Nutritional Values of Wheat and Wheat By-Products as Affected by Modern Production and Milling Techniques

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Modern civilization ranks wheat among the cereal grains consumed mainly as a food commodity rather than as animal feed. In antiquity, neither man nor animal likely had much selectivity concerning types of wild grasses available to be eaten. However, there is evidence that when man learned selectivity among the grains that could be grown, for a period he regarded barley more highly than wheat as human food. Wheat, apparently for a time, was not regarded especially as human food and was, therefore, used mainly as animal feed. Use of wheat for feed is at present on the upswing of popular interest, so it now has gone the full cycle of utility.

The situation today does not differ in principle from what has prevailed in the past, namely, when wheat is available and comparable in cost to other sources of nutrition for domesticated animals, it is used for feed. However, because in the processing of wheat for human use as food, portions of the wheat supply are utilized as feed, the consideration of wheat as feed becomes complicated.

Since the earliest times, efforts have been made to devise ways in which grain could be ground conveniently and portions of the endosperm separated from the germ and branny outer parts of the kernel. Wheat, for example, in the early development of processing procedures, was

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ground between stones by a rubbing motion, and the outer portions of the kernel partially separated by means of sieves made from hairs of animals (12). The branny parts were not used for food but became either feed for animals or were used as fuel.

Wheat obtained its prominence as human food when man discovered that flour mixed with water developed a dough, and that this dough retained gas as fermentation set in. The baking industry resulted from knowledge gained that the fermented doughs could be baked to produce an acceptable food. This entire procedure depends on the unique properties of wheat proteins to form gluten—a phenomenon duplicated nowhere else by either plants or animals. For this reason, throughout the world, wheat has been for centuries the cereal grain for which there was no substitute insofar as the production of white bread was concerned. To fulfill the demand for wheat flour relatively free from bran, complicated procedures for processing wheat were developed, although it has long been recognized that the methods used discarded portions of the kernel richest in proteins, vitamins, lipids, and minerals for human nutritional needs. Cobb (4), in 1905, produced a diagram of the cross section of a wheat kernel showing the increased protein content of five arbitrary zones, ranging from the starchy endosperm to the outer layer of bran. The distribution of the nutrients of the wheat kernel and how the milling process redistributes these constituents between flour and co-products, depending on extraction rate, has been discussed in books by Bailey (2) (3), Hlynka (6), Storck and Teague (12), and Swanson (14).

The processing of wheat in the United States came about rather slowly. Wheat is not indigenous to the American continent and was first introduced into Mexico by the Spanish about 1529; however, it was first grown in what is now continental United States on Roanoke Island off the coast of South Carolina in 1585. It was the mid 1600's before sufficient wheat was produced in the North American colonies to warrant concern about flour mills and flour milling. Centers for processing wheat developed in New York City, Rochester, Buffalo, St. Louis, Minneapolis, and Kansas City, Missouri, as settlers moved west and land was planted to wheat. At all milling centers, finding markets for the by-products of wheat processing, namely, screenings, shorts, and bran, became a problem as milling enterprises increased in size and capacity. In fact, legal measures had to be taken in Buffalo in the mid 1800's to restrict milling companies from dumping bran and shorts into the canals and obstructing navigation. These products of wheat milling traditionally have been subject to considerable price fluctuation and discriminatory reactions to their feed value. With the development of the formula feed industry, co-products of milling industry began to establish a definite place as the base of feed formulations.

The flour miller is the victim of circumstances insofar as feed manufacturing is concerned. Roughly, about 72% of the total material comprising the wheat kernel during processing becomes wheat flour for human consumption. Thus, the miller has approximately 28% of the processed wheat to sell as feed, mainly as bran, shorts, red dog and germ. Because the miller must fractionate the wheat kernel in a manner that will produce a flour of specific analytical limits and use-properties, feed co-products must absorb the quality and quantity fluctuations. The miller has no other choice.

There have been many improvements and changes in equipment and milling procedures, but none alters the basic concept that milling merely separates the various parts of the wheat kernel. The products will be characterized by the quality of the processed wheat, and the processing will neither add nor subtract from the original nutritive value. The important consideration is the knowledge that in milling wheat, the more nutritious parts of the wheat kernel become feed.

Millfeeds are defined by the Association of Feed Control Officials, Inc. (1970) as follows:

Wheat Bran is the coarse outer covering of the wheat kernel as separated from cleaned and scoured wheat in the usual process of commercial milling.

Wheat Germ Meal consists chiefly of wheat germ together with some bran and middlings or shorts. It must contain not less than 25% crude protein and 7% crude fat.

Wheat Middlings consists of the fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and some of the offal from the "tail of the mill." This product must be obtained in the usual process of commerical milling and must contain not more than 9.5% crude fiber.

Wheat Shorts consists of fine particles of wheat bran, wheat germ, wheat flour, and the offal from the "tail of the mill." This product must be obtained in the usual process of commercial milling and must contain not more than 7% crude fiber.

Wheat Red Dog consists of the offal from the "tail of the mill" together with some fine particles of wheat bran, wheat germ, and wheat flour. This product must be obtained in the usual process of commercial milling and must contain not more than 4% crude fiber.

Efforts are now in progress to enact a Uniform State Feed Bill, and both the Association of American Feed Control Officials and the American Feed Manufacturers Association have passed resolutions favoring such an act. However, at present, State regulations determine the limitations on chemical or ingredient composition and these vary among States. It is obvious from the definitions of the kinds of millfeeds that there is, in commercial milling operations, a wide range of overlap in the con-

Table 1. Average composition of cereal grains[1]

Name of Analysis[2]	Wheat (Hard)	Rye	Corn (Dent)	Barley	Oats	Rice	Sorghum
Moisture, %	10.0	10.5	15.0	10.6	9.8	11.4	10.6
Protein, % (Nx6.25)	14.3	13.4	10.2	13.0	12.0	9.2	12.5
Fat, %	1.9	1.8	4.3	2.1	5.1	1.3	3.4
Fiber	3.4	2.2	2.3	5.6	12.4	2.2	2.2
Ash, %	1.8	1.9	1.2	2.7	3.6	1.6	2.0
Thiamine, mg./kg.	5.5	4.4	4.6	5.7	7.0	3.2	4.6
Niacin, mg./kg.	63.6	1.3	26.6	64.5	17.8	40.0	48.4
Riboflavin, mg./kg.	1.3	1.8	1.3	2.2	1.8	0.7	1.5
Pantothenic acid, mg./kg.	13.6	7.7	5.9	7.3	14.5	7.0	12.5

[1] Source: Feed Composition—Joint United States—Canadian Tables, Publication 1232, National Academy of Sciences—National Research Council, 1964.
[2] All values reported on moisture-free basis.

signing of feed constituents into definite categories. For example, there is often no difference between Wheat Middlings and Wheat Shorts as manufactured during a particular milling operation. For this reason the term wheat middling will not be used, and the term "shorts" will include considerations that could otherwise be included under wheat middlings.

Although the protein value of wheat in any marketing year in the United States varies from seven to twenty-two percent, depending on variety and growing location, the average protein content of wheat is higher than that of other cereal grains, and its essential amino acid distribution compares favorably with that of other grains as shown in Figure 1 (11). A number of very important papers on this subject were presented at the annual meeting of the Animal Nutrition Research Council in Washington, D. C., October 15, 1958. Average compositions of the more important cereal grains are compared in Table 1.

The milling industry has long known that it manufactured an important nutritive constituent for the feed industry. However, millfeed represents no more than 10% of the total ingredients used by the formula feed industry and probably comprises no more than 5% of the total volume of feed consumed. The production, distribution, and selling price of millfeed depend on many interacting variables such as feed-grain price, livestock population, competition from noncereal concentrates, and the fact that millfeed results from flour demand, and thus is manufactured often when prices and demand for millfeed are depressed. In addition, millfeed stocks do not store conveniently and, therefore, must be disposed of soon after manufacture.

In an effort to analyze and improve its competitive position, the milling industry, through the Millers' National Federation, held a panel discussion during the annual convention in Chicago, Illinois, May 14, 1963, on "Millfeed: By-Product, Co-Product, or Product?" (8). The result was clearly that millfeed should not be considered or regarded as a by-product of the processing of wheat. Also equally clear was that the

industry had been laggard compared with other industries in researching, developing, promoting and selling, on a sound business basis, the total products resulting from its processing operations. The question was, what to do to improve millfeed and the feed industry's concept of millfeed?

The milling industry formed a Millfeed Research Committee headed by Dr. W. R. Johnston, Vice President for Research and Development, International Milling Company, Inc., to guide the industry in making millfeed better understood and a more marketable commodity.

Dr. Johnston discussed some of the functions of the Millfeed Research Committee in a paper presented at the Association of Operative Millers Technical Conference at Minneapolis, Minnesota, in May 1965 (7). It has been recognized that a major difficulty in the use of millfeeds by the feed industry has been lack of knowledge of the nutritional and economic worth and nomenclature misunderstanding of such products as bran, shorts, red dog, and durum. Convenient formulations by large feed manufacturers using computerized systems do not lend themselves readily to the use of ingredients that lack standardization and vary widely in chemical analysis and nutritive values. Differences result in the analysis and feed value of millfeeds when made from hard or soft, red or white, winter or spring wheat. Also, two geographical origins of the same kind of wheat will result in different values of the same feed ingredient from one variety.

To clarify the situation, research was sponsored by the Millers' National Federation to completely analyze flours and millfeed made from different wheat types when milled by the same procedure. The results, reported by Farrell *et al.* (5), and Waggle *et al.* (16), show the range of difference in the proximate analysis of the wheat, flour, and millfeed, and of the amino acid, minerals, vitamins, and gross energy values. The nutritional values of these millfeeds were investigated by Moran *et al.* (9) (10), and Summers *et al.* (13), and results were reported for metabolizable energy, metabolizable dry matter, protein quality, nitrogen digestibility, and growth and feed conversions of chicks when diets contained the various fractions, namely, bran, shorts, red dog, and germ. The wheat protein range of the various samples varied from 13.8% for hard red spring to 9.2% for soft white, and other constituents of the wheat kernels varied similarly. However, protein qualities of the millfeeds from these wheats (as measured by net protein utilization, protein efficiency ratio, and nitrogen retention) all agreed well. As would be expected, because of its lower digestibility, the nitrogen in bran in all cases was used less than nitrogen of the other feed products.

In Table 2 are summarized for comparison a few of the data from Summers, Slinger, Pepper, and Moran (13). They show the variability of the metabolizable energy and net protein utilization values for millfeeds manufactured from five hard red winter wheats and a soft white wheat. Variability is as great within a single wheat class as between classes even when the protein content range is from 13.3% to 9.2%. Such differences show the need for accurate nutritive information concerning a millfeed for it to be used efficiently and to maximum extent in the formulation of a feed.

Table 2. Selected data showing metabolizable energy and net protein utilization of millfeeds from five hard winter wheats and one soft white (13).

Wheat Class	Metabolizable Energy Kcal./gm.				Net Protein Utilization			
Hard Red Winter	Bran	Red Dog	Germ	Shorts	Bran	Red Dog	Germ	Shorts
13.3% protein H	1.22	2.96	2.65	1.95	44.1	55.9	56.5	53.7
11.9% protein R-3	1.27	2.81	2.38	2.03	40.6	57.0	57.3	60.9
11.5% protein R-1	1.42	3.35	2.46	2.49	40.5	55.8	53.8	55.7
11.2% protein R-2	1.26	3.22	2.71	2.14	38.6	54.4	65.3	57.7
10.7% protein	1.10	3.17	2.47	2.13	42.7	57.9	58.8	59.0
Soft White Winter 9.2% protein	1.38	2.75	2.56	1.98	41.1	59.9	59.4	60.3

Summers *et al.* (13) also determined the sequence of limiting amino acids for each of the mill fractions for the various wheat types and found in all cases, small but statistically significant differences; however, the differences were attributed to an accumulation of procedure errors rather than to inherent alterations in the samples themselves. The limiting amino acids are not the same for all millfeed products, and this fact is distracting in formulating a feed ration because of the overlap in the production of the milling fractions.

Wheat yields flour, bran, shorts, and red dog in the milling process, the amounts depending on the physical properties of the wheat, the milling operation, and the products desired. All products produced cannot, at the same time, be accurately manufactured to analytical standards. There is no practical way for the usual milling operation to produce flour to the buyer's specification and also to produce standardized millfeed. The problem is difficult and complicated, but the industry is aware of the urgent need to promote more extensive use of millfeed by the formula feed industry, and of the need to standardize both products and product definitions. A start has been made to bring about improvement; progress now can be expected in the following areas:

1. Establish for the milling industry definitely defined chemical and physical property limits for bran, shorts, red dog, and germ, and thus market to the feed industry a more uniform product.
2. Provide to the feed industry protein, amino acid, and metabolizable energy values for all millfeed products.
3. The feed industry should be supplied with reliable information from the milling industry on the nutritive value of millfeeds for various purposes compared with other competitive feed ingredients.

4. Research will continue to supply information on the full potentialities and nutritive values of millfeeds for all types of animals and this knowledge, combined with improvement in product uniformity and better marketing systems will establish millfeed as a reliable feed ingredient.

The nutritional value of millfeed for livestock and poultry is well established; however, the problem to be overcome by the flour milling industry is to develop ways in which millfeeds can be supplied to the feed market as a more uniform and standardized product. The future will undoubtedly bring about many improvements in the procedures for the manufacturing and marketing of millfeeds for livestock and poultry feed formulations.

Bibliography

1. Amino Acids in Animal Nutrition. Papers presented at the Annual Meeting of the Animal Nutrition Research Council, Washington, D. C. Oct. 15, 1958.
2. Bailey, C. H. The Chemistry of Wheat Flour. The Chemical Catalog Company, Inc. New York, N. Y. (1925).
3. Bailey, C. H. The Constituents of Wheat and Wheat Products. Reinhold Publishing Corporation, New York, N. Y. (1944).
4. Cobb, N. A. Universal nomenclature of wheat. Dept. Agr. N. S. Wales Misc. Pub. 539 (1905).
5. Farrell, E. P., A. Ward, G. D. Miller, and L. A. Lovett. Extensive analyses of flours and millfeeds made from nine different wheat mixes. I. Amounts and analyses. Cereal Chem. 42: 39-47 (1967).
6. Hlynka, I. Wheat Chemistry and Technology. American Association of Cereal Chemists, Inc., St. Paul, Minn. (1964).
7. Johnston, W. R. Millfeed—Present and future. Bul. Association of Operative Millers. pp. 2895-2898, Dec. 1965.
8. Millfeed: By-Product, Co-Product, or Product? Panel discussion at the 61st Annual Convention, Millers' National Federation, May 14, 1963. Chicago, Ill.
9. Moran, E. T., Jr., and J. D. Summers. Nutritional value of wheat millfeeds. Feedstuffs pp. 26-38, Apr. 25, 1970.
10. Moran, E. T., Jr., J. D. Summers, and W. F. Pepper. Nutritional evaluation of selected milling fractions from wheats of different type and geographical area of production: First three limiting essential amino acids for chick and performance under dietary conditions calculated adequate. Poultry Sci. 49: 371-387, 1970.
1. Shellenberger, J. A. Importance of protein in wheat. Association of Operative Millers Bul. pp. 3039-3041, May 1968.
2. Storck, J., and W. Teague. A History of Milling. Flour for Man's Bread. University of Minnesota Press, Minneapolis, Minn. (1952).
13. Summers, J. D., S. J. Slinger, W. F. Pepper, and E. T. Moran, Jr. Biological evaluation of selected wheat fractions from nine different wheat samples for energy and protein quality. Poultry Sci. 47: 1753-1760 (1968).
14. Swanson, C. O. Wheat Flour and Diet. The Macmillan Company, New York, N. Y. (1928).
15. Swanson, C. O. Wheat and Flour Quality. Burgess Press, Minneapolis, Minn. 1937.
16. Waggle, D. H., M. A. Lambert, G. D. Miller, E. P. Farrell, and C. W. Deyoe. Extensive analysis of flours and millfeeds made from nine different wheat mixes. II. Amino acids, minerals, vitamins and gross energy. Cereal Chem. 42: 48-60 (1967).