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Factors determining the nutritional value of wheat varieties for poultry

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The chemical composition of wheat is believed to influence its apparent metabolisable energy (AME) value for young poultry. In a preliminary study, 10 samples of wheat were assessed biochemically and AME was determined by chick bioassay. Diets were formulated to include wheat at 90%. Biochemical analyses of the wheat and excreta included starch, dietary fibre components, nitrogen, lipid and gross energy. Although the wheats tested did show a compositional variation, none were identified as being low-AME types. Mean values ranged from 11·98 to 14·90 MJ/kg of dry matter. Significant differences were found between the contents of starch (g/kg DM; range of 608–744, $p < 0{\cdot}001$) and protein ($N \times 5{\cdot}83$; g/100 g DM; range of 9·57–14·69, $p < 0{\cdot}001$), although these were not correlated with AME. AME was correlated with apparent starch digestibility in each trial ($r^2 = 0{\cdot}96$ and 0·74) and apparent starch digestibility was found to be independent of the NSP level or composition. The arabinoxylan content was not correlated with AME or energy metabolisability. No relationship was observed between the AME and starch or the non-starch polysaccharide (NSP) content. Recoveries of NSP from excreta were high (up to 86%) and AME was independent of NSP digestibility. A strong negative correlation ($r^2 = -0{\cdot}92$) existed between the AME and the ratio of arabinose-to-xylose in the NSP. Fractionation of the NSP into soluble and insoluble components revealed a variable ratio of between 0·28 and 1·00. No significant correlation existed between either of these two variables and the AME.

INTRODUCTION

Wheat is an important source of energy in poultry diets within the UK, contributing up to 800 g/kg diet for finishing broilers (Longstaff & McNab, 1986; Wiseman & Inborr, 1990). Recently, however, there has been increasing concern from the feed compounders over certain varieties having low AME values, since AME values as low as 10·0 MJ/kg DM have been reported. Rogel and co-workers (1987) have shown that the inclusion of some wheat varieties into broiler diets decreased the AME value. Generally, the nutritive value of cereals is defined in terms of digestibility and chemical composition. Some evidence, largely anecdotal, has implied that the chemical composition of wheat is related to the AME value, and previous work has shown that low-AME wheats are rather poorly digested (Mollah *et al.*, 1983). It is believed that high levels of wheat pentosans, accounting for 50–80% DM of the NSP and consisting mainly of arabinose and xylose (Annison, 1990), exhibit anti-nutritive activity (Choct & Annison, 1990) and are the cause of the poor nutritive value. These workers (Annison & Choct, 1991; Choct & Annison, 1992) have obtained a tenuous, inverse relationship between the bioavailability of nutrients to chicks and the pentosan (arabinoxylan) level in the grain. These pentosans were found to reduce the digestibility of all nutrients and, as a consequence, lower the AME.

The objectives of this research programme were:

(i) to identify wheat varieties with low AME values;
(ii) to compare and contrast the chemical composition of such wheats with wheats possessing high AME values;
(iii) to quantitatively identify the factor(s) responsible for the low-ME phenomenon by precise chemical and nutritional analysis.

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EXPERIMENTAL

Wheats were obtained from the 1990 harvest from the University of Nottingham farm (four in Trial 1) and from the Institute of Animal Physiology and Genetics Research (Roslin) (six used for bioassay in Trial 2).

Wheat samples were assessed both biochemically and biologically in two preliminary trials. Bioassays were carried out using one-day-old male broiler chicks obtained from a commercial hatchery. The birds were housed two per cage in wire-bottomed metabolism cages with six replicates (cages) for each wheat in Trial 1 and either three, four or five replicates in Trial 2 according to the availability of wheat. Diets were formulated to include wheat at 90% as the sole source of carbohydrate and protein. Food and water are provided *ad libitum*. After acclimitisation for one week on a post-hatching starter diet, experimental diets were administered for six days. Accurate measurement of excreta and food intake (including spillages) were made on the last three days of each trial.

AME was measured using a classical AME assay (total collection method) and determined by calculation:

$$\text{AME(wheat)} = \frac{\text{AME(diet)} - ([\text{AME oil} \times \text{IL}] + [\text{AME met or lys} \times \text{IL}])}{\text{Wheat inclusion level}/100}$$

where IL = inclusion level; met = methionine; lys = lysine.

Biochemical analysis of starch was carried out according to a method developed in this laboratory using a thermostable α-amylase (Termamyl, Novo) and amyloglucosidase (Novo). The Englyst procedure (Englyst *et al.*, 1982; Englyst & Cummings, 1984) was used to determine the non-starch polysaccharides (NSP) and its components. Nitrogen (Kjeldahl), lipid (Weibul) and gross energy (adiabatic bomb calorimeter) measurements were made using standard procedures. Results were analysed statistically using ANOVA. Varietal differences were assessed using unpaired Student t-tests.

RESULTS AND DISCUSSION

Despite variations in the chemical composition of wheat, none were identified as being low-AME types. Mean values ranged from 11·98 to 14·90 MJ/kg DM but differences were mainly due to non-dietary factors. Up to 21% of the birds were shown to react adversely to the diets given. It was difficult, therefore, to make any meaningful comparisons between the different wheats due to the lack of extremes. Differences in gross energy measurements between the wheats were minimal, which may have been reflected in the AME values obtained. Significant differences were found in both starch content (g/kg DM; range of 608–713 in Trial 1 and 633–744 in Trial 2; $p < 0{\cdot}001$) and protein ($N \times 5{\cdot}83$) content (g/100 g DM; range of 9·88–14·69 in Trial 1 and 9·57–12·92 in Trial 2; $p < 0{\cdot}001$), but these were not correlated with AME. No significant differences were observed in the lipid content of the wheats (Tables 1 and 2). As the starch of the lower-AME wheats was poorly digested by poultry, the apparent starch digestibility was used as an indicator of anti-nutritive activity. AME was correlated with apparent starch digestibility in each trial (Fig. 1) and apparent starch digestibility was found to be independent of the NSP level or composition. Mean data showed that wheat starch was almost completely digested (>90%) with the indication that the availability of starch *per se* is an important factor. Lower values were the result of a few individuals being poor starch digesters, and consequently, feed intakes were disproportionately high and excreta were excessive and watery. These findings corroborated those of Wiseman and Inborr (1990). The inability of some chicks to completely digest wheat starch from some varieties has not been fully explained, but it is known that the physical and chemical properties of a starch may influence its digestibility by α-amylases. A correlation was obtained between the digestible starch content and AME in Trial 1 (Fig. 2), indicating the importance of starch availability to the digestive enzymes. Wheat total pentosan level was correlated with NSP content in Trial 2 (Fig. 3), which might have been expected according to the NSP composition. Contrary to expectation, neither trial in this study showed a correlation between the AME or energy metabolisability of the wheats and the total content of pentosans. These findings were nevertheless consistent with those of Annison (1991). This was probably attributable to the comparatively narrow range of arabinoxylan contents amongst the wheat samples, and to the presence of a few seemingly anomalous birds. Choct and Annison (1990) demonstrated that the AME of different cereals was negatively correlated with total NSP contents. They suggested that specific types of soluble NSP contribute to the anti-nutritive activity.

Annison (1991) later showed that a strong negative correlation existed between the AME of wheat and the levels of neutrally-extracted NSP (comprised mainly or arabinoxylan) when supplied endogenously. The following year, Choct and Annison went on to show that both water-extractable and alkali-extractable pentosan-rich fractions, when added to experimental diets as purified isolates, reduced the AME. No relationship was observed between the AME and starch or NSP contents in this study. Recoveries of dietary NSP in excreta were high (up to 86%), indicating their low utilisation by the young chick, and AME was independent of NSP digestibility. No correlation was evident between the non-cellulosic polysaccharides (NCP) and

Table 1. Chemical analyses determined in Trial 1 (mean data)

Wheat variety	AME (MJ/kg)	AME/GE	Content digestible starch (g/kg)	Coefficient of starch digestibility	NSP content	Pentosan content	Ara:xyl ratio	Sol:insol NSP ratio	Lipid content	Protein content
					(mg/g)				(g/100 g)	
Hornet	11·98	0·666	532·8[a]	0·825	137·94	82·98[a]	0·63	0·78[a]	2·25	12·17[a]
Riband	14·43	0·816	696·6[b]	0·977	143·88	82·79[a]	0·67	1·00[b]	2·25	9·88[b]
Mercia	12·17	0·673	537·8[a]	0·820	141·27	88·71[b]	0·69	0·85[ab]	2·48	13·25[ac]
Pastiche	14·90	0·824	600·3[ab]	0·987	142·74	85·92[a]	0·61	0·57[c]	2·34	14·69[d]

Data expressed on a dry weight basis.
[a–d]Within columns, values with different superscripts refer to significant differences between the wheats ($p < 0.05$).

Table 2. Chemical analyses determined in Trial 2 (mean data)

Wheat number[e]	AME (MJ/kg)	AME/GE	Content digestible starch (g/kg)	Coefficient of starch digestibility	NSP content	Pentosan content	Ara:xyl ratio	Sol:insol NSP ratio	Lipid content	Protein content
					(mg/g)				(g/100 g)	
18	13·96	0·799	636·8[ab]	0·980[a]	103·38[a]	66·22[a]	0·60[a]	0·30	2·35	12·92[a]
20	12·91	0·752	608·7[a]	0·938[ab]	104·49[a]	66·88[ab]	0·64[ab]	0·28	2·39	11·64[b]
23	12·68	0·705	665·3[b]	0·967[ab]	107·24[a]	67·47[ab]	0·63[ab]	0·37	2·15	12·48[a]
37	13·85	0·771	647·5[ab]	0·962[ab]	116·46[b]	75·56[b]	0·61[ab]	0·44	2·32	10·98[b]
88	12·26	0·733	621·3[ab]	0·904[b]	107·08[ab]	69·63[ab]	0·65[b]	0·36	2·44	10·23[c]
98	13·61	0·786	724·1[c]	0·973[ab]	109·46[ab]	69·53[ab]	0·62[ab]	0·39	2·52	9·57[d]

Data expressed on a dry weight basis.
[a–d]Within columns, values with different superscripts refer to significant differences between the wheats ($p < 0.05$).
[e]Reference Number is in accordance with that given by the Institute of Animal Physiology and Genetics Research (Edinburgh).

the AME. Although cellulose is largely indigestible in poultry, the hemicelluloses including the pentosans may be utilised to some extent. A strong negative correlation ($r^2 = -0.92$) was obtained between the arabinose:xylose ratio (an indicator of the degree of branching) in NSP and AME (Fig. 4), but data failed to show a significant link with starch digestibility. However, there was an indication that apparent starch digestibility decreased as the ratio increased. No relationship was apparent between the pentosans and the arabinose:xylose ratio. Fractionation of the NSP into soluble and insoluble components revealed a

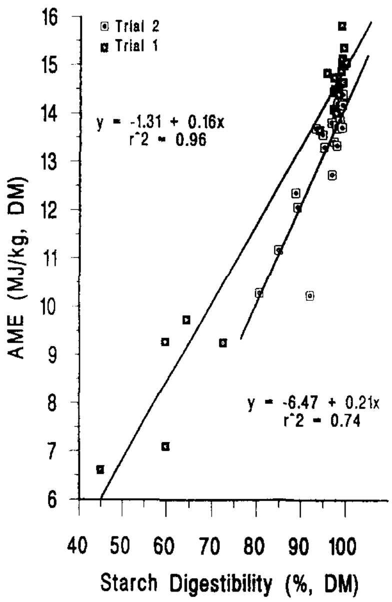

Fig. 1. Correlation between apparent starch digestibility and apparent metabolisable energy (AME) of wheat.

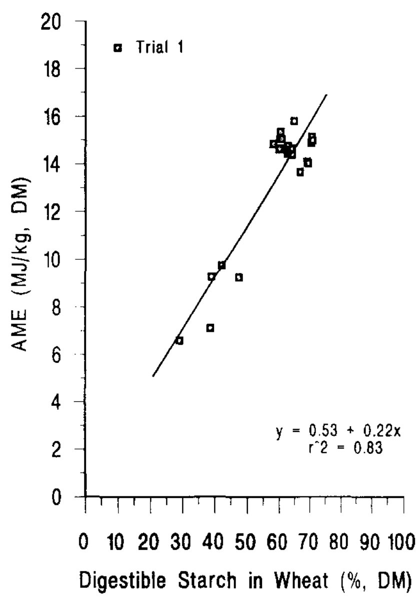

Fig. 2. Correlation between digestible starch content in wheat and apparent metabolisable energy (AME) value.

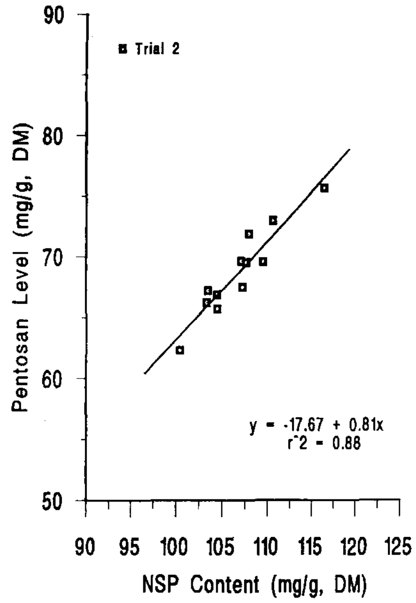

Fig. 3. Correlation between non-starch polysaccharide (NSP) content and pentosan level in wheat.

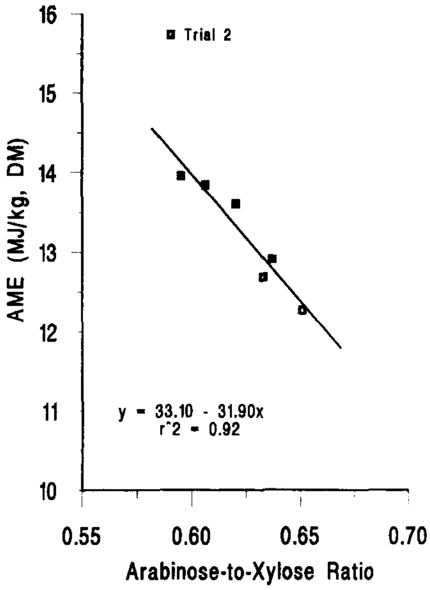

Fig. 4. Correlation between arabinose-to-xylose ratio in wheat and apparent metabolisable energy (AME) value.

variable ratio of between 0·57 and 1·00 for Trial 1 and between 0·28 and 0·44 for Trial 2 wheats. While there was a slight positive correlation between the content of soluble NSP and AME, suggesting that the soluble fraction may contribute to the energy provision of the chick, the correlation did not reach significance ($p > 0{\cdot}05$). This observation is contrary to the recent findings of Annison (1991) who concluded that the water-soluble NSP of wheat possesses anti-nutritive activity in the gastrointestinal tract of young birds, causing a general, non-specific inhibition of nutrient digestion. This was attributed to an increase in the viscosity of the gut contents reducing digestive processes by limiting the free access of enzymes to their substrates. The insoluble NSP appeared to be biologically inactive in the young chick.

CONCLUSIONS

To date, no wheat sample with a low AME value has been indentified using the chick bioassay, although it seems apparent that some unidentifiable factor(s) within certain varieties exhibit anti-nutritive properties which are manifested by depressed digestibility of starch and reduced AME. In these preliminary studies, it is not known whether the other major nutrients are affected to the same extent. This decrease was also extended to protein and lipid in a recent study carried out by Annison and Choct (1991), who suggested that the pentosans were responsible for reduced nutritional value. To date, these studies have implied that the pentosans may not be the sole anti-nutrient, and the exact identity and nature of these factors is unknown. Bioassays in progress may provide more positive information regarding the causes of the variability in AME of different wheats.

Further research is needed to elucidate the exact mechanisms of action of NSP and the pentosans and the precise fraction(s), if any are involved, in reducing the bioavailability of nutrients to broilers. Recent bioassays have identified wheat varieties with contrasting AME values. Detailed chemical characterisation studies on these wheats should enable the factors responsible for the low AME values to be identified.

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