NUTRITIONAL ADVANTAGES AND PROBLEMS RELATED TO THE USE OF CEREAL GRAINS IN FEEDS

by

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Grains and their by-products are by far the most important sources of carbohydrates and energy used for livestock feeding. Although they are used principally as energy sources, grains also supply important amounts of protein, vitamins and minerals. The level of protein and the level and balance of amino acids in each grain as well as the presence or absence of inhibitory or toxic substances determine the real worth of a grain in economic animal production (Pond and Maner, 1984). The major factors which influence the nutritive value of the common grains will be addressed in this paper.

Maize

Maize (*Zea mays*) is the most common grain used for feeding livestock, especially swine and poultry. The energy value of maize is commonly used as a standard with which other energy sources are compared. Thus, if the relative energy value of maize is taken as 100, the energy value of other grain sources is generally lower. The efficient utilization of the gross energy is mainly due to the low fibre content of the maize kernel and the high digestibility of its starch.

The crude protein content of maize is relatively low, ranging from 8-11%. More importantly for monogastric animals, maize contains a poor balance of amino acids and is deficient in several of the essential amino acids, especially lysine and tryptophan. Without adequate supplementation with high-quality protein and/or essential amino acids, maize is an inadequate protein source for swine and poultry.

Grain sorghum (Milo)

Sorghum (*Sorghum bicolor L. Moench*) grain is valued for its content of energy in the form of starch. Different types of starch are present in existing varieties and hybrids. Waxy starches are contained in varieties derived from strains introduced from China and Africa and are composed entirely of amylopectin, a branched-chain polymer of glucose units. Nonwaxy or normal sorghum starch contains about 27% of amylose, a straight-chain polymer of glucose, and 73% of amylopectin. The whole grain contains 6.5 - 12% protein. 73% starch, and about 2% fibre. Sorghums also contain intrinsic substances that occur naturally in the plant; these include tannins (polyphenols), phytates, cyanogenic glycosides and possibly others not yet identified.

Early studies with pigs showed that grain sorghums were equal or superior to maize in supporting daily gain, but inferior for feed conversion. Sorghum varieties and hybrids differ in palatability and nutritional value which may be associated with tannin content.

Studies in the 1970s, with maize, wheat, oats, and barley fed to finishing pigs, demonstrated that when good quality protein is fed, sorghum had a feeding value equal to maize. However, with poor quality protein (peanut meal or cottonseed meal), the value of sorghum grain was only about 70% that of maize. Other studies have shown that sorghum is equal or superior to barley and oats and similar to wheat.

The efficiency of utilization of sorghum for poultry appears to be either the same as that of maize or 10 to 15% lower, apparently depending on processing method or the amount of polyphenol (tannin) in the pericarp. Different methods of processing may affect both the site of starch digestion and extent of digestion, with marked effects on overall efficiency of utilization.

The detrimental effects of high-tannin sorghums on the growth and feed efficiency of the chick are well documented. The amount of polyphenol affects the efficiency of utilization of so-called bird-resistant varieties because of decreases in the digestibility of starch, fibre and protein. Intake may also be lowered. There is a highly significant negative correlation between the metabolizable energy content of sorghum and the concentration of tannin.

Sorghum is an excellent grain for pigs and poultry if properly supplemented to provide the essential amino acids. Protein content and quality may not necessarily be related to tannin content but tannins alter amino acid availability as has been demonstrated with chicks for methionine. To be utilized efficiently, sorghum diets should be supplemented with protein and/or amino acids to provide adequate quantities of all essential amino acids, especially lysine, threonine, tryptophan, isoleucine, and methionin, which are first limiting.

<u>Barley</u>

Barley ranks fourth in total world cereal production with an annual production of 173.1 million metric tons (FAO 1980).

A summary of 32 experiments with swine indicates that barley has a feeding value of 91% that of maize. Some studies have demonstrated that barley is equal to maize, sorghum, and wheat for young starter pigs and for growing pigs. This apparent inconsistency appears to be mitigated by a high fibre and low energy content, on the one hand; and a high level of crude protein and essential aminoacids, on the other.

Limitation of available energy is an important factor in the inferior performance of growing-finishing pigs and poultry fed barley rations in contrast to those fed maize and wheat. This reduced feeding value of barley is due to its relatively higher crude fibre content and the apparent inability of the pig and chicken to consume enough net energy to gain at a maximum and efficient rate. Barley hull fibre acts as a diluent of available nutrients and may also contain factors which physically or chemically inhibit nutrient digestion, absorption or utilization. Growth inhibitors in barley have also been suggested in work with poultry. Digestibility data indicated that the observed effect on growth and feed conversion is primarily caused by lowering the digestibility of the energy-supplying nutrient of the diet, a reduction that is greater with fibre from barley hulls than from cellulose. It is also suggested that the more pronounced depression with hulls could result from a physical interference with the activity of digestive enzymes due to the form of the fibre or from direct chemical inhibition of enzyme action.

A comparison of the crude protein and essential amino acid content of barley and maize indicates that barley contains more total protein and higher levels of lysine, tryptophan, and the sulphur containing amino acids, methionine and cystine, and suggests that barley may be superior to maize in its capacity to meet the requirements of young growing pigs for these nutrients. During the early growth period, pig performance is more heavily dependent on level of dietary protein and level and balance of essential amino acids than on total energy concentration. It appears, therefore, that caloric concentration of barley-based rations is adequate to meet the needs of the young growing pig and that improved level and balance of limiting amino acids, especially lysine and tryptophan, are able to support pig performance similar to that obtained with complete mixed rations based on maize, wheat or sorghum.

Wheat

Wheat is low in fibre and high in metabolizable energy and compares favourably with other grains in energy content. Expressed on a dry matter basis, wheat contains an average of 4 430 kcal/kg gross energy with a high percentage being digestible by swine, poultry and cattle. The ME values for wheat for swine and poultry are 3 660 kcal/kg and 3 460 kcal/kg, respectively.

The protein content of wheat from the world collection was shown to vary from 6 to 22%, but the wheats most commonly used contain 13-15% crude protein. Although grains of higher protein content are of interest to livestock producers, use of wheat should be based on type and amino acid analysis, since it has been shown that red wheats are inferior to white wheats and hard superior to soft. The percentage of some essential amino acids (histine, lysine, cystine, threonine, and tryptophan) in wheat decreases with increasing protein content. The protein of wheat is highly digestible and generally of high quality. For pigs, lysine has been shown to be the first limiting amino acid followed by threonine, valine and methionine.

The relative feeding value of wheat has been estimated to be between 91 and 106% that of maize, 109-114% that of barley and similar to that of sorghum. When properly supplemented with protein and/or amino acids wheat can be used as the sole cereal in growing and finising pig diets without reducing performance or carcass quality. Researchers at Kentucky showed that soft red winter wheat is an excellent substitute for maize in diets for growing-finishing pigs, if properly formulated to meet lysine requirements. Wheat substitution for maize should be on a basis of weight or lysine and not protein.

When properly supplemented, wheat is an excellent feed grain for poultry. Canadian researchers (Gardiner et al., 1981) used an 11.3% protein wheat as the sole grain source in 28-day-old broiler chicks and demonstrated that it was equal to maize and superior to sorghum. When the supplement was soybean meal 0.23% supplemental methionine was required to support maximum gains and efficiency.

Feeding wheat to ruminants must be done with some caution as it can cause acute indigestion in unadapted animals. Oltjen et al., (1966) fed rations containing 90% soft, red, winter wheat or 90% maize or 60-30% combinations of each grain. Steers fed 60% or 90% maize rations gained significantly faster (1.4 kg/day) than steers fed 60 or 90% wheat rations (1.1 kg/day).

Oats

The protein content of oats (Avena sativa L) is relatively high (11-14%) and the amino acid distribution is more favourable than that of maize. Nevertheless, oats are not widely fed to swine or poultry because approximately one-third of the grain is hull. Gains and feed efficiency of growing pigs are decreased as the quantity of ground oats is increased in the diet. This depression in performance is due to the hull portion of the oats and results from the dilution of utilizable energy and lowered feed intake. The feeding value of oats is principally determined by the proportion of hulls, which in composition are equal to straw and, thus poorly utilized by pigs and poultry.

Recent studies with cattle of different age groups indicate that steers and non-lactating cows digest completely the starch of rolled oats and that steers digested more of the starch of the whole grain than did cows. Nevertheless, the lower ME content of oats compared to maize and barley is reflected in overall animal performance. During fattening, oat-fed calves had lower average daily gains, consumed more grain, were less efficient and produced lighter carcasses with lower dressing percentages than those fed maize but were similar to barley-fed calves except that these produced carcass weights and dressing percentages similar to maize-fed calves.

The lower ME content of oats compared to maize, barley and wheat grains is generally reflected in poor growth rates by both sheep and cattle. However, with lactating animals, the production of milk and milk solids is influenced by rumen fermentation patterns which depend on dietary nutrients other than energy per se. In a recent study to compare diets containing 60% rolled barley, rolled wheat or oats, cows fed the oats diet produced the most milk and 15% more milk fat, while those fed the barley diet produced the least milk. It has also been found that lactating cows produced more milk and milk fat with rolled oats as against rolled wheat, rolled barley or ground ear maize when fed at 32% of the ration dry matter.

Rye

Rye is a cereal not commonly used as a grain for swine and poultry and only to a slightly greater extent for sheep and cattle. Research has demonstrated that pigs, poultry and cattle perform poorly when fed rye. Bowland (1966) showed that substituting 25% rye for an equal quantity of wheat reduced gains of finishing pigs. Several workers have reported the growth-depressing effect of rye when it replaced maize in the rations for poultry. Moran et al., (1970) observed growth depression when rye constituted more than 25% of the grain component of the ration. MacAuliffe and McGinnis (1971) noted growth depression of chicks when rye replaced wheat as 40% of the diet. Patel and McGinnis (1976) noted chick growth depression at levels as low as 25%.

It is now commonly recognized that although rye contains more than 12% protein and a good level and balance of the essential amino acids and a level of ME similar to that of barley, the presence of undesirable factors has limited its use as a livestock feed.

Several factors have been studied in an attempt to explain the detrimental effect of rye on pig and poultry performance. The presence of ergot (Claviceps purpurea) in rye grain has been studied as a causative agent for the poor performance of pigs and poultry. Ergot in rye grain fed to pregnant sows caused reproductive problems, abortion, agalactia and loss of piglets at farrowing. Levels of 1.0 or 2.0% ergot in swine rations severely reduce both feed intake and weight gains.

Other studies (Wieringa, 1967) indicate that rye contains a fat-soluble, growth inhibiting substance. This substance is reported to be a mixture of resorcinols. The growth of pigs on diets with 50% rye or an equivalent amount of the growth-inhibiting substance contained in rye oil was 11-12% slower than on diets formulated with 50% barley.

When fed to chicks, rye is rachitogenic as well as growth depressing. The component or components of rye that cause these effects have not been identified. MacAuliffe and McGinnis (1971) postulated that the low nutrition value of rye is related to the presence of a substance which stimulates the growth of an adverse microflora in the intestinal tract of the chick. Wagner and Thomas (1977) and Misir and Marquardt (1978) postulated that rye contained one or more pectin-like compounds which interfere with the absorption and retention of nutrients. Rye contains 7.9% pectin on an as-fed basis whereas barley, maize, oats, and wheat contain 0.5, 0.2, 0.6 and 1.2% pectin, respectively. Later studies have indicated that rye contains factors, possibly pectin-like substances, which interfere with the normal utilization of several nutrients, including protein, fat, vitamin D, and minerals, particularly calcium.

Rye grain at levels of 60-80% of the diet in calf starter depressed dry matter intake and weight gains. However, roasting of the grain improved palatability and alleviated the growth depressing effect. Replacement of barley by rye also reduced the intake in the cows but had little effect on milk yield or composition.

Triticale

Triticale is a polyploid hybrid cereal derived from an interspecific cross between durum wheat (Triticum durum) and (Secale cereale). Interest in triticale as a feed has been generated because of its reported higher protein and improved amino acid composition as compared to other cereal grain. Although triticale has shown promise as a nutritionally competitive feed grain with maize, wheat, sorghum, and barley in some studies, several feeding studies with growing and finishing pigs indicated that triticale was inferior to maize, wheat, sorghum and barley.

The differences in nutritive value of triticale for swine are due in part to the method of substitution of this grain in the diet. Most experiments have made comparisons based on either a substitution of grains by triticale on a weight basis or adjustment on an isonitrogenous basis. Several studies demonstrated that triticale was equal to barley when substituted on an equal weight basis in swine starter diets; however, triticale could not be substituted on an isonitrogenous basis without having a detrimental effect on pig performance. Allee and Hines (1972) showed that triticale was equal to sorghum as an energy source for growing swine, but on an equal protein or lysine basis, gains and feed efficiency were reduced.

Sell et al., (1962) reported that on a weight basis, triticale was approximately equal to wheat in nutritive value for chicks. The limiting amino acids were lysine and threonine and overall protein quality was somewhat inferior to wheat. Bixler et al., (1968) observed that chicks fed triticale did not grow as well as those fed maize or wheat in diets of equal nitrogen content. These researchers and others have confirmed that triticale was a suitable replacement for wheat if dietary lysine and energy contents were maintained. Wilson and McNab (1975) and Yaqoob and Netkz (1976) concluded that triticale is superior or equal to maize in broiler diets. Rao et al., (1976) reported that triticale could replace increasing proportions of maize in diets of equal nitrogen and energy content for broilers without affecting performance. Reddy et al., (1979) found that triticale could replace up to one half of the maize in broiler diets wthout affecting performance. Replacing more of the maize on either an equal nitrogen basis or a weight basis adversely affected performance. Also, quantitative replacement of maize by triticale in laying hen diets was shown not to adversely affect egg production and egg weight.

The inconsistencies in nutritive value reported for triticale are related to the fact that triticale is not a discrete entity. Considerable variation exists among the numerous crosses and varieties. Screening tests for protein and lysine at CIMMYT on 2 400 lines of triticale showed a mean protein content of 13.4% with a range of 12.9 - 19.1%, and mean lysine was 3.4% with a range of 2.6 - 3.9% (Villegas, 1973). Michigan workers also observed wide variation in amino acid content of four varieties produced during the same season.

Genetic selection of varieties of improved nutritional value

As crop yields have peaked, geneticists have sought other means of plant improvement to meet world nutritional needs. They have searched for unique genes that improve the nutritional quality of many of the grains. Development of grain cultivars with higher than normal contents of specific amino acids has been described by Mertz et al., (1964) for opaque-2 maize. Grain cultivars with higher than normal protein content have been described by Munck et al., (1971) for Hiproly barley and by Reeves (1974) for high protein oats. Hull-less barley and oat varieties with reduced fibre and increased energy content have also been produced.

Plant geneticists, in their search for maize of improved nutritional value, have identified mutants with interesting nutritional qualities. The existence of opaque-2 genes in maize has been known since 1935. However, it was not until 1963 that Purdue University scientists determined that the opaque-2 mutant contained more lysine than normal maize kernels. Subsequent studies demonstrated that the endosperm of opaque-2 kernels contained twice as much lysine and tryptophan, 50% more arginine, aspartic acid, and glycine and 30% less alanine and leucine than isogenic lines that did not contain the opaque-2 mutant gene. The contents of the two most limiting amino acids, lysine and tryptophan, are increased because of a reduction in the ratio of zein to glutelin from 41-52% zein and 17-28% glutelin to approximately 16% zein and 42% glutelin.

The value of opaque-2 maize for pigs and poult depends upon its amino acid adequacy in supplying the requirements of animals of different ages and in performing different functions.

These requirements are adequately furnished by normal maize supplemented with soybean meal, fish meal or a combination of these with other high protein supplements and/or crystalline amino acids. Therefore, the value of opaque-2 maize is associated with the ability of this grain to substitute for a portion of the supplemental protein.

A limitation of opaque-2 maize is its 15-25% reduced yield compared with similar common maize varieties and its susceptibility to ear rot in the field and insect damage in storage. These poor agronomic characteristics have discouraged its production, even in areas where supplemental protein sources are scarce and expensive.

During the past 13 years (CIMMYT) breeders have developed dent and flint varieties of high-lysine maize that have similar nutritional qualities to the original opaque-2 maize but with grain characteristics similar to those of common maize. Breeding pools have been developed for both tropical and semitropical environments. New varieties developed from these pools have yields not different from their normal counterparts and significantly improved ear quality. Recently produced varieties contain 4.0-4.2% lysine and 0.9-1.0% tryptophan, and in rat trials have supported protein efficiency rations (PER) and biological values (BV) not different from those produced with opaque-2 maize counterparts.

These agronomic improvements and stabilized nutritional value have stimulated renewed interest in these hard-endosperm, high-lysine maize varieties in both developed and developing countries. Guatemala leads in acreage of "quality protein maize" in commercial production, and many other countries, including Honduras, Bolivia, Haiti, Dominican Republic, Mexico and China, are significantly increasing the area seeded to these new varieties.

The genetic removal of hulls from barley and the production of hull-less varieties of interest to livestock producers. Even though it has been shown that differences other than crude fibre content may exist in the nutritive value of hull-less barley varieties, most hull-less varieties are superior to isogenic hulled varieties for growing-finishing swine. Hull-less barley contains more digestible energy than its hulled counterpart (3 300 to 3 400 versus 2 960 to 3 130 kcal/kg).

The protein and amino acid contents of 289 samples of oat grains have been examined and it has been determined that increased protein in oats is not accompanied by decreased lysine concentration in the protein as in many other grains. Oat varieties of high protein content are now available. Workers at North Dakota replaced up to 60% of the maize in growing-finishing diets for pigs with a high protein oat cultivar (DAL) with no difference in weight gains or efficiency of feed utilization. Another high-protein oat cultivar (Hinoats) was efficiently utilized by pigs in experiments by Canadian researchers. In experiments in South Dakota, milk production was higher when cows were fed high-protein oats rather than regular oats (23vs 21 kg/d); production with maize was 22 kg/d. Weight gains, feed intake and feed efficiency of calves were similar when isonitrogenous diets contained high protein oats, regular oats or maize. High protein oats can effectively replace maize and soybean meal in the concentrate mix fed to lactating cows and growing calves.

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