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# LACK OF RELATIONSHIP BETWEEN EITHER SPECIFIC WEIGHT OR PRESENCE OF THE 1B1R GENE AND NUTRITIVE VALUE OF WHEAT IN BROILER DIETS

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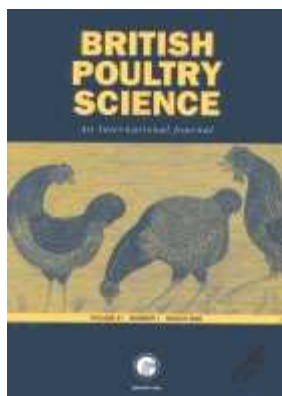
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**LACK OF RELATIONSHIP BETWEEN EITHER SPECIFIC WEIGHT OR PRESENCE OF THE 1B1R GENE AND NUTRITIVE VALUE OF WHEAT IN BROILER DIETS**

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3 **LACK OF RELATIONSHIP BETWEEN EITHER SPECIFIC WEIGHT OR PRESENCE**  
4 **OF THE 1B1R GENE AND NUTRITIVE VALUE OF WHEAT IN BROILER DIETS**  
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7  
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30 **Short title**                              **Low specific weight wheat for broilers**  
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## Abstract

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1. A study of the relationship between specific weight and nutritive value of wheat in diets offered to broilers up to 4 weeks of age was carried out using 10 varieties of wheat grown at 3 different locations; this gave rise to a range of specific weight from 59 to 76 kg/hl.

2. Because five varieties contained the 1B1R translocation and 5 did not, this allowed the effects of 1B1R on the performance of birds given high concentrations of dietary wheat to be further investigated.

3. The diets, which contained wheat at 744 g/kg with casein (142 g/kg) as the sole protein supplement, were heat-treated and pelleted. They were fed *ad libitum* to male, Ross broiler chicks from 7 to 28 d, in individual cages in a controlled environment room.

4. A 7d excreta collection was made from 14-21d for determination of apparent metabolisable energy (AME) content and wheat AME was calculated from the diet values. A separate determination of true metabolisable energy (TME) was undertaken using the method of McNab and Blair (1988).

5. Wheat samples were analysed for proximate constituents, starch, total and soluble non-starch polysaccharides (NSP), amino acid content and gross energy and specific weight, thousand grain weight and *in vitro* viscosity were recorded. They were also subjected to near infrared reflectance spectroscopy (NIRS) with a view to establishing relationships with chemical constituents and performance parameters.

6. At 28 d the birds were humanely killed and *in vivo* viscosity was determined on the jejunal digesta supernatant.

7. There was quite a narrow range of crude protein content (Nx5.83) across the 30 wheat samples, the means for the three locations (Crossnacreevy, Downpatrick, Limavady respectively) being

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3 112, 121, 122 g/kg. Starch contents of individual samples ranged from 604 to 679 g/kg, total NSP  
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5 from 92.1 to 122.6 g/kg, soluble NSP from 17.6 to 32.6 g/kg and *in vitro* viscosity from 10.6 to  
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7 26.3 cps.  
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9  
10 8. There were no significant varietal effects for dry matter intake (DMI), liveweight gain (LWG)  
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12 or gain:feed ratio. Apparent metabolisability of energy (ME:GE) for the diets ranged from 0.738  
13  
14 (Hussar) to 0.778 (Harrier) the effect being significant ( $P < 0.05$ ) and there was a significant  
15  
16 ( $P < 0.001$ ) relationship ( $r^2 = 0.46$ ) between ME:GE and gain:feed ratios. Calculated wheat AME  
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18 for individual varieties ranged from 14.1 to 15.0 MJ/kg DM ( $P > 0.05$ ). TME values ranged from  
19  
20 16.3 to 16.6 MJ/kg DM (NS).  
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23  
24 9. *In vivo* viscosity ranged from 12.3 (Ritmo) to 23.7 cps (Hussar), the varietal effects being  
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26 significant ( $P < 0.001$ ). Viscosity was significantly higher for the IBIR varieties than for the non-  
27  
28 IBIR (22.7 vs 16.3 cps) but there were no significant effects on mean DM intake, LWG, gain:feed,  
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30 ME:GE, calculated wheat AME, ME:gain (MJ AME per kg gain) or TME.  
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34 10. Wheat AME was negatively correlated ( $p < 0.05$ ) with total NSP (slope -0.035) but was  
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36 significantly affected by variety, constants ranging from 16.74 to 17.79. For wheat TME there  
37  
38 were significant variety\* total NSP interactions with slopes ranging from 0.29 to -0.07. There was  
39  
40 no significant relationship between wheat AME and soluble NSP and there were significant  
41  
42 variety\* soluble NSP interactions for TME with slopes ranging from 0.09 to -0.14.  
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46 11. Despite the relatively wide range of *in vitro* viscosity there was no significant correlation of  
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48 either calculated wheat AME or wheat TME with *in vitro* viscosity. For TME there were  
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50 significant variety\* viscosity interactions with slopes ranging from 0.21 to -0.13 ( $P < 0.001$ ). There  
51  
52 was also no significant correlation between soluble NSP and *in vivo* viscosity.  
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56 12. AME values for the NIRS calibration set varied from 13.7 to 15.6 MJ/kg and averaged 14.6  
57  
58 MJ/kg, whereas for the validation set, the values ranged from 14.0 to 16.1 MJ/kg with the mean  
59  
60 value being 14.7 MJ/kg. The best correlation coefficient ( $r^2$ ) of 0.90 was obtained when the

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3 calibration sample set was subjected to SMLR using the second order derivatized data. However,  
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5 moving to validation, the outcome was extremely poor with 1-VR values being 0.12 and 0.09  
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7 respectively for the external validation and an internal validation subset.  
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11 13. In summary, none of the production characteristics showed a good correlation with specific  
12  
13 weight. Using the linear estimates for wheat AME and TME the effect of a 10 kg/hl change in SW  
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15 equates to a 3 or 1.4 per cent change respectively. The estimate for AME is likely to be a worst-  
16  
17 case value due to the high inclusion level of wheat. The range of calculated wheat AME  
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19 (approximately 1MJ) across the 30 wheat samples is similar to that seen in previous studies for  
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21 wheat grown in N.Ireland and much lower than in some other studies.  
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25 14. None of the other parameters examined gave any better relationship with nutritive value  
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27 (assessed as AME or TME) than SW. This is a disappointing outcome, particularly in view of  
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29 some previous studies which suggested that *in vitro* viscosity provides a good prediction of  
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31 nutritive value.  
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### 34 35 36 **Introduction**

37  
38 Wheat is widely used as a major ingredient for poultry feed and is normally traded on the basis of  
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40 specific weight (SW). The minimum for feed grade wheat is internationally accepted as 72 kg/hl.  
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42 A review of nutritional value of low specific weight wheat (Miller and Wilkinson, 1998)  
43  
44 highlighted the lack of definitive information on this important subject and the need for reliable,  
45  
46 rapid methods of assessing the nutritive value of samples before diet formulation. One major  
47  
48 problem with previous studies such as that of Hickling (1994) is that factors such as variety and  
49  
50 location of production were confounded with SW. *In vitro* viscosity has been implicated as an  
51  
52 important factor in determining wheat feeding quality for broilers (Bedford and Morgan, 1996)  
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54 and some reports (eg Classen *et al*, 1995; McCracken and Clements, 2001) have suggested that  
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56 this may provide a more satisfactory basis for assessment of nutritive value than SW. Varieties  
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3 containing the IBIR rye translocation tend to have higher *in vitro* viscosity than non IBIR and  
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5 there is some evidence that insertion of the IBIR translocation causes reduced nutrient digestibility  
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8 (Short *et al.*, 2000). However, in the studies of McCracken *et al.* (1998) and McCracken and  
9  
10 Clements, 2001), there were no differences in performance of broilers given IBIR or non-IBIR  
11  
12 varieties. The 1998 harvest at three sites in Northern Ireland (Crossnacreevy, Downpatrick,  
13  
14 Limavady) yielded a good range of specific weight for a number of varieties. Ten wheats (5 IBIR,  
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16 5 non-IBIR) were selected giving a total of 30 samples (10 wheats \* 3 sites) for study with a view  
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18 to (a) determining the effects of SW with variety effects controlled (b) examining alternative  
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20 methods of assessment such as *in vitro* viscosity and (c) further examining the nutritive value of  
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22 varieties containing the 1B1R translocation.  
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## 29 **Materials and Methods**

### 30 *Diets*

31  
32 The 10 varieties selected and their characteristics are summarised in Table 1. Specific weight  
33  
34 ranged from 59-76 kg/hl with the mean values at the three sites being respectively 63.6, 69.2, 72.2  
35  
36 (P<0.001) for Crossnacreevy (C), Downpatrick (D) and Limavady (L). There were also significant  
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38 differences (P<0.01) between varieties with mean values ranging from 66 for Equinox to 71 for  
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40 Cantata, but no significant difference between the pooled 1B1R and non1B1R varieties. Wheat  
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42 was ground in a hammer-mill using a 5 mm screen. The diet formulation (Table 2) was based on a  
43  
44 modification of the Australian protocol (Choct *et al.*,1994) using high wheat inclusion but  
45  
46 incorporating 50 g/kg of a typical fat blend to mirror commercial practice. The fatty acid profile of  
47  
48 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;  
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50 C18:3, 3.2; C20:1, 2.8. The diets were heat-treated to 80°C (direct low pressure steam for 90 sec),  
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52 pelleted (3 mm die), floor-cooled and crumbled.  
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### *Experimental design*

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5 The 10 wheats by 3 sites gave rise to 30 diets. Sixty birds were used in each of five consecutive  
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7 time replicates and allocated to 2 blocks of 30 according to initial weight. Over the 10 blocks, the  
8  
9 10 wheats were allocated to sub-blocks of 3 birds in a balanced 10 x 10 Latin Square arrangement,  
10  
11 to minimise the effects of weight distribution within blocks. The sites were randomly allocated  
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13 within sub-blocks of 3 for each wheat. This created a split-plot design with varieties as the main  
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15 plot factor and sites as the sub-plot factor.  
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### 18 19 20 21 *Birds and Management*

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23 Male Ross broiler chicks were obtained at hatching and kept in a commercial brooder for 1 week  
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25 with *ad libitum* access to a crumbled commercial starter and water. At 7 d, all birds  
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27 (approximately 90) were weighed. The lightest and heaviest birds were discarded and 60 allocated  
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29 to experiment according to the randomisation. Birds were placed in individual cages in a room at  
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31 an initial temperature of 32°C; this was reduced by 1°C every 2 d down to 24°C. The light:dark  
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33 cycle was 18:6 and relative humidity was set for 50%.  
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41 Birds were fed *ad libitum* from 7-28d, with feed intake and weight being recorded on a weekly  
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43 basis. A total excreta collection was made from 14-21d to determine apparent metabolisable  
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45 energy (AME) content. At 28d, birds were humanely killed and the contents of the jejunum (end  
46  
47 of duodenum to Meckel's Diverticulum) removed for determination of supernatant viscosity.  
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49 Empty bird weight (after removal of all digesta) was recorded and the carcasses were retained for  
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51 later measurement of total carcass energy (McCracken and Clements, 2001).  
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### 56 57 *Analysis of diets, excreta and ileal digesta*

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59 The wheat samples were analysed for crude protein (Nx5.83), neutral detergent fibre (NDF), non-  
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starch polysaccharides (NSP, total and soluble), starch, amino acid content and gross energy.



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3 Specific weight, thousand grain weight and *in vitro* viscosity were also recorded. The diets were  
4 analysed for DM, crude protein (Nx6.25), crude fat (acid hydrolysis), ash, NDF, and gross energy.  
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6 Starch and NSP concentrations in diets were calculated from the values for the individual wheats.  
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8 The excreta samples were oven-dried for 24 h at 85°C, milled and analysed for crude protein (N x  
9 6.25), crude fat, ash, starch and gross energy. All analyses were carried out in duplicate and results  
10 reported on a dry matter (DM) basis. DM was determined by oven drying at 100°C for 24h and ash  
11 content was determined by incinerating samples in a muffle furnace at 450°C for 16h (AOAC,  
12 1990). Crude fat was extracted with petroleum ether (40-60°C BP) in a Soxtec System, after 3M-  
13 HCl hydrolysis (Stoldt, 1952), NDF according to Van Soest (1963) and crude protein (CP) by the  
14 Kjeldahl method (AOAC, 1990) and also using an automated nitrogen analyser (Leco FP2000,  
15 Leco Instruments, UK Ltd.). Total starch was determined using a commercial enzyme assay kit  
16 (Megazyme International Ireland Ltd) as described by McCleary *et al* (1997). Non starch  
17 polysaccharide (NSP) content of the wheat samples was determined using a commercial enzyme  
18 assay kit as described by Englyst *et al* (1994). *In vitro* viscosity of wheats was determined using a  
19 modification of the method described by Bedford and Classen (1993) with the resulting sample  
20 supernatant viscosity being measured with a Brookfield Viscometer. Gross energy of diet and  
21 excreta samples was determined using an isothermal automated bomb calorimeter (PARR, Model  
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#### 45 46 47 48 *Determination of True Metabolisable Energy (TME)* 49

50 TME was determined in a separate experiment using adult cockerels with 6 replicates of each of  
51 the 30 diets in a randomised block design. Ground samples (50g) of wheat were tube-fed to  
52 starved (48h) birds and the excreta collected over the subsequent 48h were dried, weighed and  
53 homogenised. TME/TME<sub>n</sub> values were derived according to McNab and Blair (1988).  
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### *Calculation of wheat AME concentration*

The diet AME contents determined over the 7d collection were used to calculate wheat AME. The AME values for casein and poultry fat in the diets, respectively, were assumed to be 16 (Im *et al*, 1999) and 34 MJ /kg. Correcting for the lower DM content of the wheat relative to the other ingredients the equation used was : Wheat AME (MJ/kg DM) = (Diet AME – 4.15) / 0.73.

### *Statistical analysis*

The results of the main study were subjected to analysis of variance (GENSTAT 5) taking account of the split-plot Latin Square design and testing for the main effects of wheat variety and site (specific weight) and their interaction. For growth parameters initial weight was used as a co-variate. The TME results were separately subjected to a two-way analysis of variance according to the randomised block design. In both cases, contrasts were estimated to compare the 1B1R -ve and +ve varieties. The wheat physical and chemical characteristics (Tables 1 and 3) were also subjected to a two-way analysis of variance using the interaction term as the residual as there was only one bulked sample from each site. Regression relationships between various parameters were established and a number of multiple regressions were examined.

### *Near Infrared Reflectance Spectroscopy (NIRS)*

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. The thirty wheat

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3 samples were used initially for calibration and the 12 samples from the study of McCracken *et al*  
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5 (2002) were used as a validation set.  
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## 10 **Results**

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12 In addition to the differences in specific weight between varieties and sites there were also  
13 differences in thousand grain weight ( $P<0.001$ ) the mean values for C, D and L respectively being  
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15 40.2, 42.1 and 45.0 kg/hl and values for varieties ranging from 39.4 (Madrigal) to 48.2 g  
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17 (Cantata). *In vitro* viscosity was significantly affected by variety ( $P<0.001$ ) ranging from 11.4  
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19 (Ritmo) to 24.0 cps (Hussar) with the mean for 1B1R varieties (19.4) being higher ( $P<0.01$ ) than  
20  
21 for non1B1R (15.0).  
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27 There was quite a narrow range of crude protein content ( $N \times 5.83$ ) across the 30 wheat samples,  
28  
29 the means for Crossnacreevy, Downpatrick and Limavady respectively being 112, 121, 122 g/kg  
30  
31 ( $P<0.001$ ; Table 3). Starch contents ranged from 604 to 679 g/kg with the mean value at Limavady  
32  
33 (659) being higher ( $P<0.001$ ) than those observed at Crossnacreevy and Downpatrick. There were  
34  
35 significant effects of variety, site and 1B1R for NDF ( $P<0.001$ ,  $P<0.05$ ,  $P<0.001$  respectively),  
36  
37 varieties ranging from 121 (Cantata) to 151 g/kg (Hussar). Similarly, total NSP varied with  
38  
39 variety, site and 1B1R ( $P<0.001$ ) with varieties ranging from 97.4 (Reaper) to 113.7 g/kg  
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41 (Brigadier), the value for L (100) being lower than for C, D (107) and the mean value (110) for  
42  
43 1B1R being greater than for non 1B1R (100). There were no significant differences ( $P>0.05$ ) in  
44  
45 gross energy the mean value being 18.35 MJ/ kg. The range of measured CP (228-262 g/kg) in the  
46  
47 diets (Table 4) tended to be greater than would have been calculated from the wheat values. Gross  
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49 energy values of all diets were similar, ranging from 19.3 to 19.6 MJ/kg DM.  
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57 There were no significant variety effects for dry matter (DM) intake, liveweight gain (LWG) or  
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59 gain:feed (Table 5). However all three parameters tended to be least for Chaucer and greatest for  
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3 Harrier. There were significant variety\* site interactions ( $P= 0.02$ ) for DM intake and LWG  
4 because values for Brigadier and Riband were highest at Limavady and those for Chaucer and  
5 Madrigal were lowest at Limavady. Apparent metabolisability of energy (ME:GE) ranged from  
6 0.738 (Hussar) to 0.778 (Harrier) the effect being significant ( $P<0.05$ ). Calculated wheat AME  
7 ranged from 14.06 to 15.04 MJ/kg DM ( $P>0.05$ ). ME:gain was not significantly affected by  
8 variety, averaging 19.8 MJ/kg gain. TME values ranged from 16.3 to 16.6 MJ/kg DM (NS).  
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20 *In vivo* viscosity ranged from 12.3 (Ritmo) to 23.7 cps (Hussar), the varietal effects being  
21 significant ( $P<0.001$ ). Viscosity was significantly higher for the IBIR varieties than for the non-  
22 IBIR (22.7 vs 16.3 cps) but there were no significant effects on DM intake, LWG, gain:feed,  
23 ME:GE, calculated wheat AME , ME:gain or TME (Table 6).  
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32 DM intake was similar for all 3 sites and there was no significant site effect on LWG (Table 7).  
33 Gain:feed was 2 per cent lower at Crossnacreevy than at the other sites and the effect just failed to  
34 attain significance ( $P=0.054$ ). ME:GE was significantly lower at Crossnacreevy than at Limavady  
35 ( $P<0.05$ ), the means being, respectively, 0.755, 0.762, 0.777 for C, D, L sites but ME:gain was  
36 highest at Limavady ( $P=0.01$ ). Calculated wheat AME increased from 14.4 MJ/kg DM at  
37 Crossnacreevy to 14.9 MJ/kg DM at Limavady ( $P<0.05$ ). TME values for C, D, L were 16.3, 16.5,  
38 16.5 MJ/kg DM (NS). Ileal digesta viscosity was similar across all three sites. However, there  
39 was a significant variety \*site interaction ( $P<0.001$ ) with values for 2 varieties (Cantata and  
40 Chaucer) being higher for Limavady than for Crossnacreevy and the reverse being true for the  
41 varieties Hussar and Equinox.  
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58 Taking the values for the 30 wheats there was a weak positive relationship between starch content  
59 and specific weight (Figure 1). There was no significant relationship between specific weight and  
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3 DM intake, LWG or gain:feed (Figures 2-4). There was a weak ( $P < 0.05$ ) positive relationship  
4 between ME:GE and specific weight (Figure 5) and between calculated wheat AME content and  
5 specific weight (Figure 6) and a significant ( $P < 0.001$ ) relationship ( $r^2 = 0.46$ ) between ME:GE  
6 ratio and gain:feed (Figure 7). There was also a weak positive relationship between wheat TME  
7 and SW (Figure 6) but the slope was even lower than for AME. Neither calculated wheat AME  
8 nor wheat TME (Figure 8) correlated with starch content ( $P > 0.05$ ). Wheat AME was negatively  
9 correlated ( $p < 0.05$ ) with total NSP (slope -0.035) but was significantly affected by variety,  
10 constants ranging from 16.74 to 17.79. For wheat TME there were significant variety\* total NSP  
11 interactions with slopes ranging from 0.29 to -0.07. There was no significant relationship between  
12 wheat AME and soluble NSP and there were significant variety\* soluble NSP interactions for  
13 TME with slopes ranging from 0.09 to -0.14 (Figure 9). Despite the relatively wide range of *in*  
14 *vitro* viscosity there was no significant correlation of either calculated wheat AME or wheat TME  
15 with *in vitro* viscosity (Figure 10). For TME there were significant variety\* viscosity interactions  
16 with slopes ranging from 0.21 to -0.13 ( $P < 0.001$ ). There was also no significant correlation  
17 between soluble NSP and *in vivo* viscosity (Figure 11).  
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41 NIR calibration and validation statistics for AME are shown in Table 8. AME values for the  
42 calibration set varied from 13.7 to 15.6 MJ/kg and averaged 14.6 MJ/kg, whereas for the  
43 validation set the values ranged from 14.0 to 16.1 MJ/kg with the mean value being 14.7 MJ/kg.  
44 The best correlation coefficient ( $r^2$ ) of 0.90 was obtained when the calibration sample set was  
45 subjected to SMLR using the second order derivatized data. Using the same set for self-  
46 prediction, an identical  $r^2$  (0.90) value was obtained (Figure 12). However, despite the high  
47 correlation coefficient obtained for the calibration and a low SEC = 0.175,  $r^2$  for the validation set  
48 (McCracken *et al* 2002) was poor, being 0.12 with SEP = 2.346 (Figure 13). Splitting the main set  
49 into a subset of 20 samples resulted in an improvement, with  $r^2$  being 0.99; however the  
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3 correlation coefficient for the residual validation set of 10 samples (Figure 14) was very poor (1-  
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5 VR = 0.09).  
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## 10 Discussion

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12 Despite the wide range of SW, the ranges of concentration of crude protein (CP), starch and total  
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14 NSP were quite narrow. For CP the range (105-131 g/kg DM) was similar to that seen for the N.  
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16 Ireland variety samples in 1996, 1997 and 1998 (George, 2000), narrower than that reported by  
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18 Nicol *et al.* (1993) and (correcting to N x 5.83) similar to that reported by  
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20 Choct *et al.* (1999). In agreement with the report of Hickling (1994) there was a poor relationship  
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22 between CP and SW. The range of starch concentrations (604 to 679 g/kg DM) was almost  
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24 identical to that reported by George (2000) for all N. Ireland wheats during the period 1997-1999  
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26 and similar to other reports (Annison, 1991; Classen *et al.*, 1995). The relationship between starch  
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28 and SW was much poorer ( $r^2 = 0.10$ ) than that reported by Hickling (1994) and the slope was less  
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30 (0.17 vs 0.55) but similar to that observed (0.21) by McCracken and Clements (2001).  
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39 Although there were no statistically significant variety effects (Table 5) for DM intake, LWG or  
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41 gain:feed it is important to note that the differences between the lowest and highest values were,  
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43 for DM intake, LWG and gain:feed respectively 4, 8 and 4 per cent, with all three values being  
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45 least for Chaucer and best for Harrier. Such differences, if real, would be of considerable  
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47 commercial importance. Significant variety differences did occur in ME:GE and, although  
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49 differences in calculated wheat AME did not attain significance, the range of values was  
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51 approximately 1MJ i.e. a 7 per cent difference, similar to that observed by Stewart (1998) and  
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53 McCracken and Clements (2001). Variety differences have been reported in other studies (e.g.  
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55 Rose *et al.*, 1993; Stewart, 1998; McCracken *et al.*, 2002) but it is difficult to determine specific  
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57 varieties which consistently perform well or badly. Furthermore, the present results highlighted  
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3 variety \* site interactions, suggesting that specific environmental or soil-related factors may play a  
4 part in the observed variability.  
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10 The range of TME values was small (NS) and there was a poor correlation between wheat AME  
11 and TME values. The actual TME values were considerably higher than those reported by  
12 Wiseman and McNab (1995) but the lack of difference due to variety accords with their results.  
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18 The lack of difference in performance between the varieties with or without the 1B1R  
19 translocation (Table 6) is notable. This accords with previous observations from this laboratory  
20 (McCracken *et al.*, 1998) and provides further evidence that the 1B1R translocation is not  
21 detrimental to the nutritive value of wheat sources commonly used in UK. Indeed, the variety  
22 Harrier which gave the best performance in terms of DM intake, LWG, gain:feed and calculated  
23 wheat AME is a 1B1R variety.  
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34 In terms of the main objective of the study, the performance results (Figures 2 to 4) show a poor  
35 correlation with SW which was not improved by seeking to take account of variety effects.  
36 Similarly, calculated wheat AME and TME were poorly correlated ( $r^2=0.16$ ) with SW. The  
37 equation for wheat AME is very similar to that found by McCracken *et al.* (2002) and the  
38 regression was significant ( $P<0.05$ ).  
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50 If one accepts the slopes of these relationships at face value then a 10kg/hl increase in SW would  
51 correspond respectively to an improvement of 1.6, 1.4 and 3.3 per cent in gain:feed, TME or  
52 calculated wheat AME respectively. The value for TME is similar to that calculated from the data  
53 of McNab (1991). The effect for calculated wheat AME is probably a worst-case scenario,  
54 bearing in mind the high level of wheat inclusion in the present study and the fact that *in vivo*  
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3 viscosity values are higher with the wheat/casein diets used here than with more typical  
4 commercial formulations (Stewart, 1998).  
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10 In view of the poor relationships established with SW a number of other chemical and physical  
11 attributes of the wheats were studied. There was no significant correlation for either TME or  
12 wheat AME with starch concentration (Figure 8). This is in agreement with the results of  
13 McCracken *et al.* (2002) and previous reports (Mollah *et al.* 1983; Rogel *et al.* 1987; Hickling,  
14 1994).  
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24 For TME there was no significant relationship with total NSP but there was a weak negative  
25 relationship ( $P < 0.05$ ) between wheat AME and total NSP, the slope of which corresponded to a 4  
26 per cent change in AME with 20 g/kg change in total NSP. This is a much smaller effect than that  
27 reported by Choct and Annison (1990) on addition of water insoluble pentosans to a sorghum-  
28 based diet.  
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39 There are conflicting reports in the literature as to the role of soluble NSP but in general it is  
40 concluded that higher levels of soluble NSP result in higher *in vivo* viscosity and consequent  
41 reductions in nutritive value. In the present study there was no significant relationship between *in*  
42 *vivo* viscosity and soluble NSP concentration (Figure 11) and no significant relationship between  
43 either wheat AME or TME and soluble NSP (Figure 9).  
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53 Previous studies (Classen *et al.*, 1995; Dusel *et al.*, 1997) have suggested that *in vitro* viscosity  
54 (IVV) may provide a suitable basis for the rapid estimation of energy value and this is being used  
55 commercially (Bedford and Morgan, 1996). The study of McCracken *et al.* (2002) established a  
56 strong relationship between calculated wheat AME and *in vitro* viscosity ( $r^2 = 0.64$ ) and it was  
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3 concluded that IVV appeared to be a better measure of nutritive value than SW. In contrast,  
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5 despite a similar range of IVV in the present study, there was no significant relationship between  
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7 either wheat AME or TME and IVV (Figure 10).  
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12 Thousand grain weight (TGW) is another physical parameter which potentially could be used as a  
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14 measure of nutritive value although published results are inconsistent. In the present study there  
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16 was a fair spread of TGW and reasonable correlation between TGW and SW (Figure 15). When  
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18 wheat AME was regressed against TGW there was no overall significant relationship but when  
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20 variety was included as a factor in the analysis the regression was significant ( $P < 0.05$ ), the  
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22 equation being  $Y = 9.65 + 0.076 \text{ TGW}$ , for Cantata and the constant ranging from 9.65 to 10.94.  
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24 The slope corresponds to a 6 per cent increase in wheat AME for a 10g increase in TGW. The  
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26 major effect of variety on this relationship could explain why previous studies have given  
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28 inconsistent results. From a practical point of view this effect undermines any potential usefulness  
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30 of the relationship since it would be difficult, under commercial conditions, to establish the  
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32 variety.  
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41 Part of the problem in defining good predictive relationships lies in the extent of bird variation on  
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43 any one treatment. This aspect has been discussed at some length by McCracken and Clements  
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45 (2001) using the data from this study. Variation was high for all wheat varieties and this was not  
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47 caused by random error as shown by the good correlation between gain: feed and ME:GE (Figure  
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55 The NIRS calibration set consisting of 30 wheats from the present study gave correlation  
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57 coefficients  $\geq 0.90$ ; however, moving to validation, the outcome was extremely poor with 1-VR  
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59 values being 0.12 for the 12 wheats (Figure 13) from the study of McCracken *et al* (2002) and  
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0.09 for a random subset of 10 of the 30 samples. 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<sub>n</sub> of ingredients, the equation failed to predict the AME<sub>n</sub> 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."

### Summary and conclusions

In the current study, 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.

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.

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

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3 previous studies which suggested that *in vitro* viscosity provides a good prediction of nutritive  
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8 The NIRS calibration was encouraging, particularly considering the small range of AME values.  
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10 However the prediction of values for the separate validation set and even for the randomly  
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12 selected subset suggests that NIRS may not provide accurate prediction of AME in poultry  
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14 although further work on this is warranted.  
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25 Development and the Home Grown Cereals Authority.  
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Table 1 Specific weight (kg/hl), thousand grain weight (g), *in vitro* viscosity (cps) and 1B1R status of selected wheats at Crossnacreevy (C), Downpatrick (D) and Limavady (L) sites

Variety	IBIR	Specific weight			Thousand grain weight			<i>In vitro</i> viscosity		
		C	D	L	C	D	L	C	D	L
Cantata	-	66	71	76	46.8	47.9	49.9	10.6	12.4	15.9
Ritmo	-	62	67	71	42.5	43.9	43.9	10.8	11.5	11.9
Riband	-	66	69	72	40.4	44.4	46.2	13.0	15.2	13.1
Chaucer	-	61	68	70	37.6	40.1	44.1	15.9	14.2	12.3
Reaper	-	65	69	72	41.8	42.9	46.1	25.0	22.2	20.8
Brigadier	+	65	68	72	37.5	38.1	43.8	22.2	15.3	24.8
Madrigal	+	62	70	73	35.8	40.3	42.2	14.3	14.4	19.6
Hussar	+	65	69	75	40.0	37.6	43.5	24.2	21.5	26.3
Harrier	+	65	71	73	39.7	42.8	44.9	16.6	15.3	19.9
Equinox	+	59	70	68	40.1	42.6	45.4	16.1	18.3	22.7
ANOVA		Specific weight			Thousand grain weight			<i>In vitro</i> viscosity		
Varieties	P= 0.008	SEM 0.86			P<0.001 SEM 0.75			P< 0.001 SEM 1.41		
Sites	P< 0.001	SEM 0.47			P<0.001 SEM 0.41			P=0.065 SEM 0.77		
IBIR	NS	SEM 0.38			P< 0.001 SEM 0.34			P< 0.01 SEM 0.63		



Table 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 Chemical composition (g/kg DM) and gross energy (GE) content (MJ/kg DM) of wheat samples from Crossnacreevy (C), Downpatrick (D) and Limavady (L)

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

ANOVA	Variety		Site		IBIR	
	P	SEM	P	SEM	P	SEM
Crude protein	NS	2.90	<0.001	1.59	NS	1.30
NDF	<0.001	3.05	0.026	1.67	<0.001	1.36
Starch	NS	9.4	<0.001	5.1	0.014	4.2
Total NSP	< 0.001	2.32	<0.001	1.27	<0.001	1.04
Soluble NSP	NS	1.92	NS	1.05	NS	0.86
Lysine	NS	0.12	NS	0.07	NS	0.05
Threonine	0.016	0.10	NS	0.05	NS	0.04
Gross energy	NS	0.032	NS	0.018	NS	0.014

Table 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	57.0	128.5	63.0	75.5	16.3	449	19.47
2		D	246.5	51.3	122.0	59.0	75.2	20.1	478	19.31
1		L	228.5	52.0	119.2	55.8	68.5	15.3	505	19.31
6	Ritmo	C	248.5	56.4	125.0	63.0	79.2	16.5	471	19.38
5		D	243.0	57.3	116.6	62.7	79.6	14.7	469	19.32
4		L	256.0	57.9	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	57.2	114.7	63.1	76.0	17.7	487	19.38
7		L	241.9	54.3	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	14.1	500	19.41
20		D	239.5	64.4	130.2	59.6	72.8	20.7	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

For Peer Review Only

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Table 5 Effects of variety on performance and energy metabolism (df 261)

	Cantata	Ritmo	Riband	Chaucer	Reaper	Brigadier	Madrigal	Hussar	Harrier	Equinox	SEM	P=
Initial weight (g)	136.3	135.0	134.0	133.1	133.0	133.5	133.9	135.2	134.4	132.9	2.48	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	0.92	NS
LWG (g/d)	51.8	52.0	51.7	49.1	51.3	50.1	51.9	51.2	53.1	51.4	0.77	NS
Gain:food	0.747	0.755	0.757	0.739	0.750	0.751	0.759	0.743	0.768	0.755	0.0076	NS
ME/GE	0.754	0.770	0.770	0.769	0.759	0.775	0.774	0.738	0.778	0.757	0.0084	0.047
ME:gain	19.6	19.8	19.8	20.2	19.7	19.9	19.9	19.5	19.7	19.6	0.21	NS
Calc wheatAME†	14.31	14.76	14.78	14.73	14.52	14.83	14.96	14.08	15.03	14.50	0.220	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		NS
Gizzard/EBW	17.2	17.3	17.9	17.2	16.8	18.1	18.1	18.1	18.5	17.9	0.57	NS
Viscosity(logtran)	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	1.70	<0.001

† MJ / kg DM

Table 6 Effects of IBIR translocation on performance and energy metabolism

	IBIR	Non IBIR	SEM	P=
Initial weight (g)	134.0	134.3	1.19	NS
Final weight (g)	1217	1209	8.2	NS
DM intake (g/d)	68.4	68.3	0.44	NS
LWG (g/d)	51.5	51.2	0.39	NS
Gain:food	0.755	0.750	0.0039	NS
ME:GE	0.764	0.764	0.0042	NS
ME:gain	19.7	19.8	0.43	NS
Calc wheat AME †	14.7	14.6	0.11	NS
TME (MJ/kg DM)	16.4	16.4	0.12	NS
Gizzard/EBW	18.1	17.3	0.20	0.003
Viscosity (cps)	22.7	16.3	0.72	<0.001

† MJ/kg DM

Table 7 Effects of site (specific weight) on performance and energy metabolism (df 261)

	Crossnacreevy	Downpatrick	Limavady	SEM	P=
Initial weight (g)	134.4	133.9	134.1	1.48	NS
Final weight (g)	1196	1226	1216	10.2	NS
DM intake (g/d)	68.2	68.6	68.3	0.54	NS
LWG (g/d)	50.6	52.0	51.5	0.49	NS
Gain:food	0.743	0.758	0.756	0.0049	0.054
ME:GE	0.755	0.762	0.777	0.0052	0.009
ME:Gain	19.7	19.6	20.0	0.11	0.011
Calc. wheat AME †	14.4	14.6	14.9	0.13	0.012
TME (MJ/kg DM)	16.3	16.5	16.5	0.15	NS
Gizzard:EBW	17.6	17.7	17.8	0.24	NS
Viscosity (logtrans)	17.5	17.3	16.6		NS
Viscosity (cps)	20.0	19.7	18.6	0.87	NS

† MJ/ kg DM

Table 8. NIRS calibration and validation statistics for wheat AME (MJ/kg DM) using

Site/Year	nc	D	Range	Mean	SD	R <sup>2</sup>	SEE	nv	SEP	1-VR	
CDL 98	30	2	13.7 - 15.6	14.6	0.45	0.90	0.175	12	2.35	0.12	1224, 1256, 1264,
CDL 98	20	2	13.7 - 15.6	14.7	0.44	0.98	0.071	10	0.99	0.09	1268, 1280, 1344,
CDL 98	25	1	13.7 - 15.6	14.7	0.45	0.97	0.102	5	0.41	0.63	1383, 1735, 1867,
CDL97/98	42	2	13.7 - 16.1	14.7	0.49	0.70	0.30	42	0.26		1180, 1232, 1444,
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											