the assessment of faecal output from the daily grab samples. The samples of straw and of faeces were also analysed for TiO_2, and total diet digestibility was calculated as:

Digestibility of whole diet DM = 1 – (TiO_2 (g/kg) in feed DM/TiO_2 (g/kg) in faeces DM).

Treatment means for whole diet digestibility of DM are in Table 8.10. There were no differences in digestibility due to specific weight, but there were significant ($P<0.05$) main effects of cultivar. Thus digestibility was lower for Buster and Consort than for Riband and Haven.

Table 8.10 Mean digestibility (g/kg) of whole diet DM (n=3)

		Relative specific weight					
		Low	**Quite Low**	**Quite High**	**High**	**Mean**	**s.e.d.**
Cultivar	**Buster**	751	758	718	685	**725**[a]	18.09 (P<0.05)
	Consort	742	691	729	739	**723**[a]	
	Haven	767	766	773	779	**772**[b]	
	Riband	767	766	773	779	**781**[b]	
	Mean	**752**	**743**	**758**	**748**	**750**	
	s.e.d.	17.27 (NS)					

Means with different superscripts are different (P<0.05). The s.e.d. for comparison of within-table means = 35.15 (NS).

8.3.5. Estimated metabolisable energy (ME, MJ/kg DM) of the whole diet

Table 8.11 Mean ME concentration (MJ/kg DM) of whole diet DM (n=3)

		Relative specific weight					
		Low	**Quite Low**	**Quite High**	**High**	**Mean**	**s.e.d.**
Cultivar	**Buster**	10.88[ab]	10.51[ab]	10.11[ab]	9.94[b]	**10.36**[b]	0.236 (P<0.05)
	Consort	10.95[ab]	10.11[ab]	11.01[ab]	10.86[ab]	**10.73**[bc]	
	Haven	10.31[ab]	11.65[a]	12.00[a]	11.87[a]	**11.46**[a]	
	Riband	11.09[ab]	11.01[ab]	11.42[a]	11.17[ab]	**11.17**[ac]	
	Mean	**10.81**	**10.82**	**11.14**	**10.96**	**10.93**	
	s.e.d.	0.226 (NS)					

Means with different superscripts are different (P<0.05). The s.e.d. for comparison of within-table means = 0.460 (P<0.05)

Knowing the gross energy concentrations of concentrate, straw and faeces samples, and knowing total DM intake and total faecal DM output, it was possible to calculate the digestibility of the gross energy in the whole diet dry matter (DE, MJ/kg DM) and hence the metabolisable energy concentration of the whole diet (MJ/kg DM), using the following equation (Equation 1, MAFF, 1975):

ME (MJ/kg DM = 0.81DE (MJ/kg DM)

Treatment means for estimated ME concentration of the whole diet are in Table 8.11. As with digestibility of DM, there was no effect of specific weight on ME value. The ME values for Haven and Riband were higher ($P<0.05$) than those for Buster and Consort. Comparing individual treatment means, the ME value of Buster at the highest specific weight rank (4) was lower ($P<0.05$) than that of Haven at specific weight ranks 2, 3 and 4, and also lower than that of Riband at specific weight rank 3. The trend of reducing ME value with increasing specific weight in Buster reflected the similar trend of reducing concentrate DM intake (Table 8.8).

8.4 Discussion

The sheep were given 700g of concentrate fresh weight at the maintenance level of feeding (Table 8.7) in a single daily feed. The maintenance level of feeding is the standard method for assessing digestibility and energy value of feeds in ruminants since it avoids the confounding effect of level of nutrition on digestibility (Blaxter, 1962).

Chopped wheat straw was offered *ad libitum* in an attempt to ensure that the consumption of a single daily meal of rapidly digested concentrate did not cause acute acidosis in the animals. In the event, one animal died during the experiment, presumed to have succumbed to acidosis. It was noticeable that the concentrate pellets were dusty and that they collapsed readily on compression, indicating that they were most likely digested rapidly after being eaten. It was also noted that there was variability between sheep in the speed with which the concentrate pellets were consumed, with some individuals occasionally showing some reluctance to eat the diets.

On average, the concentrate comprised 0.59 of the total DM intake. Since the proportion of wheat in the concentrate was 0.686 (Table 8.3), the proportion of wheat in the total diet was only 0.4. Hence any differences between wheats of different specific weights in digestibility and metabolisable energy value would have had to be very large for an effect to be evident in the whole diet.

An attempt was made to assess the digestibility of the concentrate part of the diet, by using a value for the digestibility of the straw determined *in vitro* by neutral cellulase digestion. Unfortunately this approach was unsuccessful because it generated some negative values for digestibility of the concentrate.

The values for estimated ME in Table 8.11 were generally in line with expected values. Assuming average values of 12.9, 13.7 and 6.0 MJ ME/kg DM for the concentrate, winter wheat grain and straw, respectively (MAFF, 1992), then the predicted ME of the whole diet was 10.06 MJ/kg DM, compared to the overall mean value of 10.93 in Table 8.11.

Titanium dioxide was used as a marker for estimating faeces output, which is considered to be a relatively reliable technique for use in digestibility studies with ruminants, since its recovery is very high and it is not specifically associated with either the solid or the liquid phases of the digesta (see review by Mayes and Dove, 2000). However, incomplete recovery of TiO_2 would result in an under-estimation of total faecal output and an over-estimation of digestibility and ME concentration.

8.5 Conclusions

There was no overall effect of grain specific weight (range 60 to 78 kg/hl) of 16 samples of four cultivars of winter wheat on the energy value of the whole diet (60:40 concentrate:straw) when given to mature sheep at the maintenance level of feeding.

With regard to the main effect of cultivar, values for digestibility of whole-diet DM were lower ($P<0.05$) for Buster and Consort than for Riband and Haven. Values for whole-diet ME were lower ($P<0.05$) for Buster than for Riband and Haven. The relatively low values for Buster at 78 kg/hl probably reflected reduced intake of concentrate DM in the first period of the experiment.

8.6 Implications for levy-payers

There appears to be flexibility over a wide range of specific weight with regard to the inclusion of home-grown winter wheat grain in concentrate diets for ruminants.

8.7 Acknowledgements

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