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The Use of Wheat In Modern Feeding Programs For Broilers or Replacement Pullets

Talmadge S. Nelson

The importance of the cereal grains in the formulation of poultry feeds was emphasized by the introduction of high energy rations about 20 years ago. Prior to that time ingredients used in diets were without specific classification. The complex nature of todays' computer formulated feeds balanced in energy, amino acids, minerals and vitamins depends on the cereal grains as the primary source of energy. In this capacity they also serve in a secondary role as sources of amino acids. Thus, both the energy and amino acid content of specific cereal grains must be considered when formulating poultry rations.

Corn is the primary cereal grain used in poultry rations in most of the United States. In the Pacific Northwest and in Canada wheat is the predominant cereal grain. Wheat is also the primary cereal grain used in poultry rations in Australia (McDonald, 1962; Cumming, 1969). Pino (1962) reported that corn, rice and wheat in that order were the energy sources used in the Pacific area.

Whether or not to use wheat in poultry rations is basically a question of availability and/or economics. Where competition with other cereal grains exists, the use of wheat may vary from year to year depending on the availability and price of other grains. Wheat has been fed to poultry since the industry has been in existence (Ewing, 1963). It is usually fed to animals when its price is low compared to corn. However,

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in the United States the use of wheat as a food for human consumption has largely priced wheat out of the feed market. This food-feed competition has existed for many decades. Wright (1899) stated "wheat was formerly too dear to be employed unless damaged; and if the damage be great, it had better not be meddled with. . ." More recently, Nichols (1970) also commented on the economics of feeding wheat. Thus, if the price of wheat becomes competitive with other cereal grains, it is possible that it may be used in feeds in geographic areas where it was not used before.

Digestibility

The digestibility of most of the components of wheat is similar to that of other cereal grains. There appears to be little or no difference in the digestion of different types of wheat. Halnan (1926) reported that the digestibility of all nutrients in two varieties of wheat were similar. Halnan (1928) also found that strong wheat, weak wheat and durum wheat and corn were all equal as sources of nutrients for poultry based on digestion trials. Morimoto and Yoshida (1954) reported that the nitrogen-free extract of both wheat and corn were completely digested. Bolton (1955) obtained complete digestion of the sugar and starch portion of wheat whereas cellulose and lignin were not digested. Eighty percent of the protein in wheat and 86% of the protein in corn was digested. Butterworth (1962) used three different methods to test protein utilization from cereal grains by chicks. Wheat, barley and corn were equal in value based on gross protein value and protein retention measured by a balance study and body composition. Vohra (1966) summarized energy sources used in poultry rations. The digestion coefficients of protein and nitrogen-free extract for corn, barley, milo and wheat did not vary greatly. The coefficient of digestion for the ether extract portion of wheat was lower than that of the other cereal grains. This is probably of little importance because of the low amount of fat in wheat.

Energy

Much of the nutritional research on feeding wheat to young chicks during the past 20 years has been studied to determine its metabolizable energy content. Hill (1952) reported that the calculated energy content of wheat was 1,423 calories per pound. The values for wheat and several other cereal grains were similar to determined values. Several investigators have reported the metabolizable energy content of unspecified types of wheat (Table 1). The values reported by Sibbald *et al.* (1960) were 26% lower than those found by Hill and Renner (1957). The metabolizable energy content of the wheats tested by Potter and Matter-

Table 1. Metabolizable energy content of wheat.

	Metabolizable energy
	Kilocalories per pound[1]
Hill and Renner (1957)	1,690
Potter and Matterson, (1960)	1,470
Sibbald, *et al* (1960)	1,340
Sibbald and Slinger, (1962)	1,540[2]
Sibbald and Slinger, (1963)	1,490[3]
Matterson *et al.* (1965)	1,470
	1,570

[1] Dry matter basis.
[2] Average of 25 samples.
[3] Average of 3 samples.

Table 2. Metabolizable energy content of wheat.

	Type or Variety	Protein	Metabolizable energy
		%[1]	Kilocalories per pound[1]
Hill, *et al.* (1960)	Hard red	17.2	1,610
	Hard yellow	13.3	1,690
	Soft red	14.0	1,650
	Soft white	10.5	1,710
	Canadian frosted	16.3	1,630
Sibbald, *et al.* (1962a)	Avon	14.1	1,530
Sibbald, *et al.* (1962b)	Northern	17.4	1,400
Sibbald and Slinger, (1962)	Western feed		1,550
	Ontario		1,530
Schumaier and McGinnis (1967)	Burt	13.1	1,380
	Marfed	13.1	1,460
	Omar	12.8	1,440
	Gaines	11.5	1,410
	Itama	14.3	1,310
Lockhart, *et al*, (1967)	Durum		1,590
Falen and Petersen	Gaines		1,280

[1] Dry matter basis.

son (1960) Sibbald and Slinger (1962) and Sibbald and Slinger (1963) were similar. Butterworth (1962) reported that the metabolizable energy content of wheat was 1140 kilocalories per pound, which is almost 50% less than that reported by Hill and Renner (1957). Matterson *et al.* (1965) found that the metabolizable energy content of wheat was 1470 kilocalories per pound. The metabolizable energy content of three samples of Australian wheat, apparently on an air dry basis, was 1,490, 1,320 and 1,480 kilocalories per pound (McDonald, 1964).

Several investigators have reported the metabolizable energy content of specific varieties or types of wheat (Table 2). Anderson (1955) and Hill *et al.* (1960) tested different types of wheat ranging in protein content from 19.5% to 17.2% on a dry matter basis. The metabolizable energy content of these samples was similar in spite of variation in protein content. The average energy content of these samples was 1,660 kilocalories of metabolizable energy per pound of dry matter. The energy content of Canadian frosted wheat was no different than that of the other samples of wheat tested. Sibbald *et al.* (1962a, 1962b) found the metabolizable energy content of Avon wheat was higher than that of Northern wheat. The energy content of wheat was not affected when it was sprouted, sprouted and frozen, or sprouted and allowed to mold. Falen and Petersen (1969) also reported no difference in the metabolizable energy content of normal and sprouted wheat. Sibbald and Slinger (1962) summarized the energy values they had obtained for various samples of wheat. The average metabolizable energy content of all samples tested was 1,540 kilocalories per pound of dry matter. The energy content of the whole grain and ground grain, or pelleted grain were similar. Schumaier and McGinnis (1967) tested five varieties of wheat grown in the Pacific Northwest. The metabolizable energy content ranged from 1,310 to 1,460 kilocalories per pound of dry matter. Lockhart *et al.* (1967) found the energy content of durum wheat was 1,590 kilocalories per pound.

The metabolizable energy content of the various samples of wheat shown in Tables 1 and 2 were not consistent. The difference between the lowest and highest was about 25%. Hill *et al*, (1960) observed that the metabolizable energy content of wheat was consistent in spite of a wide range in protein content. Schumaier and McGinnis (1967) found that the proximate analysis of wheat did not indicate metabolizable values. They also observed that the energy content was not related to pentosan content or to the location where the wheat was grown. Sibbald and Slinger (1963) tested wheat with bushel weights of 57, 61 and 65 pounds and found no difference in their metabolizable content. The condition of the wheat apparently has little or no effect on its energy content. The metabolizable energy value for Canadian frosted wheat was similar to other samples tested, Hill *et al.*, (1960). Sibbald *et al.* (1962a) found no difference in the metabolizable energy content of normal wheat and laboratory preparations of sprouted wheat or sprouted wheat that had been frozen or allowed to mold prior to feeding.

The physical form in which wheat is fed and the effect of pelleting on its metabolizable energy has been studied with inconsistent results. McIntosh *et al.* (1962a) fed wheat as the whole grain and coarse, medium and fine ground grain. No consistent effect of grinding was obtained although in two of the three tests higher values were obtained for whole wheat. McIntosh *et al.* (1962a, 1962b) and Sibbald and Slinger (1962) showed that pelleting wheat did not improve its energy content. However, indirect evidence has been reported suggesting that pelleting will improve the energy content of wheat. Cave *et al.* (1965) improved the metabolizable energy of wheat by-products 15 to 30% by pelleting. Bayley *et al.* (1968) also increased the energy utilized from wheat bran and wheat germ by pelleting but also found that this treatment decreased the energy content of middlings and shorts. Summers *et al.* (1968) reported that pelleting increased the energy content of wheat bran. If the energy content of these by-products can be increased by pelleting then it is possible that the energy utilized in whole wheat can also be improved by pelleting. The degree of improvement would be in proportion to the amount of the by-product present in the intact wheat.

Protein-amino acids

The protein content of the various types of wheat ranges from approximately 10% to 16% on an air dry basis (Crampton and Harris (1969). There is apparently little or no difference in the quality of the protein in wheat as its content varies. Hepburn and Bradley (1965) found different proportions of amino acids in varieties of hard wheat high and low in nitrogen. However, these differences were small compared to the magnitude of difference in total nitrogen. They concluded that the differences in amino acid composition were too small to be of importance in nutrition and that typical analysis tables could be used for the amino acid contribution of wheat to diets.

The protein of wheat is apparently well utilized by the chick although it is deficient in lysine and perhaps the sulfur containing amino acids. Davidson *et al.* (1962) demonstrated amino acid imbalances in oats, barley, corn and wheat when these grains were fed as the only protein source. Jeppesen and Grau (1948) fed chicks a diet containing a wheat protein concentrate supplemented with lysine, methionine, arginine, tryptophan and leucine. Growth depression occurred only when lysine was omitted from the diet. March *et al*, (1950) also showed that wheat protein is deficient in lysine. They reported that the addition of lysine to a diet containing wheat as the sole source of protein stimulated growth, whereas methionine and tryptophan depressed growth. They also showed that the combination of fish meal with low protein wheat was more effective than when combined with high protein wheat. Carpenter (1951) indicated that barley, oats, and wheat were deficient in lysine and the sulfur containing amino acids.

Slinger *et al.* (1953) conducted two experiments with chicks in which high levels of wheat were fed in the starting and finishing rations. The addition of methionine had no effect on final body weights but appeared to improve feed efficiency. McDonald (1957, 1958) reported that the sulfur amino acids were deficient in diets composed largely of wheatmeal and that a growth response by chicks was obtained by adding methionine to these diets.

Table 3. Amino acid content of wheat and the biological availability to growing chicks.[1]

Amino Acid	Content of grain %	Biological availability[2] %
Lysine	0.362	94.3c
Histidine	0.287	95.5c
Arginine	0.604	92.0bc
Aspartic acid	0.687	91.9bc
Threonine	0.391	92.7bc
Serine	0.609	94.5c
Glutamic acid	5.241	97.5c
Proline	1.394	96.6c
Glycine	0.627	70.8a
Alanine	0.394	89.9bc
Cystine	0.136	96.1c
Valine	0.543	92.2bc
Methionine	0.180	81.8b
Isoleucine	0.436	94.2c
Leucine	0.894	95.2c
Tyrosine	0.384	94.3c
Phenylalanine	0.645	95.8c
Protein (N x 6.25)	14.91	
Means		**93.6 ± 4.66[3]**

[1] Sharby, 1969

[2] Means of six individual chicks. Means not having the same superscript are significantly different ($P<0.01$).

[3] Means of 17 amino acids with standard deviation.

While much of the work on wheat protein has been defining its amino acid adequacy, the final determination of its quality is the availability of these amino acids. Sharby (1969) studied the amino acid content of wheat and their biological availability to growing chicks (Table 3). The sample studied contained 0.362% lysine and 94.3% of this was absorbed by the chick. It also contained 0.316% of the sulfur amino acids. However, the absorption of cystine was 96.1% whereas only 81.8% of the methionine was absorbed. This low availability of methionine may explain why McDonald (1957, 1958) obtained a growth response from supplemental methionine when chicks were fed diets containing wheatmeal. The average availability of the amino acids in wheat reported by Sharby (1969) was 93.6%. The average biological availability of the amino acids in soybean meal and grain sorghum was 89.7 and 97.6 (Bragg *et al.* (1967, 1969).

A portion of the amino acids in wheat is in the aleurone cells which comprise about 7% of the wheat kernel. Kohler *et al.* (1970) observed that many of these cells pass through the alimentary tract intact, reducing the amount of nutrients digested. These cells are ruptured by pelleting, which released the nutrients for utilization by the chick. Thus undigested aleurone cells could explain some of the beneficial effects of pelleting on the energy content of wheat by-products. This may also explain why

Sharby (1969) found that the amino acids were not completely available to the chick.

Feeding trials

The feeding of wheat as a portion or as all of the cereal grain in the diets of growing chicks has produced variable results. Crampton (1936) reported that barley, corn and wheat were essentially equal in balanced rations. Poley (1938a) fed chicks diets containing 75% wheat. When the wheat was finely ground feed accumulated on the beaks of the chicks whereas it did not when the wheat was coarse ground. Biely *et al.*, (1951) found that wheat could replace corn pound for pound in the Connecticut broiler ration. However, when the levels were adjusted for protein content growth depression occurred which, they stated, may have been the result of amino acid or mineral imbalances. A reduced energy content of the diets may have also contributed to the growth depression. Slinger *et al.* (1953) grew chicks to 10 weeks on diets containing wheat as the primary cereal grain and concluded that growth was satisfactory. Summers *et al.* (1959) fed diets containing various combinations of wheat and corn and including the complete replacement of corn by wheat. They reported that diets containing wheat were equal to or superior to diets containing corn based on the rate of growth and efficiency of feed conversion. Sibbald *et al.* (1960) also reported that chicks fed wheat gained better than those fed corn. Davidson *et al.* (1961) concluded that when protein and energy were controlled in rations containing individual and mixed cereal grains there was no difference in the energy utilization.

Yoshida (1962) fed chicks various cereal grains in isocaloric and isonitrogenous diets. Compared to corn, the index of weight gain for oats, wheat, and barley was 93, 90, and 83.

McIntosh *et al.* (1962b) fed growing pullets diets containing wheat and corn alone and in combination. Weight gains and feed efficiencies were superior when the diets contained both grains compared to wheat alone. The form in which the grain was fed influenced the rate of gain when the diet contained wheat as the only cereal grain but not when the diet contained wheat and corn. Ground wheat was approximately equal to corn plus wheat. Pelleted and whole wheat were not as efficiently utilized in the all wheat diets. Older chicks appeared to utilize whole wheat better than young chicks. They suggested that wheat may be included in the starting ration at a level of 30% without affecting weight gain and feed efficiency. After 5 weeks of age wheat can be fed as the sole cereal grain without adverse effects.

McDonald (1964) concluded that corn and wheat were equal on direct comparison in high energy diets. However, if diets are adjusted for protein content, wheat-fed chicks grew less. Milner and Woodford (1965) dried high moisture wheat and fed it as the sole cereal grain and protein source. No difference was obtained for wheat dried at various temperatures. Lambert *et al.* (1968) compared pre-ripe and ripe wheat when it replaced a portion or all of the grain. No difference occurred in body weight of chicks although feed efficiency was better when chicks were fed control diets. Chicks fed sprouted wheat perform as well as those fed normal wheat (Sibbald *et al.,* 1962a; Falen and Petersen, 1969).

Adams and Naber (1969a) compared the performance of chicks fed diets containing equal amounts of corn, wheat or barley. When these grains were untreated, chicks fed the diet containing corn gained slightly more weight in five of six experiments and had better feed efficiency in four of these tests. Soaking wheat in dilute hydrochloric acid improved chick growth but steam expansion did not. Adams and Naber (1969b) obtained better growth and feed efficiency of chicks fed soft wheat than those fed hard wheat. Soaking these wheats in water improved the performance of chicks fed hard wheat but not those fed soft wheat. Naber and Touchburn (1969) compared the performance of chicks fed diets containing either corn, wheat or barley. When these grains were untreated, chicks fed corn grew faster and had better feed conversion rates at four weeks of age followed by those fed wheat then barley. Water treatment of the grains resulted in a statistically significant improvement in growth rate of chicks fed both wheat and barley which the authors attributed to increased starch utilization in these grains.

Petersen (1969) fed chicks diets containing 50% cereal grains. Their ability to promote growth was evidenced in descending order by corn, oats, sorghum low in tannin, wheat, sorghum high in tannin, and barley. Average feed consumption was similar for the corn, sorghum and wheat diets but was higher when the chicks were fed diets containing either barley or oats.

Diets containing high levels of wheat will be deficient in two and perhaps three vitamins and in pigments. Poley (1938a) reported a vitamin A deficiency in chicks fed a diet containing wheat. This deficiency was prevented by alfalfa meal. Wagstaff *et al.* (1961) obtained a growth response by adding biotin to diets containing 75% of each of several cereal grains. Dermatitis occurred when the diets contained wheat or barley but not when they contained either corn, milo, or oats. When the diets contained supplemental biotin, the growth of chicks fed wheat and corn was similar and was better than that of chicks fed the other grains. McDonald (1957) showed that wheat diets were marginal in folic acid.

Wheat contains neither leutin nor zeaxanthin, the pigments responsible for the yellow color in the shanks and skin of chickens. In some areas of the world where wheat is the primary cereal grain fed, light

skinned breeds have been developed. However, if pigmentation is desired, it must be supplied by some ingredient other than wheat.

Body Composition

The effect of the different cereal grains on body composition has created sporadic interest among investigators. Maw (1935-36), Maw and Maw (1938-1939) and Maw *et al.* (1938-39) fed cockerels and broilers diets containing either corn, barley, oats or wheat. The corn diet produced more fat in the edible portions of the flesh. Wheat, barley and oats produced more fat in the abdominal area and skin. Poley *et al.* (1940a, 1940b) fed diets containing corn, barley and wheat to fryers and roasters. The corn fed chickens had more fat in the edible portions than those fed wheat or barley. However, the different treatments had no effect on the dressing and cooking percentage. The aroma, juiciness and tenderness of the meat of the chicks fed the various grains were the same. Lewis *et al.* (1956) reported the ether extract content of chicken carcass when different grains were fed. The highest mean percentage of ether extract in the dark and light meat occurred when the chicks were fed diets containing barley followed by wheat, oats and corn. When the whole carcass was examined, the distribution of fat in the abdominal, neck and subcutaneous regions was greatest for corn followed by wheat, oats and barley. Petersen (1969) studied the effect of various grains on body composition and taste of meat. None of the grains caused differences in the protein and ash content of the carcass. The variation was greater for fat, moisture and dry matter. Fat composition was highest when the diet contained sorghum, lowest when it contained barley, and intermediate when the diets contained wheat, oats, and corn. This investigator suggested that the grain fed may influence fat synthesis in the body. No differences were found in the appearance, consistency, or taste of the meat from the chicks fed the various grains.

Phytase

One aspect of wheat in the nutrition of the chick which appears to have been overlooked is its phytase content. This enzyme hydrolyzes phytate to inositol and inorganic phosphate. Phytate phosphorus is not available to the chick (Gillis *et al.* 1957) but after hydrolysis by phytase can be utilized as well as a supplemental inorganic phosphate (Nelson *et al,* (1968a). Mellanby (1944) and McCance and Widdowson (1944) reported that certain cereal grains including wheat contain phytase. Peers (1953) found that phytase was concentrated in the endosperm. Acker and Beutler (1963) observed that the breakdown of wheat phytate increased when the relative humidity increased from 45 to 80%. They found this hydrolysis to be enzymatic and bacterial. Evidence suggesting that wheat phytase increased the utilization of phytate phosphorus in the diet of chicks has been reported.

The total and phytate phosphorus content of wheat apparently varies according to variety. Lee and Underwood (1948) and Nelson *et al.* (1968b) reported that approximately two-thirds of the total phosphorus in wheat occurred as phytate. Hay (1942) noted that white wheat may contain less phytate phosphorus than red wheats. Young and Greaves (1940) found that phytate did not vary directly with total phosphorus and that both total and phytate varied with both variety of wheat and the treatment during the growing season. The contribution of wheat phytase to phytate hydrolysis has not been investigated sufficiently to conclude that it actually occurs when wheat is a dietary ingredient.

Summary

Wheat can be fed as the sole cereal grain in rations for growing chickens. This is confirmed by the fact that it is being fed in geographic areas where it is the predominant cereal grain available. The performance of chicks has been variable when comparisons were made of diets containing wheat as the sole cereal grain, diets containing other cereal grains, or combinations of wheat and other grains. The primary reason for this variation in chick response appears to be the energy content of the diet.

The energy level is the primary problem encountered when using wheat as the only cereal grain in diets for growing chickens. This is particularly true when a high energy diet is required. However, this is an economic rather than a nutrition problem. The cause of this problem is the higher protein content of wheat combined with its energy level. When diets contain adequate levels of amino acids, less wheat or other ingredients are required to supply these amino acids. This results in lower energy in the diet unless it is added as fat. The cost of the supplemental fat must be considered in terms of improved chick performance and the price of competitive grains.

The energy content of wheat is variable. However, as much variation in its energy content occurs among investigators as among types and varieties of wheat tested. The variation in the energy content of wheat is probably no greater than that reported for other cereal grains.

In addition to energy, the cereal grains supply from one-fourth to one-third of the amino acids in broiler diets and from one-third to one-half of the amino acids in diets for replacement pullets. None of the cereal grains has a distinct advantage in amino acid pattern. The average biological availability of the amino acids in wheat is in the range of 90 to 95%. The average biological availability of the amino acids in grain sorghum exceeds 95%. No information is available concerning the availability of the amino acids in other cereal grains. Until such information is available, the cereal grains must be compared on the basis of total protein or total amino acid content when this is the consideration. This is especially true for wheat because of the difference in the protein content of the types and varieties available for feed use.

The physical form in which wheat is fed can be important. Finely ground wheat becomes sticky if it gets wet. Diets containing high levels of fine ground wheat may stick to the beaks of chicks, especially if they are young. In order to avoid this the wheat should be coarse ground, or the feed should be pelleted.

Wheat does not contain the pigments responsible for the yellow color in the skin and shanks of chickens. If pigmentation is desired, it must be supplied by other ingredients. The need for diets containing pigments may also contribute to the economic disadvantage of wheat compared to corn.

All of the cereal grains are deficient in some of the vitamins and mineral elements. With the possible exception of the beta-carotene content of corn, none of the cereal grains has a distinct advantage over the others in vitamin or mineral content. The availability of commercially prepared supplements essentially eliminates vitamin and mineral deficiencies as a problem in diet formulation.

Wheat appears to have a greater advantage as an ingredient in diets for growing chickens other than broilers. This is primarily an economic factor since less energy and little or no pigmentation is needed when chickens are grown for replacement purposes. McIntosh *et al.* (1962b) recommended that the wheat content of starter diets fed to growing chickens be limited to 30%. After five weeks of age wheat can be fed as the sole cereal grain. It should be fed as coarse ground grain, or the feed should be pelleted.

The value of wheat in the rations of growing chickens will be based on its nutrient content and the cost of competing nutrient sources. This can be determined easily and rapidly by computer formulation.

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Wheat for Energy and Amino Acids in Layer Diets

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Prior to the price support era beginning with the late 30's, there was considerable interest in the use of wheat for layer diets. For many years thereafter it wasn't feasible to use wheat. In recent years, the reduced cost of wheat as a feed grain has caused it to again become attractive for use in animal feeds. However the information at hand for laying hens on nutrient availability and utilization from wheat is either very old or found in just a few limited recent reports. This simplifies surveying the literature for such information, but leaves something to be desired as to obtaining confirmatory data for making reliable recommendations.

An early report from our laboratory by Poley & Wilson (1941) indicated that bushel test weight of wheat, corn or barley had little consistent influence upon their nutritional values for laying hens. The diets used were rather crude or deficient in some nutrients by today's standards—i.e. 79% grain, 10% meat and bone scraps, 5% buttermilk, 5% alfalfa meal, 1% salt and 0.5% fish oil concentrate. The latter was included only from Nov. 1 through April 1 of each year. The best performance of any group of hens was only 55.4% egg production on a hen-day basis with a diet using 60 lbs./ bushel test weight wheat. In 3 of 4 studies, the hens fed higher test weight wheat outperformed those on the lower test

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