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With dietary modifications, wheat can be used for poultry

ABSTRACT

Wheat is an excellent ingredient for poultry, but dietary modifications need to be made when substituting wheat for corn. The poorly digestible water-soluble NSP fraction of wheat has been identified as the primary anti-nutritive component, having a high water-holding capacity and forming a viscous environment. This article examines wheat as a feed ingredient for poultry.

By N.E. WARD

TABLES

1. Crude protein (CP; 6.25 x %N) and the amino acid content and digestibility for wheat

	Amino acid content as % listed dry matter						--True digestibility, %--			
	1993 NRC	A	B	C	D	E	1993 NRC	B	E	F
CP, %	13.3	12.4	13.57	12	12.1	12.8	_	_	_	_
Dry matter, %	88	88	88.6	98.3	88	87.5	_	_	_	_
Lysine, %	0.37	0.44	0.41	0.43	0.34	0.32	81	81.4	79.9	81.1
Methionine, %	0.21	0.23	0.23	0.2	0.2	0.19	87	86.7	81.6	86.9
Cystine, %	0.3	0.32	0.27	0.32	0.28	0.26	87	87.3	82	87.5
Tryptophan, %	0.16	0.16	0.17	0.15	0.16	_	_	_	_	_
Threonine, %	0.39	0.37	0.43	0.37	0.36	0.33	83	81.9	79.1	83.0
Argine, %	0.60	0.61	0.68	0.68	0.59	0.55	88	87.1	83.4	87.8

Source A: ADM BioProducts, Decatur, Ill..
Source B: Heartland Lysine, Chicago, Ill.
Source C: Novus International, St.Louis, Mo.
% CP determined as 6.25 x %N
Source D: Degussa, Ridgefield Park, N.J
Source E: RhonePoulenc, Atlanta, Ga.
Source F: FinnFeeds International, Chicago, Ill.

Amino acid estimation equations for wheat

(1)% Lysine = 0.147 + 0.016 (%CP)
%Methionine = 0.031 + 0.015 (%CP)
% TSAA = 0. 1 16 + 0.032 (%CP)

(2)% Lysine = 0.3902 + 0.0137 (% CP) - 0.01 95 (% moisture) + 0.0812 (% fat) + 0.01 63 (% CF) - 0.01 44 (% ash)
% Methionine = 0. 196 + 0.0098 (% CP) - 0.0086 (% moisture) - 0.0412 (% CF) - 0.0032
(% ash) % TSAA= 0.0074 + 0.0582 (%CP) - 0.0054 (%moisture) + 0.0435 (%fat) - 0.01 95 (% CF) -0.0285 (% ash)

2. Nonstarch polysaccharide (mixed linked glucans and arabinoxylan) content of cereals

Cereal	Mixed linked Water-soluble	Beta-glucans Total	Arabinoxylans Water-soluble	Total
Corn	_	_	0.7	4.2
Barley	2.7	4.4	0.2	5.7
Oats	2.3	3.3	0.4	7.7
Wheat	0.7	0.7	1.2	6.6
Rye	0.7	1.9	2.6	8.5

Values expressed as a percent of dry matter

Wheat is not a typical ingredient in U.S. poultry and swine diets, in large part due to its higher price in comparison to corn. The period of 1992-94 was an exception, when the price of wheat was substantially lower than that of corn, which prompted some U.S. commercial poultry and swine nutritionists to replace as much as 100% of their corn with wheat.

The International Wheat Council estimates that 20% of the total global wheat production for 1993-94 was used in animal feeds, with the primary users being Europe, the former Soviet Union, Canada, Australia and Japan. No more than 8 million tons of wheat were used in U.S. animal feeds, a figure approximating about 10% of U.S.-grown wheat. Wheat production in the last several decades has increased world-wide, and in conjunction with the North American Free Trade Agreement, General Agreement on Tariffs & Trade and other trade agreements, this grain may become competitive with corn on a routine basis.

Furthermore, in recent years, research has led to a much-improved understanding as to how exogenous enzymes can improve the nutritional value of wheat and other cereals. Coupled with a lower cost of commercial enzymes through improved production technology, it is possible that wheat and exogenous enzymes may eventually become steadfast in some U.S. poultry and swine diets. Recent estimates indicate that more than 95% of the wheat- and barley-based broiler diets in the U.K. contain added enzymes, as does about two-thirds of such diets world-wide (Wyatt, 1995.)

The 1992-94 U.S. experience

In the U.S. during 1992-94, a considerable amount of low-priced spring wheat arrived from western Canada, and when completely replacing corn in diets, usually resulted in devastating performance problems. There are indications that some of this wheat was early frost-damaged, in part because the Canadian Prairies experienced early frosts during 1992 and 1993. Frost-damaged wheat could have higher levels of non-starch polysaccharides (NSP.) NSP tends to be higher in

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immature wheat, resulting in lower energy and feeding value. There were indications that mycotoxins also were present, which, if true, would only exacerbate the problems with this wheat. By law, however, the importation of mycotoxin-laden wheat is not legal.

In many cases, nutritionists in other countries have completely replaced corn with wheat with excellent results, but the wheat imported to the U.S. a few years ago certainly did not allow this degree of substitution. According to some nutritionists, feed enzymes were used with this wheat with good success rates. In a similar vein, Scott (1994) reported a study on 1992 Canadian wheat that had been frozen in the field prior to harvest. The inclusion of multi-enzymes in the broiler diets with 80% wheat improved the metabolizable energy by about 10%.

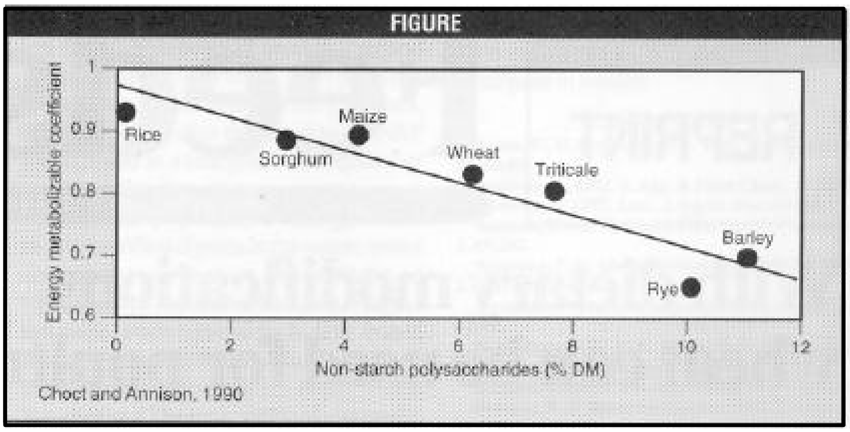
ME, amino acid values for wheat

An adjustment must be made in diet formulations to account for an energy value of wheat that is roughly 10% less than that for corn. Metabolizable energy (ME) values for wheat used in the U.S. tend to be within a range of about 1,300-1,360 kcal/lb. Broader ranges of 1,195-1,803 (Longstaff and McNab, 1986) and 1,130-1,727 kcal/lb. (Choct et al., 1994) exist.

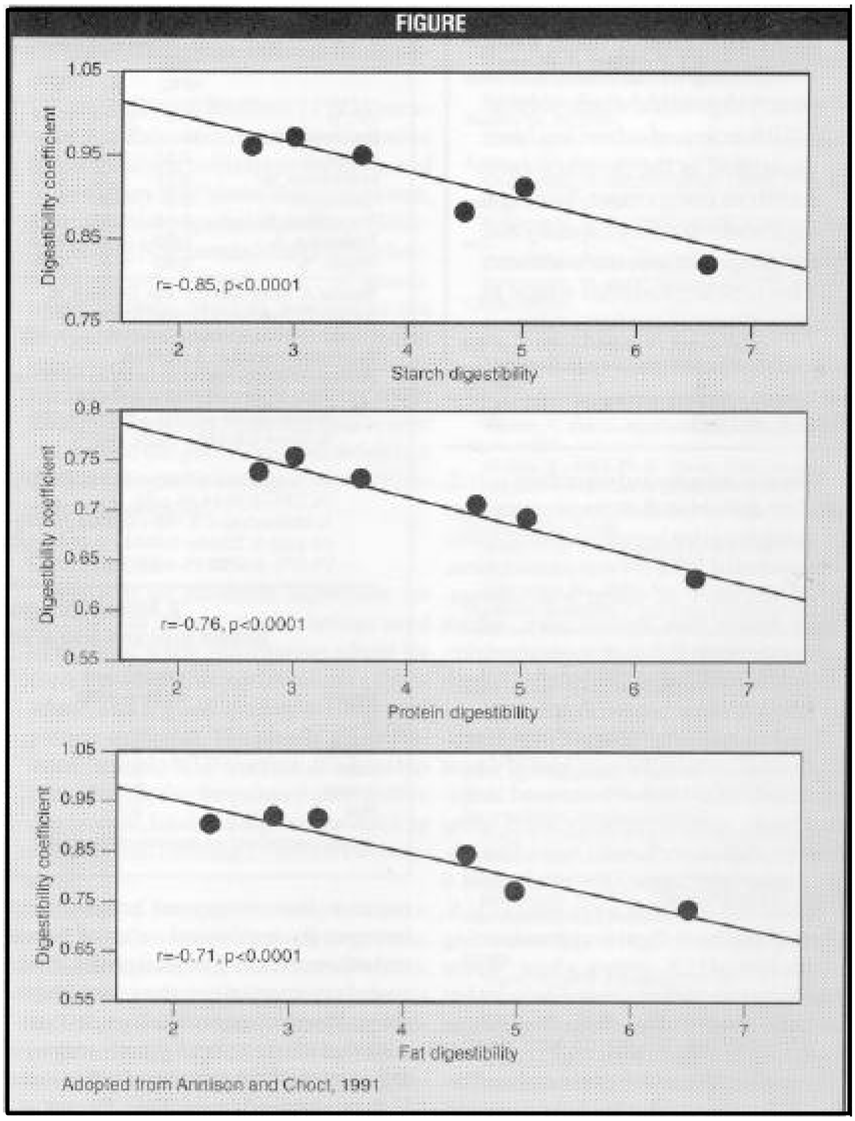
The ME of wheat has been predicted with components of proximate analysis (Janssen, 1989), as well as total starch and crude protein (% CP; Mollah, 1983), but the accuracy of these estimates is often poor. Starch content and %CP do not correlate well with apparent ME, whereas the digestibility of starch is closely related to wheat ME (Mollah and Annison, 198l; Rogel et al., 1987). Water-soluble NSP content is negatively associated with ME (Mollah, 1983), but difficulty in analysing the polysaccharide content of wheat hampers its use on a routine basis. Neutral detergent fibre (NDF), as opposed to acid detergent fibre, gives a higher predictability of digestible energy (Batterham et al., 1980), probably because NDF includes hemicellulose.

Complicating the prediction of wheat ME is that some wheats experience the "low ME wheat phenomenon," which describes wheat with lower-than-expected ME. Chemical and gross energy determinations are unable to distinguish this wheat. In Australia, the low ME wheat makes up about 25% of the total wheat.

Values for %CP from five amino acid suppliers show a relatively small range of 12.0-13.5% (Table 1), although wheat is more variable than corn. In a survey of U.S. corn, U.S. wheat and Canadian Spring hard wheat, the coefficients of variation for %CP were



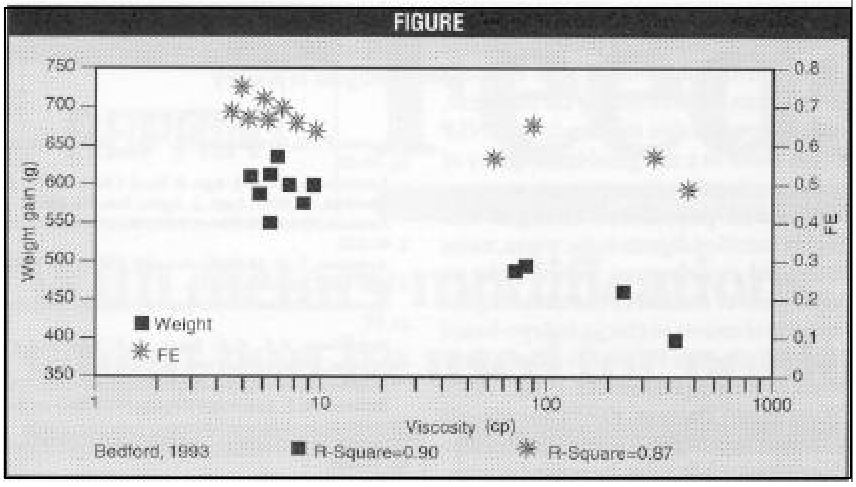
1. Relationship between metabolizable energy of cereals and their non-starch polysaccharide content (pentosans + beta-glucans, % of dry weight)



2. Relationship between total dietary arabinoxylans and ileal digestibility

7.1, 10.2 and 11.6%, respectively (Ward, 1989). Values for the more critically essential amino acids are also provided (Table 1), and for some, the variability is not especially large. Since the mid 1980s, the amino acid content has been estimated based on either %CP values (Ward, 1989) or a combination of proximate components (Monsanto, 1986). Both sets of equations have shown good accuracy, and are listed in Table 1.

For %CP, the Kjeldahl protein adjustment is typically 6.25, and is based on a 16% N composition of protein. Wheat is relatively high in amide N, calling into question the 6.25 adjustment. A conversion of 5.7-5.8 would be more accurate (Simmonds, 1989), although most tables report



3. Effect of viscosity on weight gain and feed efficiency of broilers to 21 days

%CP for wheat using the 6.25 adjustment. For poultry, swine and other non ruminants, this would inflate the true protein by about 9%.

Considerations for feeding wheat

The use of enzymes for wheat and other such cereals is commonplace in Europe, Canada and other areas of the world. This topic will be discussed in more detail in a subsequent article. Wheat is often associated with wet litter for poultry, especially when fed at a level exceeding about 20% of the diet. Pasted beaks and vents, and sticky feces can occur with wheat in poultry diets. Known for many years, this can be decreased by increasing the grinding particle size (Poley, 1938). Higher mortality has been associated with hammer mill-ground wheat, as opposed to roller mill-ground wheat (Branton and Reece, 1987). In this latter study, high levels of wheat in diets predisposed the broilers to necrotic enteritis; *Clostridium perfringens* was found as the pathogen. Several growth promotants are effective against *Clostridium perfringens*, although none were fed in this study. There is an association between necrotic enteritis and coccidiosis, which may explain recent studies that found a greater severity of coccidiosis in broilers fed wheat (Williams, 1992; Morgan and Bedford, 1995).

As a group, wheat, barley and oats are unique in suffering a "new crop" phenomenon which leads to reduced performance and poor digestibility. Poultry and swine producers in Europe will seldom feed wheat and other cereals within 4-8 weeks post-harvest, after which the problem subsides. This situation seems related to the soluble fibre of these cereals which declines during the immediate weeks following harvest (Aman et al., 1989). A decrease in content and chain length of this fiber improves (decreases) intestinal viscosity, and probably is due to the activity of the carbohydrase enzymes already present in the cereal (Graham, 1994).

Of the vitamins, biotin may be the most critical due to its presence in the bound form. Coupled with the high variability of biotin in wheat (Putnam, 1977), its bioavailability can be quite low. To compensate, an additional 3-5 mg of biotin per ton of feed is occasionally recommended for every 10-15% wheat that replaces corn in the diet. The biotin supplementation rates for U.S. corn/SBM diets were recently found to be 72, 63 and 55 mg per ton for starter, grower and finisher broiler feeds (Ward, 1993). In addition, the absorption of fat-soluble vitamins may be less since fat digestibility is decreased when feeding wheat.

Nonstarch polysaccharide fraction

Wheat contains relatively high levels of NSP as a structural carbohydrate in the endosperm cell wall (Table 2). Arabinoxylans (pentosans) make up the largest portion mainly in the form of arabinose and xylose with a small amount of mixed-linked beta-glucans. The arabinoxylans consist of a main chain of beta-(1-4) linked xylose to which side chains of arabinose are attached. A portion of the NSP is water-soluble, which is notorious for forming a gel-like viscous consistency in the intestinal tract (Antoniou and Marquardt, 1982; White et al., 1983). The digestibility of this fibre is very low, with fecal recoveries of up to 86% (Nicol et al., 1993).

According to Annison (1993), four important research findings characterise the negative effects of this fibre fraction in wheat: (1) wheat ME values are negatively correlated with soluble NSP levels; (2) a level about 3% of chemically pure NSP depresses the ME of nonwheat broiler diets; (3) degradation of the cell wall polysaccharides *in situ* by glycanases added to broiler diets increases ME values, and (4) addition of purified wheat arabinoxylan to broiler diets depresses the ME in a dose-dependent manner.

Evidence has consistently highlighted negative effect of water-soluble NSPs. The isolation of the soluble carbohydrates from the digesta of chicks fed a wheat/rye diet showed that a high molecular weight (>500,000 kilodaltons) portion, which comprised 10% of the total polysaccharides, accounted for 80% of the digesta viscosity (Bedford and Classen, 1992). This fraction had a very high degree of arabinose units, and clearly impacted digesta viscosity. In another study, the total water-soluble NSP negatively correlated with AME (r = -0.9 1), as did the water-soluble arabinoxylans (r = -0.86). The insoluble NSP and arabinoxylans were not meaningfully (P>0.05) correlated with AME (Annison, 1991). In fact, this fraction seems to act as an inert material and passes through the birds virtually intact.

The negative relationship between ME and the water-soluble NSP holds true for several cereals, as shown in the somewhat classical Figure 1 (Choct and Annison, 1990). Cereals that are higher in NSP are clearly those with the lower ME.

To determine if the NSP fraction is responsible for the low energy of wheat ("low ME wheat phenomenon"), the NSP was extracted from wheat and added to a commercial broiler diet (Choct and Annison, 1991). Progressively with the added NSP, the measurements for live performance, ME and digestibility were significantly impaired. Illeal digestibilities for starch, protein and fat were decreased, with fat digestibility being depressed to the greatest degree (Figure 2). The birds in this study also produced large amounts of watery feces. Similar findings were recently reported elsewhere (Scheele et al., 1994). Certainly, wheat NSP (mainly arabinoxylans) can bring about a substantial decrease in the nutritional value of diets.

NSP and intestinal viscosity

It is the arabinose side chains that impart a water-soluble nature to a portion of NSP. The long polymers entangle and have a high water-holding capacity, resulting in an increase in intestinal viscosity. Viscosity is directly proportional to the molecular weight of wheat arabinoxylans (Bedford and Classen, 1992; Izydorczyk and Billiaderis, 1992). With no arabinose, the xylan would precipitate from solution and virtually no change in viscosity would be expected. Thus, the water-soluble NSP increases the viscous nature to intestinal digesta.

Live performance. The substandard performance when feeding these cereals is attributed to the increased intestinal viscosity. In fact, up to 70-80% of the variation in bodyweight and feed/gain can be explained by intestinal viscosity (Bedford and Classen, 1992). Bodyweight gain and feed/gain are negatively associated with increased foregut viscosity (Figure 3). Data collected by Finnfeeds International indicate that for each centipoise unit decrease in gut viscosity of diets having reasonably high initial viscosity, feed/gain can be improved by about 2 points (Graham, 1994).

Digesta passage rate. Increased intestinal viscosity reduces the passage rate of digesta (Antoniou et al., 1981; Antoniou and Marquardt, 1988), in spite of the fact that gut motility is actually increased (Silah et al., 1991). With a reduction in digesta passage rate, the overall feed consumption per unit time would be less and contribute to a decrease in live performance. The effect on gut motility may be responsible for the increased endogenous secretion of proteins, water, minerals and fatty acids observed by Low (1989) in swine fed NSP. Such a metabolic loss is costly and, in part, could be related to excessively wet feces.

Digesta mixing. For proper digestion, dietary components require mixing with stomach, pancreatic and other intestinal secretions. The gel-like environment reduces this mixing, thereby interfering with enzyme substrate reactions. Likewise, the movement of sugars, amino acids and other nutrients to the mucosal sites for digestion would be impeded. This in particular would contribute to the reduction in fat absorption since the fat micelle molecule is rather large, and would have difficulty moving through the viscous environment.

Enzyme binding. The viscous NSP fraction physically complexes with intestinal enzymes (Ikeda and Kusano, 1983), thus taking them "out of action" with respect to reacting with substrates. This would be consistent with the lowered digestibility of protein, fats and starch attributed to NSP. Large amounts of enzymes are secreted by the pancreas, but it is conceivable that binding by NSP could result in a marginal inadequacy of enzymes for digestive purposes.

Bacterial population changes. The highly nutrified digesta in the warm, moist intestinal environment would make an ideal growth media for bacteria. Higher microbial counts in chicks fed rye-based diets, as opposed to those fed corn, have been reported (Fernandez et al., 1973; Wagner and Thomas, 1977). Salmonella faecium, an intestinal microbe that can deconjugate bile salts, increased in numbers when wheat was fed to broilers (Fuller, 1984). Inadequate levels of bile salts could contribute to lower fat digestibility.

Campbell and Bedford (1992) reckoned that dislocation is a major limitation to intestinal microbial proliferation, and since dietary NSP slows the passage rate, the microbial population could proliferate. Wheat NSP seems to encourage bacterial growth (Choct et al., in press), which in turn, tend to migrate to the foregut where most nutrient absorption takes place. This would magnify the competition between the bird and microbes for needed nutrients. High bacterial counts can irritate the gut lining, and result in a thicker lining with damaged microvilli to reduce absorption.

Conclusions

Wheat is an excellent ingredient for poultry, but dietary modifications need to be made when substituting wheat for corn. Considerable variation can exist in wheat and a good quality control programme is essential. The poorly digestible water-soluble NSP fraction of wheat has been identified as the primary anti-nutritive component, having a high water-holding capacity and forming a viscous environment.

Increased foregut viscosity is associated with a slower feed passage rate, reduced digestibility of various nutrients, increased endogenous secretory losses and increased intestinal microbial populations. In all, higher viscosity can account for as much as 70% increased viscosity has been shown to account for 70-80% of the variation in bodyweight and feed/gain in poultry.

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