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WHEAT, ITS PRODUCTS AND USES

Prepared by
Commodity Development Division
Northern Regional Research Laboratory
Peoria, Illinois

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Wheat is adapted to production over a wide variety of soils and climates, and is grown extensively throughout the world. In fact, the only inhabited regions from which it is absent are the hot low-lying areas of the Tropics. It keeps well during storage and shipment. These characteristics and the unique physical and chemical properties of wheat gluten, which give wheat flour superiority over flour from other cereals in the production of leavened breads, have made wheat one of the major food plants of the world.

ORIGIN

The origin of wheat is unknown, but it is certain that it was grown and used for food long before the dawn of recorded history. It is mentioned in ancient literature, and archaeologists have found carbonized grains of wheat in the tombs of Egypt and in the excavations of ruins in Turkey, some of which date as far back as 6,000 years.

Many scientists believe that wheat originated in Mesopotamia (Iraq) and spread in all directions from there. Nearly all the cultivated types of wheat are being produced in that area, which fact indicates that wheat may have originated there. Wild wheat has been reported to have been found growing in that region, but some doubt exists concerning the accuracy of this report.

1/ This is a compilation of selected information from various sources for use in the development of new scientific, chemical, and technical uses and new and extended markets and outlets for wheat, its products and byproducts. The sources of this information, in some instances, are cited in direct connection with the information presented, but in other instances mention of them is only by inference by their inclusion in the selected list of references given at the end of this pamphlet.

BOTANICAL DESCRIPTION

Wheat is a mid-tall, annual grass with flat blades and a terminal spike. It belongs to the grass family (graminaceae), the tribe Hordeae and the genus Triticum. The following eight divisions of the genus Triticum were used by Hackel 2/ and recognized by others for many years.

- Triticum
  - sativum
    - tenax
      - vulgare Vill ...... Common wheat
      - compactum Host .... Club wheat
      - turgidum L .... Poulard wheat
      - durum Desf .... Durum wheat
    - dicoccum Schrank .... Emmer
    - spelta L .... Spelt
  - polonicum L .... Polish wheat
  - monococcum L .... Einkorn

In recent years the species of wheat have been classified on the basis of chromosome numbers, and new species have been described. Classification by Flaksberger et al. 3/ in 1939 of the species known at the present time, grouped according to chromosome number and with their common names used in the United States, is as follows:

Diploid series 14 chromosomes	Tetraploid series 28 chromosomes	Hexaploid series 42 chromosomes
T. spontaneum Flaks., wild einkorn	T. dicoccoides Körn., wild emmer	T. spelta L., spelt.
T. monococcum L., einkorn	T. timopheevi Zhuk., timopheevi	T. vulgare (Vill.) Host. (T. aestivum L.), common wheat.
	T. dicoccum (Schrank) Schübl, emmer.	T. compactum Host., club wheat
	T. durum Desf., durum wheat.	T. sphaerococcum Perc., shot wheat.
	T. abyssinicum Vav., Abyssinian wheat	T. macha Dek. et Men., macha
	T. turgidum L., poulard wheat.	
	T. polonicum L., Polish wheat.	
	T. persicum Vav., Persian wheat.	

2/ Hackel, Eduard. The True Grasses. Transl. from Die Natürlichen Pflanzenfamilien by F. Lamson. Scribner and E. A. Southwarth. Westminister 1896.

3/ Flaksberger, C. A., et al. Key to True Cereals, Wheat, Rye, Barley, Oats. The People's Commisariat of Agriculture of the U.S.S.R. Lenin Mem. all-Union Acad. Agri. Sci., Inst. Plant Cult. 1939.

Of the wheat types listed, the only commercially important species in the United States are common, club, and durum.

In general, crosses between wheats with the same number of chromosomes are easily made, and the resulting hybrids are self-fertile. Crosses between wheats with different numbers of chromosomes are difficult to make, and resulting hybrids are generally self-sterile, although some varieties of wheat, for example Thatcher, have resulted from crosses between wheats of 42 and 28 chromosomes.

STRUCTURE AND COMPOSITION

Wheat grains vary considerably in weight, size, shape, and color. The weight of 1,000 kernels of plump common wheats ranges from 25 to 40 grams according to variety; and of Durum wheats from 30 to 45 grams. The weight per measured Winchester bushel of wheats ranges from 42 to 66 pounds depending upon a number of factors including moisture content, plumpness of individual kernels, soundness, and variety. The wheats generally met with in commerce weigh between 56 and 61 pounds per bushel. The legal weight per bushel is 60 pounds, and all wheat is purchased on that basis regardless of its actual weight per bushel.

All of the commercially important wheat varieties are either red or light amber (in the case of soft wheats referred to as white) in color of kernel. Some Abyssinian varieties, however, have grains of a rich purple tint. The particular shade of color in red and white wheat depends not only upon the amount of color in the episperm but also upon the thickness, tint, and transparency of the outer coats or pericarp, and upon the character of the endosperm.

The hardness or texture of the wheat kernel is determined by a combination of factors such as variety, soil, and climate. Many normally hard wheats tend toward softness if grown in a sandy soil or if ripened in a cool, wet season. The specific gravity of sound wheat varies from about 1.30 to 1.42 depending upon its relative hardness.

The wheat grain or kernel is called a seed by farmers and a caryopsis by botanists. It has three main parts, namely: (1) the germ or embryo, (2) the endosperm or flour portion, and (3) the bran or protective skins. (For further details of structure see figure 1).

The germ is by weight about 1.5 to 3 percent of the entire grain. It lies on the dorsal side at the base of the grain and is characterized by having high contents of fat, or oil, and protein.

The endosperm, with the exception of the small space occupied by the germ, makes up the interior of the wheat grain and consists chiefly of starch. On the average it constitutes about 85 percent of the kernel.

The outer and inner layers of the seed coat represent about 13 to 15 percent of the kernel. In milling, it is impossible to separate perfectly all of the endosperm from the seed coats. The outer coat consists of the epidermis, the epicarp, and the endocarp, and the innercoat consists of the testa, episperm and aleurone cells. Most of the coloring matter of the bran lies in the episperm and determines the kernel color.

Chemically the wheat kernel is made up of a number of types of organic compounds or constituents, of which starch, protein, and oil are commercially important.

Starch constitutes about 61 to 67 percent of the weight of a normal wheat kernel of which it is the principal constituent, but it may constitute a much lower percentage depending upon the degree of plumpness of the kernel and protein and moisture contents.

Wheat starch granules are lenticular, circular, oval, or subuniform in outline. They are further characterized by occurring (in the same kernel) in two size groups. According to Wallis 4/ these groups are (1) up to 10 microns in diameter, and (2) from 16 to 50 microns, with average sizes, 5 and 20 to 25 microns, respectively, but with more than 400 granules per milligram greater than 40 microns in diameter. Furry 5/ measured the length and width of more than 50 granules and found them to average 13.5 and 11.2 microns for ungelatinized and 70.0 and 56.9 microns for the swollen granules, respectively. Granule aggregates are rare. Reichert 6/ reports that the hilum of each granule is usually centric, sometimes slightly eccentric. The hilum form is usually not visible; in large granules there may be a cavity or a cleft and occasionally radial fissures; in minute granules, a clear cleft. The polariscopic figure is usually centric, fairly distinct, and regular. Gelatinization, as indicated by the disappearance of the polariscopic figure, is complete at 63 to 65 degrees Centigrade. The larger granules swell and fold into a characteristic saddle shape upon the gelatinization.

It is now considered by most chemists that starch consists of two main molecular components, one straight-chained in character, the other branched. Both types are thought to be composed almost exclusively of maltose units. It is known that no simple sugar other than glucose is a component of starch molecules, since the latter can be quantitatively decomposed to glucose. There are, however, traces of non-carbohydrate constituents present in starch granules.

4/ Wallis, T. E. Pharm. Jour. 131: 396. 1933.

5/ Furry, M. S. U. S. Dept. Agr. Tech. Bul. 264. 1932.

6/ Reichert, E. T. The Differentiation and Specificity of Starches in Relation to Genera, Species, Etc. Carnegie Institution Monograph 173. 1913.

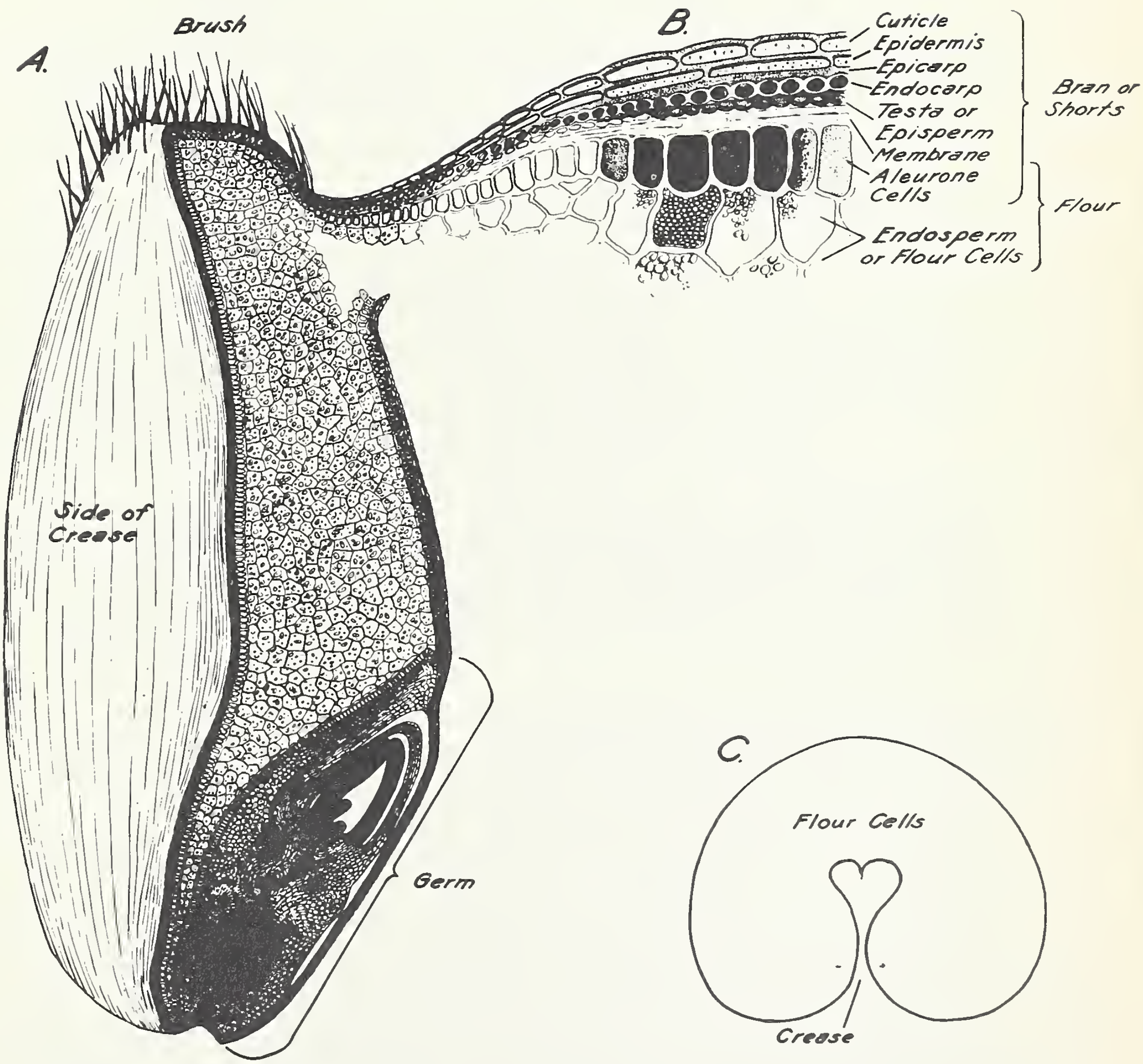

Fig. 1 - Structure of the wheat kernel. A. - General shape of kernel and location of the principal parts. B. - Internal structure. C. - Cross-section of kernel showing location and shape of crease. (Drawn by G. D. George, University Farm, St. Paul, Minn.)

Edwards and Ripperton 7/ report the following non-carbohydrate constituents of commercial wheat starch (dry basis):

Phosphorus, as PO_4	0.176%
Calcium	0.027
Magnesium	0.008
Potassium	0.036
Sodium	0.025

Mangels 8/ made a detailed study of variation of phosphorus and nitrogen in starches of several varieties of wheat grown at a number of different stations. He reports (dry basis) the phosphorus content varied from 0.035 to 0.081 percent, and the nitrogen from 0.040 to 0.055 percent.

Many workers have reported wheat starch viscosities, but since both the manner of preparation of starches for study and the instruments used have varied widely, results are seldom comparable. Wheat starch pastes are less viscous than similarly prepared cornstarch pastes, and like all typical cereal starch pastes are opaque and short in texture, in contrast to the transparent, tacky pastes of root starches. A 5 percent wheat starch paste will set to a gel, on cooling, which is less firm than a corresponding cornstarch gel; formation of a gel is typical of cereal starches, while root starches remain viscous when cooled.

The protein content of wheat ranges from about 6 to 22 percent and consists of a number of different proteins including a prolamin, gliadin; a glutelin, glutenin; a globulin; an albumin, leucosin; and a proteose. The first two named predominate, which is a characteristic peculiar to wheat and most cereals. The predominating proteins in most seeds other than cereals are globulins.

The proteins of wheat endosperm may be grouped into two main classes, the gluten forming and the non-gluten forming proteins, with the gluten-forming proteins greatly predominating. The work of Osborne 9/ led to the general acceptance of the belief that gluten consists of an intimate mixture (in nearly equal parts) of the two distinct proteins, glutenin and gliadin. More recent work, however, according to Blish 10/ has led to the strong belief of the probability that gliadin is an indefinite and inhomogeneous substance while glutenin - as isolated according to Osborne's directions - is a degraded and irreversibly altered or "denatured" protein product. The true nature and character of gluten is highly uncertain and indefinite. A similar state of uncertainty exists with reference to the individualities of the non-gluten proteins designated by Osborne as albumin (leucosin) and globulin. Until these matters are cleared up, it is perhaps convenient and desirable to retain Osborne's classification. Osborne considered that

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7/ Edwards, D. E., and Ripperton, J. C. Jour. Agr. Res. 47: 179. 1933.
8/ Mangels, C. E. Cereal Chem. 11: 571. 1934.
9/ Osborne, T. B. (See selected references).
10/ Blish, M. J., Chief, Protein Division, Western Regional Research Laboratory, Bureau of Agricultural Chemistry and Engineering. Personal communication, May 1942.

the proteins of the embryo consist of an albumin, a globulin, and a proteose. The albumin, leucosin, amounts to about 10 percent of the embryo and represents the greater part of the total embryo protein.

The proteins 11/ of the seed coats (bran) of the wheat kernel consist principally of a globulin, an albumin, and a prolamin and differ essentially from the corresponding proteins of the endosperm and embryo both with respect to their elementary analyses and to their amino acid composition. Of the total protein of commercial bran the albumin represents approximately 17 percent, the globulin 14 percent, and the prolamin 31 percent. Of the total nitrogen of the wheat kernel, 22 percent is contained in the bran.

The method 12/ used in determining protein content of wheat and the products thereof is one of estimation based on an assumed proportional relationship of nitrogen to protein. The nitrogen content is determined and then multiplied by a factor of conversion which reflects the assumed relationship. In the case of whole wheat and wheat flour, the general practice is to use 5.7 as the conversion factor. Jones (see selected references), however, states that the true relationship is variable (1) because nitrogenous substances may be present which are not proteins and (2) because not all proteins contain the same proportion of nitrogen. He suggests use of the following conversion factors as being the most accurate:

Wheat, whole kernel	5.83
Wheat, embryo	5.80
Wheat, bran	6.31
Wheat, endosperm	5.70

11/ Jones, D. B., and Gersdorff, C.E.F. Proteins of Wheat Bran, Part I, Jour. Biol. Chem. Vol. LVIII No. 1. Nov. 1923.

12/ The Agricultural Marketing Administration has developed a simpler and more direct method for determining the protein content of wheat and wheat flour. (Reference - Zeleny, L., Cereal Chem. 18: 86-92, 1941, and Zeleny, L., et al., Cereal Chem. 19: 1-11, 1942.) The method is based on the principle that the gluten protein, which accounts for practically all of the wheat proteins, may be rapidly extracted and transformed into a stable colloidal suspension the optical density of which is a measure of the gluten protein content and may be determined quickly and easily by means of the photoelectric cell. This procedure determines only the gluten protein of the wheat or flour and should therefore give results more closely related to bread making potentialities than does the total protein calculated from the nitrogen content. The method has not yet been perfected and has not yet been recommended for commercial use.

The oil (fat) content of the whole wheat seed normally is about 2 percent; of commercial bran, 6 percent; and of the germ, 12 to 18 percent 13/. The wheat germ oil of commerce is obtained from the germ and, according to Kass 14/, contains approximately 15.5 percent of solid acids, 25.5 percent of oleic acid, 52.6 percent linoleic acid, and 6.4 percent of linolenic acid in the form of the mixed glycerides. Although similar in fatty acid content to many of the other semi-drying vegetable oils, wheat germ oil is higher than most of them in unsaponifiable matter (3.5 - 4 percent) and in its content of vitamin E. Properly prepared wheat germ oil has good keeping qualities and is equal to corn oil for food purposes. Because of the limited supply and its high cost, its use at present is in the pharmaceutical and veterinary trade where it is valued for its high vitamin E potency.

The moisture content of commercial wheats has an extreme range of 5 to 25 percent, depending upon the climatic conditions under which the grain is harvested and stored. Ordinarily, however, commercial wheats contain in the neighborhood of 11.5 to 13.5 percent moisture. Wheats of the lower moisture contents are generally found only in the western rim of the Great Plains area, in certain sections of the Rocky Mountain Region, and in the Pacific Northwest where low rainfall conditions prevail.

Because of the fact that the moisture content of wheat is very markedly influenced by the humidity and other atmospheric conditions under which it is handled or stored, the other chemical constitutents, in order to be comparable as between samples, must be reported on a dry matter or uniform moisture content basis. In the tables on chemical composition which follow, all results are reported on one or the other of these bases.

Data showing the general chemical composition of wheat and the products thereof are presented in tables 1, 2, and 3.

Because protein content is used for price evaluation purposes in the marketing of a large portion of the wheat crop, special data tables, Nos. 4 and 5, are presented for this constituent to show variations in its content between commercial classes and between crop years.

The quantities of the various mineral constituents occurring in wheat are shown in table 6. The iron content of wheat and its distribution in the various milling products are shown in Table 7.

13/ Jamieson, G. S. Vegetable Fats and Oils, Chemical Catalog Company, New York. 1932.

14/ Kass, J. P., Chemist, Northern Regional Research Laboratory, Peoria, Illinois.

Table 1. - Composition of wheat, flour, and germ (Basis 13.5 percent moisture)

Material	Protein	Fat	Ash	Carbohydrates	
				Fiber	Other
	Percent	Percent	Percent	Percent	Percent
Wheat:					
All types	12.6	1.9	1.6	1.8	68.6
Hard red	13.5	2.0	1.6	2.2	67.2
Soft red	11.1	1.9	1.7	2.2	69.6
White	10.4	1.9	1.7	1.8	70.7
Flour, straight:					
All types	11.0	1.1	0.5	0.4	73.5
Hard red	11.8	1.2	0.5	0.4	72.6
Soft red	10.6	1.0	0.5	0.4	74.0
White	9.1	1.0	0.5	0.4	75.5

Source: Proximate Composition of American Food Materials. By Charlotte Chatfield and Georgian Adams. U. S. Dept. Agr. Cir. 549, table 2, pages 89-90. 1940.

Table 2. - Chemical composition of the various classes of wheat (Basis 13.5 percent moisture)

Class of wheat	Crude protein (N x 5.7)	Crude fat	Ash	Soluble carbohydrates	Crude fiber	Starch	Undetermined
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Spring	12.60	2.25	1.85	3.94	2.85	58.85	4.16
Hard winter	12.30	2.23	1.81	4.37	2.79	58.73	4.27
Soft winter	9.94	2.37	1.69	3.16	2.79	62.79	3.76
White wheat							
Pacific coast	10.55	2.12	1.85	1.55	1.72	64.73	3.98
Durum	12.68	2.10	1.52	4.91	1.78	59.17	4.34

Source: Methods for the Analysis of Cereals and Cereal Products. American Association of Cereal Chemists, page 124. 1928.

Table 3. - Chemical composition of a commercial milling mix of hard red spring wheat and the products thereof

Product	Milling yield or proportion of whole kernel	Moisture at time of milling	Chemical constituents Basis 13.5 percent moisture						
			Protein (Nx5.7)	Fat	Ash	Starch 1/	Pentosans	Sugar	Undetermined
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Wheat 2/ (whole grain)	100.0	3/ 15.6	15.28	1.87	1.85	53.0	5.17	2.61	6.75
Products therefrom:									
Patent flour	65.3	13.8	14.25	0.91	0.42	66.7	1.58	1.25	1.39
First clear flour	5.2	12.5	15.19	1.43	.65	63.1	2.03	1.37	2.81
Second clear flour	3.2	13.4	18.09	2.43	1.41	56.3	2.56	2.09	3.65
Red dog flour	1.3	12.0	18.54	3.79	2.71	41.4	4.48	4.60	10.96
Shorts	8.4	13.5	18.49	5.25	4.99	19.3	13.80	6.72	18.01
Bran	16.4	13.8	16.71	4.58	6.50	11.7	18.10	5.48	23.46
Germ	.2	13.8	30.91	12.60	4.32	10.0	3.68	16.61	8.36

1/ Starch determination by A. O. A. C. diastase method.

2/ Tempered wheat.

3/ Before tempering this wheat had a moisture content of 11.9 percent.

All analyses here reported, except "moisture at time of milling" were performed by the Analytical and Physical Chemical Division, Northern Regional Research Laboratory.

Table 4. - Protein content of wheat, by classes: State Experiment Station varietal samples, 1915-21 crops (Basis 13.5 percent moisture)

Class	Samples analyzed	Protein (N x 5.7)	Content
		Average	Range
	Number	Percent	Percent
Hard red spring	1310	13.6	7.3 - 21.5
Durum	432	14.9	9.6 - 20.8
Hard red winter	728	12.6	7.6 - 18.5
Soft red winter	457	11.3	6.8 - 19.0
White	580	12.0	6.4 - 19.8

Source: Milling and Baking Experiments with American Wheat Varieties. By J. H. Shollenberger and J. A. Clark. U. S. Dept. Agr. Bul. 1183. 1924

Table 5. - Average percentages and standard deviations in protein content (Basis 13.5 percent moisture) of specified numbers of samples of spring (excluding Durum), soft red winter, and white winter wheats; 1931-37 crops

Class of wheat	Crop of 1931	1932	1933	1934	1935	1936	1937
Number of Samples Analyzed							
	Number	Number	Number	Number	Number	Number	Number
Spring (exc. Durum) 1/	17,182	45,027	23,829	12,900	28,544	16,698	12,185
Soft red winter 2/	3,061	3,429	3,798	5,310	5,332	4,632	4,501
White winter 3/	352	497	307	245	577	525	--
Protein Content							
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Spring (exc. Durum) 1/	4/15.00	13.92	14.69	14.45	15.01	4/15.92	14.51
Soft red winter 2/	10.44	9.99	10.84	11.81	10.06	9.66	9.52
White winter 3/	10.48	9.17	10.10	11.39	9.13	9.14	--
Standard Deviation in Protein Content (N x 5.7)							
Spring (exc. Durum) 1/	1.22	0.99	0.89	1.04	1.71	1.64	1.28
Soft red winter 2/	0.67	0.49	0.69	0.82	0.64	0.49	0.59
White winter 3/	0.81	0.41	0.58	0.67	0.54	0.43	--

1/ Grown in Minnesota, North Dakota, South Dakota, and Montana; marketed through Minneapolis, Minnesota.

2/ Grown in Ohio, Illinois, Indiana, and Michigan.

3/ Grown in Ohio, Indiana, and Michigan.

4/ The protein content of the Spring wheat samples for the years 1931 and 1936 are not adjusted to a 13.5 percent moisture content basis as acceptable data were not available regarding the actual moisture content of the samples analyzed.

Source: Protein Surveys of American Hard Spring and Soft Winter Wheats. By C. H. Bailey. Univ. of Minn. Agri. Expt. Sta. Tech. Bul. 147. June 1941.

Table 6. - Mineral content of wheat (moisture-free basis)

Mineral	Number of Analyses	Content: Maximum	Content: Minimum	Content: Average
		Micrograms per gram	Micrograms per gram	Micrograms per gram
Potassium	264	6200	2900	4800
Phosphorus	310	5400	1500	4000
Sulphur	138	2900	1000	1800
Magnesium	267	2900	900	1700
Chlorine	80	1900	200	900
Sodium	100	2700	100	700
Calcium	290	1220	50	500
Iron	131	420	28	68
Zinc	27	100	19	63
Manganese	109	260	5	49
Copper	108	24	4	9
Barium	1	--	--	8
Titanium	?	--	--	.9
Selenium	29	1.9	.1	.5
Nickel	?	--	--	.35
Arsenic	4	.3	.15	.26
Iodine	26	.168	.000	.067
Cobalt	?	--	--	.012

Source: Calculated from data contained in The Mineral Composition of Crops. By Kenneth C. Beeson. U. S. Dept. Agr. Misc. Pub. 369.

Table 7. - Iron content of wheat and its milling products (moisture-free basis)

Material	Average iron content
	Micrograms per gram
Wheat	41.6
Patent flour	8.4
First clear flour	17.4
Second clear flour	38.7
Red dog flour	96.2
Shorts	139.0
Bran	146.2
Germ	91.3

Source: The Iron Content of Cereals. By John S. Andrews and Clarence Felt. Cer. Chem., pages 819-826, November 1941.

VITAMIN CONTENT

Vitamins are essential accessory nutritional factors which an organism cannot synthesize and which must, therefore, be ingested with the food. They contribute no appreciable amount of energy. The vitamin requirements for different species of organisms vary over wide limits both quantitatively and qualitatively. Ruminants (cud-chewing animals) generally require less vitamins since bacteria living in the rumen (auxiliary stomach) synthesize certain of these growth factors; this is equivalent to having them in the food.

Wheat, in comparison with certain other agricultural commodities, is a poor source of vitamins A, C, and D, but is a good source of thiamin (vitamin B_1), riboflavin (formerly known as vitamin G and B_2), niacin (formerly called nicotinic acid), and vitamin E. The vitamins of wheat occur principally in the germ and outer portions of the kernel, which parts are discarded or lost in the production of white flour. In tables 8, 9, 10, 11, 12, 13, and 14 data are presented showing the thiamin, riboflavin, and niacin contents of wheat and its milling products and similar information for other cereal grains.

Vitamin E contents reported by Cabell and Ellis 15/ for 5 varieties of wheat were estimated to range from 2.3 mg. to 5.4 mg. of equivalent alpha-tocopherol per 100 gm. of grain. The range for 6 varieties of corn was 1.5 mg. to 3.6 mg.

15/ Cabell, C. A. and Ellis, N. R. The Vitamin E Content of Certain Varieties of Wheat, Corn, Grasses, and Legumes as Determined by Rat Assay. Jour. of Nutrition, June 1942.

Table 8. - Thiamin (vitamin B_1) content of wheat and its milling products (averages of samples from several millings)

Product	Proportion of whole kernel	Thiamin content 1/	
		Amount in product	Proportion of total
	Percent	Micrograms per gram	Percent
Wheat (cleaned)	100.0	5.03	100.0
Patent flour	63.0	.68	8.0
First clear flour	7.0	3.00	3.9
Second clear flour	4.5	12.37	10.0
Red dog flour	4.0	29.65	22.0
Shorts	12.3	17.39	39.6
Bran	9.0	9.37	15.6
Germ	.2	22.93	.9

1/ Approximately 11 percent moisture content basis (this information from personal communication of June 3, 1942).

Source: Thiamin in the Products of Wheat Milling and in Bread. By R. C. Sherwood, et al. Cereal Chem., pages 811-819, November 1941.

Table 9. - Thiamin (vitamin B_1) content of wheat and other cereal grains

Kind of grain	Number of samples analyzed	Thiamin content: Average	Thiamin content: Range
		Micrograms per gram	
	Data by Shultz, et al., 1/ (Basis "as is" moisture)		
Wheat	31	5.6	4.2 - 7.3
Corn	23	5.3	4.1 - 8.0
Oats	21	7.2	4.8 -10.3
Rye	10	4.8	4.0 - 5.7
Barley	37	6.2	3.8 - 9.2
Buckwheat	5	6.0	4.2 - 8.5
Millet	3	7.2	6.0 - 8.2
	Data by Nordgren and Andrews 2/ (Basis 13.5% moisture)		
Wheat:			
Minnesota Spring	24	6.1	4.4 - 7.7
Canadian Spring	13	5.1	3.2 - 6.2
Winter	35	4.8	3.6 - 6.0
West Coast	12	4.6	3.9 - 5.4
Soft	15	4.5	4.0 - 5.2
Corn:			
Yellow	6	5.4	4.8 - 6.2
White	6	6.1	4.9 - 6.7
Grain Sorghums	7	5.9	4.2 - 8.8
Oats	6	9.3	8.1 -10.8
Rye	6	4.6	4.1 - 5.0
Barley	6	6.5	5.7 - 7.3

1/ A Preliminary Survey of the Vitamin B_1 Content of American Cereals. By Alfred Shultz, et al., Cereal Chem., pages 106-113, January 1941.

2/ The Thiamin Content of Cereal Grains. By Robert Nordgren and John S. Andrews. Cereal Chem., pages 802-811, November 1941.

Table 10. - Riboflavin content of wheat and its milling products

Material	Proportion of whole kernel	Riboflavin content 1/	
		Amount in product	Proportion of total
	Percent	Micrograms per gram	Percent
Wheat	100.0	1.00	100.0
Patent flour	65.0	.34	20.5
First clear flour	5.5	.62	3.2
Second clear flour	4.5	1.85	7.7
Red dog flour	4.0	3.80	14.1
Shorts	12.5	2.80	32.5
Bran	8.5	2.80	22.0

1/ Approximately 11 percent moisture content basis (this information from personal communication of June 3, 1942.)

Source: The Riboflavin Content of Cereal Grains and Bread and Its Distribution in Products of Wheat Milling. By John S. Andrews, et al. Cereal Chem., pages 55-64, January 1942.

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Table 11. - Riboflavin content of wheat and other cereal grains

Kind of grain	Number of samples or varieties analyzed	Riboflavin content 1/	
		Average	Range
		Micrograms per gram	
Wheat:			
Hard red spring	24 samples 2/	1.20	1.05 - 1.40
Hard winter	27 samples 3/	1.18	1.00 - 1.30
Soft	18 samples 4/	1.17	1.00 - 1.30
Cereals other than wheat:			
Yellow corn	13 varieties	1.40	1.30 - 1.50
White corn	5 varieties	1.38	1.30 - 1.50
Barley	6 varieties	1.21	1.05 - 1.50
Oats	5 varieties	1.30	1.10 - 1.45
Rye	6 varieties	1.43	1.30 - 1.65

1/ Approximately 10 percent moisture content basis (this information from personal communication of June 3, 1942).

2/ 6 varieties.

3/ 4 varieties.

4/ 16 varieties.

Source: Riboflavin Content of Cereal Grains and Bread and Its Distribution in Products of Wheat Milling. By John S. Andrews, et al. Cereal Chem., pages 55-64, January 1942.

Table 12. - Thiamin, riboflavin, and niacin (nicotinic acid) contents of various grains and cereal products ("as milled" moisture basis)

Grain or product	Vitamin content range: Thiamin	Riboflavin	Niacin
		Micrograms per gram	
Wheat	3 - 17	0.7 - 1.7	30 - 46
Wheat germ	31 - 43	6.2	38.80
Wheat bran	6	4.0	49.74
Corn	2 - 6	.8 - 2.3	9.88
Rice	2 - 3	.8	24.00
Oats	5 - 10	2.2 - 2.6	--

Source: Cereal Products, Vitamin and Mineral Restoration and Fortification from the Viewpoint of the Manufacturer. By R. T. Conner, Ind. & Eng. Chem., Vol. 33, No. 6, 1941.

Table 13. - Niacin content of wheat and milling products thereof (13.5 percent-moisture basis)

Grain or product	Proportion of whole kernel	Niacin content: Amount in product	Niacin content: Proportion of total
	Percent	Micrograms per gram	Percent
Wheat	100.0	20.64	100.0
Patent flour	63.0	6.86	23.48
First clear flour	7.0	17.13	6.52
Second clear flour	4.5	19.41	4.73
Red dog flour	4.0	31.11	6.74
Shorts	12.3	38.18	25.54
Bran	9.0	66.06	32.34
Germ	.2	60.93	.65

Source: Compiled from data presented in The Nicotinic Acid Content of Cereal Products. By James M. Thomas, et al. Cereal Chem., pages 173-180, March 1942.

Table 14. - Niacin content of wheat and other agricultural commodities with protein and ash content comparisons (moisture-free basis)

Commodity	Niacin	Protein	Ash
	Microgram per gram	Percent	Percent
Wheat mix, spring	23.87	15.97	1.97
Wheat mix, winter	14.97	14.69	1.72
Barley	17.01	11.69	2.79
Malted barley	21.33	11.86	2.42
Oats	8.07	11.59	4.11
Rye	10.84	14.02	2.03
Corn (yellow)	8.15	8.76	2.05
Corn (white)	8.22	10.14	1.56
Soybeans	22.13	36.37	5.90
Rice (unhulled)	12.74	6.74	5.41
Rice (brown)	9.06	8.54	1.18
Rice (polished)	5.27	8.23	1.02
Peanuts:			
Raw	106.03	28.17	2.46
Roasted	110.51	26.74	2.43

Compiled from data presented in The Nicotinic Acid Content of Cereal Products. By James M. Thomas, et al. Cereal Chem., pages 173-180, March 1942.

PRODUCTION DEVELOPMENT

Soft wheats were introduced into the United States by the colonists from Western Europe in the early part of the seventeenth century and moved westward with the settlers. They were sown in Virginia as early as 1611 and in Massachusetts soon after 1621. These wheats came largely from England, Netherlands, and Sweden.

Wheat production in the Pacific Coast region began about 1770 with the introduction of Spanish wheats, mostly white varieties, coming by way of the West Indies and Mexico. These and later introductions of white wheats from Mexico, Chile and Australia account for the popularity and predominance of white wheats in this region.

Hard spring wheat of the common species was not generally grown in the United States until after 1870. A few grains of this wheat, probably from Russia, were received in Canada in 1842 by a man named Fife. This wheat, under the name of Fife, was introduced into the United States from Canada about 1850. Millers objected to it because of its hardness, and accordingly it was discounted heavily on the markets until after 1870. The development of the middlings purifier and the introduction in 1878 of the roller system of milling in Minneapolis made possible the efficient milling of this wheat. The use of purifiers and rolls soon became general. After 1878 the cultivation of hard spring wheat increased rapidly, and a short time later it was selling at a premium.

Hard winter wheat was introduced into the United States by Russian Mennonite immigrants who settled near Newton, Kansas in 1873. This wheat which was brought from the Crimea became known as Turkey wheat. It proved to be very well suited to the climate of Kansas, and its ability to yield well in that area soon caused it to be grown on a large acreage. The Kansas millers at first refused to buy Turkey wheat on account of its hardness but later accepted it at a discount from the price of soft wheat. About the year 1886, mills were built at Newton, Halstead, and Moundridge, Kansas, specifically for the purpose of using Turkey wheat. Not until about 1900, however, did the mills of Kansas begin to recognize its good milling qualities, and not until 1910 did it sell at a higher price at Kansas City than soft winter wheat. By 1914 hard winter wheat ranked as one of the high quality bread wheats.

Kubanka durum wheat was introduced into the United States from Russia by the United States Department of Agriculture, and Arnautka durum wheat by Russian settlers during the period 1898 to 1900. These soon proved to be high yielding wheats in the Great Plains, probably because of their resistance to stem rust, and were grown principally in South Dakota, North Dakota, and Minnesota. Millers objected to durum wheat at first, and it was sold at a large discount. By 1911, however, it was selling only a few cents below hard red spring, and in recent years it has occasionally topped the latter.

In addition to the improvement of the wheat crop resulting from the introduction of the wheats referred to in the preceding paragraphs, further improvements in the quality and yield of wheat have resulted from selection and hybridization.

Through the selection, by leading farmers and seedsmen, of promising strains from the mixtures and natural hybrids in the field, many important wheats were developed early in the 19th century. Red May, which was selected from a field of white-kerneled May of English origin, and Fultz, an important soft red winter wheat and a descendent of a mixture of hybrid found in a field of the Lancaster (Mediterranean) variety, are two early typical examples. Some of the varieties which this method has developed more recently are Kanred, Trumbull, Fulhio, Mindum, and Blackhull.

Hybridization, or selection from the progeny of artificial crosses, dates from about 1870 and has opened the way for further improvements in wheat varieties. Scientific methods are now available for studying and improving the inheritance in wheat for color of kernel, awnedness, date of maturity, winter hardiness, disease reactions, and quality characters, i.e., protein content and baking strength. Future improvement in wheat from hybridization research is very probable. Some of the more prominent varieties developed in the United States as a result of hybridization are Fulcaster, Ceres, Thatcher, and Tenmarq.

COMMERCIAL TYPES

For purposes of commercial usage, which is principally that of food, wheat in the United States is classified as follows: Hard Red Spring, Durum, Red Durum, Hard Red Winter, Soft Red Winter, White, and Mixed Wheat. The species of the Durum and Red Durum classes are indicated by their names. The Hard Red Spring and Hard Red Winter classes are entirely of the common species, but the Soft Red Winter and White classes include varieties both of the common and club species. Durum and Red Durum are very hard in kernel texture; Hard Red Spring and Hard Red Winter range from semi-hard to hard; Soft Red Winter ranges from soft to semi-hard; and White, from soft to hard.

Wheat is primarily produced for consumption as food; therefore, the suitability of each class for particular food uses is of interest. Hard Red Spring and Hard Red Winter wheats are especially suited for the making of bread flour. These two wheats contain a relatively large quantity of strong elastic gluten - an essential element in making a bread that meets the public favor in the United States. Durum wheat is used for making semolina that is especially suited for the manufacture of macaroni, spaghetti, vermicelli, and other alimentary pastes. Red Durum is used to some extent in the manufacture of breakfast food but is principally used for poultry and stock feed. Soft Red Winter and White wheat flour, both usually low in protein content, are especially suited for making pastry, crackers, biscuits, cakes, and similar products.

PRODUCTION AREAS AND VARIETY DISTRIBUTION

Wheat is grown commercially in most of the 48 states of the Union (see figure 2) so it is not surprising that the number of varieties of wheat grown in the United States is very large. In 1941 there were 329 registered varieties. This registration is made under a cooperative agreement between the Bureau of Plant Industry, United States Department of Agriculture, and the American Society of Agronomy. Many of these varieties, however, are not grown commercially at the present time. Only approximately 120 of them are grown on 10,000 acres or more. In 1939 only 12 were grown on more than a million acres.

The production of wheat is generally limited to areas having a frost-free period of 90 days or more and, except where irrigation is possible, an annual precipitation between 12 and 45 inches. Its most extensive production is in areas having a precipitation of approximately 30 inches. It is grown in areas of India, however, where the annual rainfall is 60 inches or more and in areas of Australia and in the Big Bend area of Washington State where the rainfall is no greater than 10 inches, because related factors such as length of growing season, timeliness of rainfall, temperature, soil, and economic considerations are favorable.

In areas where it can be grown, winter (seeded in fall for harvest in early summer) wheat will usually produce higher yields than spring wheat. Winter wheat varieties require a period of low temperatures or short days or both in order to head, and as neither of these conditions is found in the tropical and subtropical regions, spring wheat varieties (seeded in the fall or early winter) are grown in these areas. Spring wheats are also produced in regions where winter temperatures are too severe for winter wheat to survive.

Hard Red Spring wheat is grown principally in the North Central States (see figure 3). In this region winters are too severe for winter wheat. The states leading in its production are North Dakota, South Dakota, Minnesota, and Montana. The leading varieties are Thatcher, Marquis, Ceres, and Reward. Thatcher is rapidly replacing Marquis and Ceres in a large part of this area because of the fact that it is very resistant to stem rust while Ceres and Marquis are rather susceptible. According to the 1939 Census of acreage of wheat varieties by the U. S. Department of Agriculture, Hard Red Spring wheat occupies approximately 20.9 percent of the wheat acreage in the United States.

Durum wheat is grown in the north central part of the Great Plains with approximately 95 percent of the United States production in North Dakota, South Dakota, and Minnesota. The leading varieties of Durum wheat are Mindum, Kubanka, and Pentad. Mindum and Kubanka are of the commercial class Durum, whereas Pentad is of the Red Durum. The latter is grown especially in South Dakota because of its high yield, in spite of the fact that it usually sells for a much lower price than other vareities. Durum acreage, according to the 1939 acreage census, accounts for approximately 5.3 percent of the total acreage of the United States.

Hard Red Winter wheat is grown principally in the central portion of the Great Plains. This region has moderately cold, dry winters with little, or at best, uncertain snow cover. The leading states in production are Kansas, Oklahoma, Nebraska, Texas, and Colorado. Hard Red Winter wheat is also grown to some extent throughout the northern part of the United States west of the Appalachian Mountains. The leading varieties are Turkey, Blackhull, Tenmarq, Kanred, Cheyenne, Iobred, and Nebred. Tenmarq, Cheyenne, Iobred, and Nebred are increasing in popularity, while Kanred is becoming less popular. Approximately 47.6 percent of the United States wheat acreage in 1939 was of Hard Red Winter wheat.

Soft Red Winter wheat is grown principally in the eastern half of the United States. This region is characterized by usually ample but seldom excessive rainfall and by moderately cold but no severe winters. Leading states in its production are Ohio, Missouri, Indiana, Illinois, Pennsylvania, and Kansas. The leading varieties are Fultz, Trumbull, Fulcaster, Kawvale, Fulhio, Leap, Red May, Nittany, and Currell. Red May has been decreasing in popularity the past few years, while the acreages of Kawvale and Fulhio have increased rapidly during this time. Kawvale is a little too hard to be good soft wheat, and its flour is unsatisfactory for making many of the products usually made from soft wheats. The Soft Red Winter wheat acreage in 1939 accounted for 19.6 percent of the total wheat acreage in the United States.

White wheat is grown chiefly in the far western states. Leading states in its production are Washington, California, Oregon, Idaho, and Michigan. The leading varieties of White wheat are Baart, Federation, Dawson, Rex, Goldcoin, and White Federation. None of the club white wheats are grown on a sufficiently large acreage to be included among the leading White wheat varieties. The leading varieties of club wheat are Hymar, Albit, and Hybrid 128. In 1939 White wheat varieties were grown on 6.6 percent of the wheat acreage in the United States.

HARVESTING DATES AND METHODS

Because of its widely distributed areas of production extending to every continent on the globe, wheat is harvested in unbroken continuity throughout the year. Following are the approximate harvest months for the various wheat producing areas:

January .... Argentina, Uruguay, Chile, and New Zealand
February ... Upper Egypt and Southern India
March ...... Egypt, Tripoli, and India
April ...... India, Lower Egypt, Iran, Iraq, Arabia, Syria, Cyprus, Mexico, and Southern Morocco
May .... Algeria, Tunis, Morocco, Central and Southern Asia, Palestine, and United States - South Carolina, Georgia, Alabama, and Louisiana

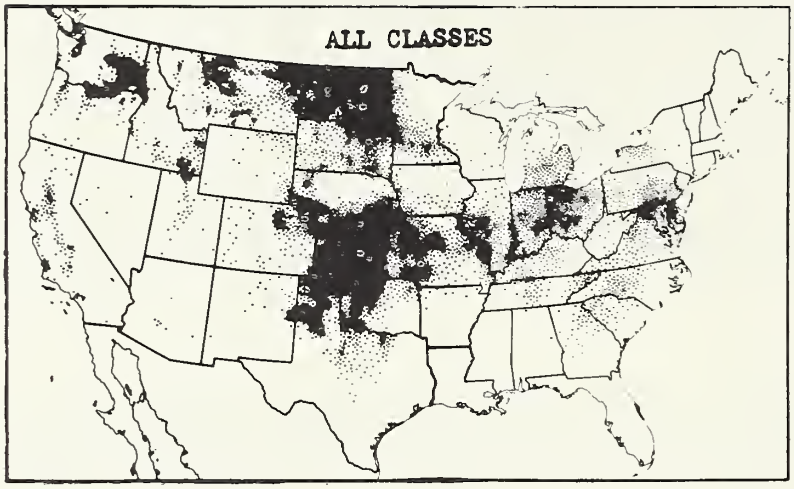

Figure 2. - Distribution of the total wheat acreage in the United States in 1939. Each dot represents 5,000 acres. Estimated area, 63,911,000 acres.

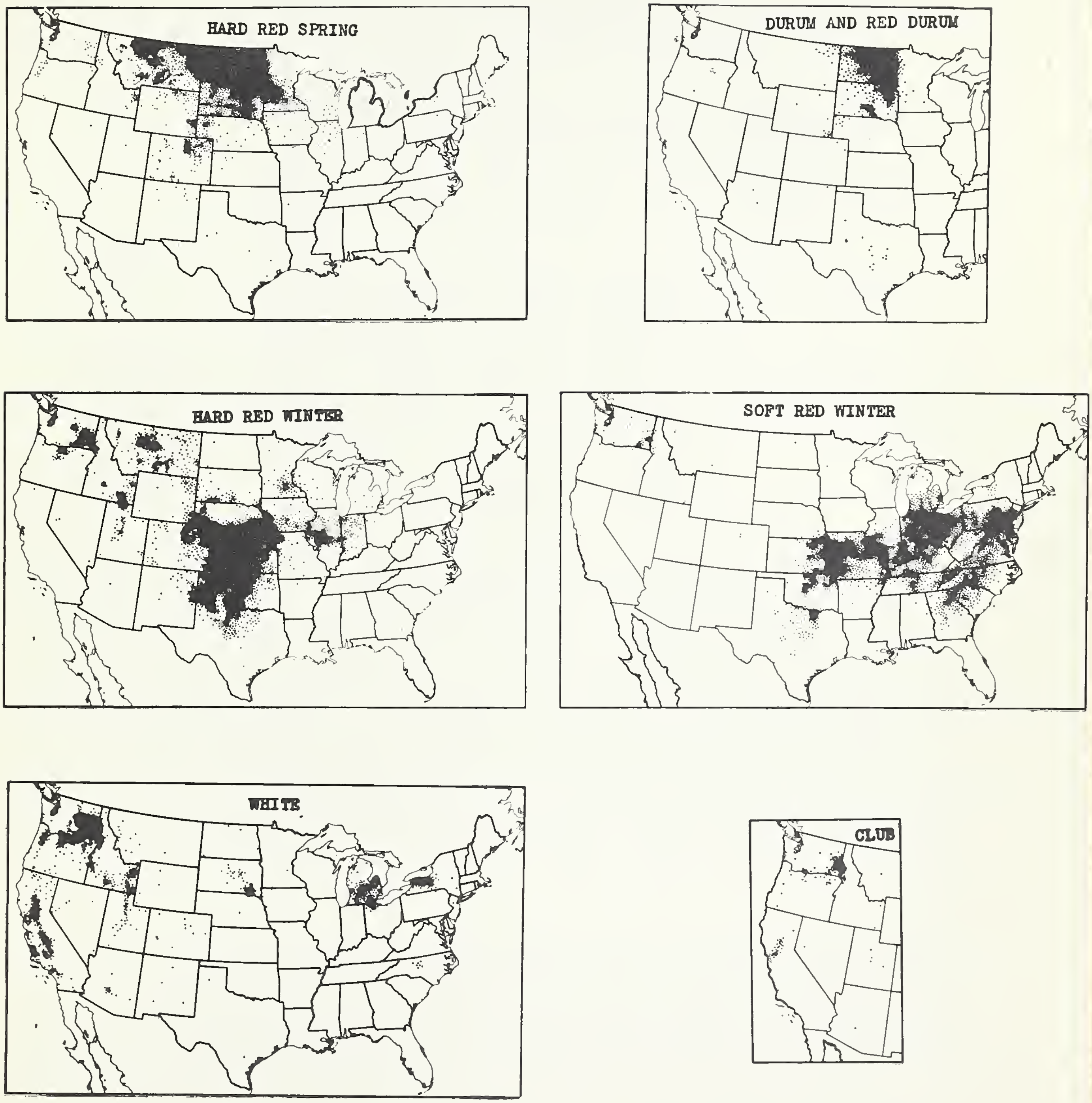

Figure 3. - Distribution of wheat classes in 1939. Each dot represents 2,000 acres. Estimated areas: hard red spring 13,330,648, durum and red durum 3,372,405, hard red winter 30,456,919, soft red winter 12,552,634, white 4,198,394, and club (some red and some white kerneled - are also included in the soft red winter and white wheat acreages, respectively) 411,282 acres.

June	Italy, Spain, Portugal, Greece, Turkey, Asia Minor, Central China, Southern France, and United States - North Carolina, Georgia, Arkansas, Texas, Virginia, Indiana, Illinois, Kentucky, Tennessee, Oklahoma, Missouri, and Kansas
July	France, Austria, Hungary, Roumania, Bulgaria, Yugoslavia, Switzerland, Southern Russia, North China, Japan, Chosen, Southern Germany, and United States - New York, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Missouri, Nebraska, Kansas, Colorado, and Oregon
August	Southern Canada, Central Russia, Great Britain, Germany, Belgium, Holland, Denmark, Poland, Manchuria, and United States - Minnesota, North Dakota, South Dakota, Montana, Oregon, and Washington
September ...	Sweden, Norway, Finland, Northern Russia, Canada, Siberia, and United States - North Dakota and Montana
October	Northern Scandinavia, Northern Russia, Northern Canada, and Alaska
November	Peru, Brazil and Northern Argentina
December	Argentina, Australia, and South Africa

In the United States wheat is usually harvested with a combine, a binder, or a header. The combine cuts and threshes in one operation, whereas the binder or header merely cuts the grain and the threshing is performed with a stationary thresher. The use of the combine causes the time of harvesting wheat to be from 7 to 14 days later than the normal time for binder cutting. This is necessary to allow the grain to become thoroughly ripened and the moisture content to be reduced to a point (14 percent or less) where the threshed grain can be stored safely. According to the best data available (see table 15), of the 1938 total wheat acreage in the United States, 49 percent was harvested with the combine, 47 percent with the binder, and 4 percent by all other methods. Since 1938 the percentage harvested by the combine undoubtedly has greatly increased because of the introduction of the small or all-crop type of combine which can be used to advantage on small farms.

In general, the type of farming practiced within an area influences to a large extent the method of harvesting wheat used. In states where extensive wheat raising is practiced the combine is nearly always used because of its lower harvesting costs; however, in states of diversified farming, where straw may be valuable for bedding and feeding livestock, the binder-thresher method of harvesting predominates.

Table 15. - Percentage of harvested wheat acreage harvested by various methods, 1938

State and Division 1/	Wheat acreage harvested with: Combine	Binder	All other methods	State and division 1/	Wheat acreage harvested with: Combine	Binder	All other methods
	Percent	Percent	Percent		Percent	Percent	Percent
New York	11	87	2	Kentucky	8	85	7
New Jersey	24	73	3	Tennessee	6	85	9
Pennsylvania	6	92	2	Alabama	22	35	43
Middle Atlantic	8	90	2	Mississippi	-	-	-
				East South Central	7	85	8
Ohio	22	77	1				
Indiana	30	69	1	Arkansas	12	68	20
Illinois	44	55	1	Louisiana	-	-	-
Michigan	16	84	2/	Oklahoma	70	28	2
Wisconsin	3	96	1	Texas	82	18	2/
East North Central	30	69	1	West South Central	75	24	1
Minnesota	6	94	2/	Montana	55	40	5
Iowa	28	72	2/	Idaho	40	57	3
Missouri	22	76	2	Wyoming	32	60	8
North Dakota	23	70	7	Colorado	44	41	15
South Dakota	19	71	10	New Mexico	58	37	5
Nebraska	51	48	1	Arizona	93	7	2/
Kansas	82	16	2	Utah	41	56	3
West North Central	48	48	4	Nevada	63	24	13
				Mountain	50	44	6
Delaware	11	89	2/				
Maryland	3	96	1	Washington	83	14	3
Virginia	3	83	14	Oregon	78	21	1
West Virginia	1	58	41	California	95	4	1
North Carolina	11	67	22	Pacific	84	14	2
South Carolina	8	62	30				
Georgia	11	45	44				
South Atlantic	6	76	18	United States 3/	49	47	4

1/ No information relative to the above harvesting practices was obtained in the New England States or Florida.
2/ Less than one-half of one percent.
3/ United States average based on states included in study. The reporting states had more than 99.9 percent of United States harvested wheat acreage in 1938.
Source: Based on data furnished by I. D. Mayer, Associate in Agr. Eng., Purdue Univ. Agr. Expt. Sta.

RELATIVE IMPORTANCE OF THE WHEAT CROP

Wheat is one of the most important crops of the United States. It is important because (a) many farmers grow it, (b) a large acreage of land is annually devoted to it, (c) it constitutes an important part of our domestic commerce, (d) it normally contributes an important part of the value of our agricultural exports, and most important of all, (e) it is the national bread crop.

It is primarily a cash crop and in some areas is almost the only source of cash farm income. Wheat is grown on about one-third, or approximately 2 million, of the farms of the United States. In the western edge of the Great Plains region and in the Pacific Northwest there are areas in which more than 50 percent of the total cultivated land is given over to wheat. Specialization of wheat growing is in many instances due to climatic conditions which prevent the production of other crops. Where such conditions prevail the development of market outlets for wheat is of vital importance to the welfare of the farmer.

The importance of wheat in the commercial life of the nation is indicated by the fact that normally it is fourth in farm value among all field crops and second in amount of cash income to farmers.

The average farm value of wheat from 1910 to 1914 was 633 million dollars annually. The higher prices resulting from World War I raised the average annual value in the 1915-19 period to 1,412 million dollars. The estimated farm value of the 1941 crop was 895 million dollars. The cash income from wheat to the farmers in these same periods was 520 million, 1,155 million, and 702 million dollars, respectively.

Table 16 shows the farm value of wheat and various other crops, and table 17 the cash income from these crops.

Table 16. - Farm value of various crops, 1937-1941

Commodity	1937	1938	1939	1940	1/ 1941
	$1,000	$1,000	$1,000	$1,000	$1,000
Wheat	842,843	522,639	519,651	554,168	894,783
Corn, all	1,372,468	1,247,010	1,476,300	1,520,047	2,012,651
Oats	350,003	253,455	290,922	377,171	484,070
Barley	119,075	92,609	110,826	122,953	184,244
Rye	34,172	18,783	17,163	17,094	24,866
Buckwheat	4,525	3,619	3,560	3,495	4,103
Flaxseed	13,222	12,965	29,492	43,745	56,298
Rice	35,132	33,630	39,095	44,208	72,476
Grain Sorghums	47,656	38,932	46,970	61,897	83,710
Cotton Lint	796,179	513,638	536,923	621,380	903,257
Cottonseed	164,375	115,695	111,259	121,578	228,158
Tobacco	319,465	269,184	288,171	234,283	331,934
Potatoes	208,785	208,835	251,586	203,345	275,578
Peanuts	63,137	67,434	58,728	83,769	106,470
Hay, all	718,973	618,676	671,329	718,999	887,934
Soybeans 2/	38,178	42,376	74,299	69,597	165,139
Other,	980,117	870,530	886,100	977,499	1,023,342
Total, 66 crops	6,108,305	4,930,010	5,412,374	5,775,228	7,739,013

1/ Preliminary.

2/ For beans only.

Source: Farm Production, Farm Disposition and Value of Principal Crops. April 1940, 1941, and 1942. Bur. Agr. Econ., U. S. Dept. Agr.

Table 17. - Cash farm income in the United States for calendar years 1937-41

Commodity	1937	1938	1939	1/ 1940	1/ 1941
Crops	$1,000	$1,000	$1,000	$1,000	$1,000
Wheat	604,910	400,538	432,586	427,541	702,039
Corn	222,693	268,516	318,931	387,932	351,271
Oats	67,022	42,850	45,724	57,296	84,951
Barley	42,673	38,259	39,720	41,270	56,027
Rye	19,856	8,582	9,016	8,182	13,415
Buckwheat	1,941	1,467	1,530	1,277	1,220
Flaxseed	13,062	12,067	26,426	34,869	58,107
Rice	32,607	34,041	31,503	39,902	52,855
Grain Sorghums	8,332	7,504	6,824	8,857	14,475
Cotton Lint	769,890	558,303	550,046	563,647	937,234
Cottonseed	113,399	88,670	76,818	82,398	170,185
Tobacco	320,518	294,035	271,061	241,404	324,872
Potatoes	183,736	127,590	156,339	164,053	152,382
Hay	93,897	60,795	66,021	75,688	79,760
Soybeans	31,073	34,205	50,833	42,813	113,305
Other	1,422,454	1,212,595	1,282,299	1,332,396	1,682,225
Total crops	3,948,063	3,190,017	3,365,677	3,509,525	4,794,323
Livestock and livestock products	4,902,089	4,495,969	4,511,308	4,869,891	6,449,799
Government payments	366,899	482,221	807,065	765,799	585,672
Grand total	9,217,051	8,168,207	8,684,050	9,145,215	11,829,794

1/ Preliminary.

Source: Cash Farm Income and Government Payments. February 26, 1942, and Gross Farm Income, June 1942. Bur. Agr. Econ., U. S. Dept. Agr.

GRADES AND PRICES

Under official grain standards of the United States wheat is divided into classes according to botanical species, habit of growth, color, or variety; into subclasses according to kernel texture or area of production; and into numerical grades according to physical condition and purity. The classes, 7 in number, are as follows: Hard Red Spring, Durum, Red Durum, Hard Red Winter, Soft Red Winter, White, and Mixed. The Hard Red Spring class is subdivided into the subclasses Dark Northern Spring, Northern Spring, and Red Spring. The Durum class is subdivided into the subclasses Hard Amber Durum, Amber Durum, and Durum. The Red Durum class has no subdivision. The Hard Red Winter class is subdivided into the subclasses Dark Hard Winter, Hard Winter, and Yellow Hard Winter. The Soft Red Winter class is subdivided into the subclasses Red Winter and Western Red. The White class is subdivided into the subclasses Hard White, Soft White, White Club, and Western White. Mixed wheats are of three categories according to the composition of the mixture, Mixed Wheat, Amber Mixed Durum, and Mixed Durum.

The grades are subdivisions of the subclasses, or of the classes for which there are no subclasses, and except in the case of the subclasses of the Hard Red Spring class are six in number, namely, No. 1, No. 2, No. 3, No. 4, No. 5, and Sample Grade. For the Hard Red Spring subclasses there are seven grades consisting of the preceding and one called No. 1 Heavy. These grades are based on definite limitations for test weight per bushel, total content of foreign material other than dockage, content of matter other than cereal grains, total content of wheats of other classes, content of wheats of special classes, content of broken and shrunken kernels, presence or absence of foreign odors, presence or absence of inseparable stones and cinders, temperature condition of the wheat, and whether or not it is of distinctly low quality.

In addition to giving wheat a numerical grade designation, the standards also provide for special grade designations, such as "Dockage - %," "Smut Dockage - %," "Light Smutty," "Smutty," "Tough," "Light Garlicky," "Garlicky," "Weevily," "Ergoty," "Limed," "Washed," "Sulphured," etc., to be affixed to the numerical grade when the wheat contains 1 percent or more of readily separable foreign material, or is smutty, or contains moisture in excess of 14 percent for some classes and 14.5 percent for other classes, garlic, live weevils and/or other insects injurious to stored grain, ergot in excess of 0.3 percent, or when it has been scoured, limed, washed, sulphured, or otherwise treated in a manner so that its true quality is not reflected by the numerical grade designation alone.

These standards further provide that each determination of moisture content, test weight, and the other factors specified in the numerical grade requirements shall be upon the basis of the grain after the removal of dockage, and that the determination of temperature, odor, garlic, and live weevils or other insects injurious to stored grain shall be on the basis of the grain including the dockage.

The percentages by classes of total market receipts of wheat, for the crop-year period 1933-37 and the crop years 1938 and 1939, falling into the various grades are shown in table 18.

Price data for some of the principal market grades at a few of the important terminal markets are presented in table 19. Complete data showing price differentials between all classes, grades, and markets are not readily available, but in general it may be stated that Red Durum class, Western Red and Western White subclasses, and No. 5 and Sample grades of all subclasses are the cheapest wheats. Also, that the areas in which the lowest wheat prices prevail are the surplus wheat producing sections of the Pacific Northwest, the Rocky Mountain States, and the Southwest Great Plains.

In the hard wheat classes the highest prices are nearly always paid for wheats of highest protein content, while in the soft wheat classes highest prices are paid for softness of texture, a quality associated with low protein content. Ordinarily there is much less range in the protein content of soft wheats than of hard wheats. Protein content does not enter into grade determination, although it is an important determinant of milling value.

PRODUCTION, SUPPLY, AND DISTRIBUTION

World production of wheat (excluding China, Manchuria, and the Union of Soviet Socialist Republics) has amounted in recent years to roughly 4 billion bushels annually (see table 20). Of this amount, the United States on the average (1930-39) produced approximately 748 million bushels (see table 21). United States production of wheat by classes is shown in table 22.

The annual supply and distribution of wheat in the United States from 1930 to 1942 are shown in table 23. During this period annual disappearance of wheat for domestic purposes remained fairly constant, ranging only from 627 to 754 million bushels, whereas production ranged from 526 to 981 million bushels, and carry-over from a low of 83 million on July 1, 1937, to an all-time high of 627 million bushels on July 1, 1942. Exports ranged from 7 to 126 million bushels. These fluctuations naturally result in wide variations in supply.

The United States has been a producer of surplus wheat since about 1860. Formerly its surplus was largely absorbed through exportations to foreign countries, and the avidity with which this surplus was absorbed, in a large measure, determined the prosperity of the United States farmer. Table 24 shows the wheat exports of the United States and other principal wheat exporting countries. Since about 1932, however, exports have dwindled to a negligible quantity, while production, despite governmental efforts to reduce acreage, has not declined accordingly. The ensuing accumulating surplus has become burdensome, climaxed by a crop carry-over in 1942 of approximately 627 million bushels, almost double that of any previous year.

Table 18. - Percentages of wheat grades by classes, average 1933-37 and annual 1938 and 1939, based on receipt inspections by licensed inspectors. All U. S. inspection points.

Class and year beginning July	Proportion of total inspected, graded as-						Quantity inspected
	No. 1	No. 2	No. 3	No. 4	No. 5	Sample	
	Percent	Percent	Percent	Percent	Percent	Percent	1000 bus.
Hard Red Spring:							
1933-37 average	40.5	12.2	14.3	8.5	7.8	16.7	74,565
1938	38.4	16.4	23.1	13.6	6.8	1.7	127,790
1939	44.4	17.5	26.4	8.8	2.5	.4	135,051
Durum:							
1933-37 average	30.8	33.5	13.3	10.3	8.6	3.5	13,310
1938	66.1	25.2	6.8	1.2	.3	.4	26,534
1939	38.2	50.8	9.1	1.4	.2	.3	22,696
Red Durum:							
1934-37 average	19.4	44.1	24.6	7.9	1.2	2.8	1,111
1938	52.0	29.5	10.0	3.8	2.5	2.2	7,562
1939	55.5	37.9	5.2	.6	.1	.7	6,870
Hard Red Winter:							
1933-37 average	41.3	34.6	12.7	5.5	3.3	2.6	248,542
1938	29.3	34.7	20.8	10.1	3.5	1.6	440,512
1939	33.9	39.8	20.5	3.4	.4	2.0	288,813
Soft Red Winter:							
1933-37 average	20.8	37.3	21.0	8.9	5.9	6.1	80,757
1938	14.1	39.4	22.7	10.2	7.5	6.1	85,410
1939	7.0	47.1	33.4	6.0	2.2	4.3	77,258
White:							
1933-37 average	32.2	52.4	11.5	2.0	.9	1.0	62,376
1938	44.4	43.8	9.1	1.7	.4	.6	71,028
1939	61.0	34.1	3.9	.4	.1	.5	52,639
Mixed:							
1933-37 average	31.7	37.7	16.4	6.4	4.4	3.4	35,188
1938	21.2	34.1	28.3	9.1	3.3	4.0	40,790
1939	22.3	50.1	21.4	2.6	.5	3.1	30,093
Total:							
1933-37 average	35.9	34.1	14.4	6.2	4.3	5.1	1/515,849
1938	31.5	32.7	20.2	9.5	4.0	2.1	799,626
1939	35.0	36.2	21.4	4.5	1.1	1.8	613,420

1/ Total of 5-year averages for each class, except for Red Durum class, which is 4-year average.

Source: Compiled from reports of Agr. Market. Adm., U. S. Dept. Agr.

Table 19. - Average prices of wheat per bushel, selected grades, and markets 1910-41

Year beginning July	No.1 Northern Spring Minneapolis	No.2 Amber Durum Minneapolis	No.2 Red Winter St. Louis	No.2 Hard Winter Kansas City	No.2 Hard Winter Chicago	No.2Hard Winter New York	Imported Liverpool 1/
	Cents	Cents	Cents	Cents	Cents	Cents	Cents
1910	105	87	99	98	100	104	107
1911	107	98	94	97	94	110	112
1912	87	85	105	88	94	103	114
1913	88	83	89	84	89	99	106
1914	120	122	110	105	111	136	157
1915	109	104	120	119	114	128	175
1916	176	180	163	171	157	208	224
1917	220	218	223	252	228	240	235
1918	2/ 236	222	223	219	234	237	240
1919	300	249	230	242	227	255	215
1920	201	200	213	183	216	210	223
1921	148	119	127	120	128	135	151
1922	126	107	121	113	113	131	144
1923	124	106	107	105	106	121	3/ 127
1924	158	156	159	135	139	170	181
1925	165	144	169	163	161	180	176
1926	151	155	138	135	140	156	163
1927	141	132	149	135	138	153	152
1928	126	113	139	112	117	131	128
1929	130	119	130	120	130	126	129
1930	82	78	83	76	84	4/ 92	80
1931	71	76	52	47	53	68	59
1932	61	58	55	51	53	69	54
1933	91	103	94	88	94	106	68
1934	116	5/ 138	94	98	102	119	81
1935	126	113	95	105	104	125	90
1936	147	157	111	121	117	143	126
1937	128	107	113	111	118	116	124
1938	79	72	70	70	70	87	70
1939	97	92	75	74	78	112	6/
1940	90	92	82	82	85	106	--
1941	110	116	110	112	109	139	--

1/ 1910-25, imported Red wheat; 1926 to date, average of all parcels at Liverpool
2/ No. 1 Dark Northern Spring beginning 1918.
3/ Average for 11 months.
4/ Average for 6 months.
5/ Hard Amber Durum beginning 1934.
6/ Market closed September, 1939.

Source: U. S. Dept. Agr., Agricultural Statistics.

Table 20. - World production of wheat excluding the Union of Soviet Socialist Republics, China, and Manchuria, 1934-42 1/

Year beginning July	U. S.	Canada	Argentina	Australia	Europe (exc. U.S.S.R.)	All others 2/	World 2/
	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels
1934	526	276	241	133	1548	837	3561
1935	626	282	141	144	1576	832	3602
1936	627	219	250	151	1481	857	3585
1937	876	180	208	187	1539	889	3879
1938	932	360	379	155	1848	962	4636
1939	751	521	131	210	1694	973	4280
1940	813	540	299	83	1300	968	4003
1941 3/	943	312	224	167	1420	914	3980
1942 3/	981	608	200	145	1380	896	4210

1/ Data are in many instances unofficial forecasts.

2/ Except U.S.S.R., China, and Manchuria.

3/ Preliminary.

Source: Compiled from official sources.

Table 21. - Harvested acreage, yield per acre, and production of all wheat in the United States by states, average 1930-39, annual 1941 and 1942

State	Acreage harvested			Yield per acre			Production		
	Average 1930-39	1941	1942	Average 1930-39	1941	1942	Average 1930-39	1941	1942
	Thousand acres			Bushels			Thousand bushels		
Maine	5	2	2	20.0	18.0	20.0	93	36	40
N. Y.	262	296	281	21.7	22.5	26.9	5,727	6,646	7,559
N. J.	55	55	50	22.2	22.0	23.5	1,230	1.210	1,175
Pa.	975	867	806	19.7	19.5	19.0	19,232	16,897	15,301
Ohio	2,037	1,959	1,724	20.2	25.0	21.0	40,958	48,978	36,205
Ind.	1,730	1,476	1,108	17.5	23.5	12.5	30,250	34,665	13,865
Ill.	2,064	1,716	981	17.9	20.0	13.1	37,118	34,320	12,818
Mich.	829	741	681	20.7	22.0	22.5	16,966	16,286	15,322
Wis.	109	79	78	16.4	17.2	22.0	1,780	1,362	1,717
Minn.	1,658	1,471	1,112	13.3	13.7	20.8	22,132	20,104	23,170
Iowa	421	181	211	17.4	12.9	22.5	7,411	2,341	4,749
Mo.	1,934	1,336	695	14.4	13.5	13.0	27,653	18,036	9,035
N. Dak.	7,392	8,155	7,321	8.1	17.8	20.5	62,839	144,799	149,844
S. Dak.	2,378	2,864	2,630	7.6	12.3	17.2	20,956	35,358	45,274
Nebr.	3,211	2,354	2,947	13.0	15.4	23.7	42,962	36,222	69,908
Kans.	10,768	11,799	10,610	11.8	14.7	19.5	131,896	173 332	206,775
Del.	84	65	60	17.4	20.5	21.5	1,465	1,332	1,290
Md.	427	345	307	19.1	21.0	19.5	8,183	7,245	5,986
Va.	597	511	470	14.5	15.0	16.0	8,633	7,665	7,520
W. Va.	138	105	94	15.1	15.5	15.5	2,073	1,628	1,457
N. C.	444	474	517	11.1	15.5	15.5	4,903	7,347	8,014
S. C.	139	244	307	10.0	13.0	11.0	1,366	3,172	3,377
Ga.	141	191	241	9.3	11.5	10.5	1,273	2,196	2,530
Ky.	387	375	371	14.0	19.0	14.0	5,456	7,125	5,194
Tenn.	392	361	361	11.3	15.0	14.5	4,388	5,415	5,234
Ala.	6	7	13	10.2	13.0	13.0	57	91	169
Miss.	---	11	7	----	27.0	23.0	---	297	161
Ark.	61	30	22	9.3	10.5	11.0	561	315	242
Okla.	4,046	4,543	3,477	11.6	10.7	16.5	47,981	48,610	57,370
Tex.	3,129	2,614	2,875	9.5	10.4	16.5	31,360	27,186	47,438
Mont.	3,236	3,703	3,267	9.9	18.4	22.6	33,619	68,239	73,783
Idaho	1,047	954	795	23.0	29.2	26.1	24,222	27,850	20,770
Wyo.	209	236	202	10.8	20.4	21.2	2,300	4,805	4,288
Colo.	991	1,368	1,269	11.9	18.3	21.9	12,186	25,036	27,848
N. Mex.	252	173	278	9.6	15.8	17.3	2,742	2,735	4,813
Ariz.	39	27	23	23.0	14.5	25.0	888	392	575
Utah	257	266	227	20.1	26.4	22.1	5,207	7,027	5,010
Nev.	16	18	17	24.8	27.3	28.5	385	491	484
Wash.	2,184	2,098	1,777	20.4	29.1	31.1	44,362	61,142	55,148
Oreg.	938	820	714	19.8	28.7	27.9	18,620	23,538	19,953
Calif.	755	752	536	18.5	15.5	18.5	14,136	11,656	9,916
U. S.	55,743	55,642	49,464	13.3	16.9	19.8	745,575	943,127	981,327

Source: Compiled from official sources.

Table 22. - Wheat production by classes for the United States, average 1930-39, annual 1940, 1941, and 1942

Year	Hard Red Spring	Durum 1/	Hard Red Winter	Soft Red Winter	White (Winter and Spring)	Total
	1000 bus.	1000 bus.	1000 bus.	1000 bus.	1000 bus.	1000 bus.
Average:						
1930-39	111,749	28,845	311,785	206,382	88,746	2/ 747,507
Annual:						
1940	159,720	34,304	329,797	206,265	83,135	813,221
1941	207,463	42,660	394,996	209,398	88,610	943,127
1942	215,321	45,505	482,791	160,285	77,425	981,327

1/ Includes wheat of the class Red Durum.

2/ This figure has been revised to 745,575, but the revisions by classes are not yet available.

Source: Compiled from official sources.

Table 23. - Supply and distribution of wheat in continental United States, 1930-42

Year beginning July	SUPPLY				DISTRIBUTION		
	Carry-over July 1	Production new crop	Imports (flour included) 1/	Total supply	Domestic disappearance	Exports and 2/ shipments (including flour)	Carry-over June 30
	1000 bushels	1000 bushels	1000 bushels	1000 bushels	1000 bushels	1000 bushels	1000 bushels
1930	288,879	886,470	354	1,175,703	747,137	115,278	313,288
1931	313,288	941,674	7	1,254,969	753,842	125,654	375,473
1932	375,473	756,927	10	1,132,410	719,582	34,889	377,939
1933	377,939	551,683	153	929,775	627,092	28,377	274,306
1934	274,306	526,393	3/ 15,569	816,268	656,246	13,314	146,708
1935	146,708	626,344	34,617	807,669	658,885	7,096	141,688
1936	141,688	626,766	34,455	802,909	688,169	12,263	102,477
1937 4/	4/ 82,802	875,676	634	959,112	703,017	103,381	152,714
1938	4/ 152,714	931,702	271	1,084,687	722,993	109,534	252,160
1939	4/ 252,160	751,435	263	1,003,858	673,912	48,343	281,603
1940	4/ 281,603	813,221	3,523	1,098,347	674,825	37,251	386,271
1941	4/ 386,271	943,127	---	1,329,398	658,000	---	627,000
1942 5/	627,000	981,327	---	1,608,327	750,000	---	

1/ Imports include full-duty wheat, wheat having a duty of 10 percent ad valorem, and dutiable flour in terms of wheat and excludes flour free for export.

2/ Shipments are to Alaska, Hawaii, Puerto Rico, and Virgin Islands. (Virgin Islands prior to December 31, 1934, included with domestic exports).

3/ Includes durum wheat returned from Montreal, estimated at 1,500,000 bushels.

4/ 1930-36 , inclusive, some new wheat included in carry-over. Beginning with 1937 only old crop wheat is included in carry-over; new wheat, in thousand bushels, was excluded as follows: 1937, 19,675; 1938, 19,566; 1939, 41,206; 1940, 13,450; and 1941, 21,509.

5/ Preliminary.

Source: Wheat Situation, WS-64, Feb. 1942 and subsequent revisions. Bur. Agr. Econ., U.S. Dept. Agr.

Table 24. Wheat exports, including flour in terms of grain, of the principal exporting countries, averages 1925-29 and 1930-34, annual 1938

Country	Year beginning July					
	Average 1925-29		Average 1930-34		1938	
	Exports	Imports	Exports	Imports	Exports	Imports
	1000 bushels	1000 bushels	1000 bushels	1000 bushels	1000 bushels	1000 bushels
Canada	307,640	796	220,491	387	159,885	2,489
United States 1/	170,077	15,815	73,403	15,591	106,645	271
Argentina	159,377	2/ 10	143,537	0	116,116	0
Australia	83,268	3	128,363	3	96,423	1
Hungary	23,539	8	17,123	1	27,875	0
U.S.S.R.	17,731	0	48,272	1,503	---	---
Yugoslavia	10,822	5	5,421	8	5,352	0
British India	10,080	8,636	4,129	3,075	10,097	7,248
Rumania	6,528	79	11,482	15	42,864	0
Algeria	5,153	1,737	11,022	1,511	3,546	1,495
Tunisia	3,518	669	5,924	864	4,568	592
Bulgaria	1,869	3/ 1,804	4,919	0	2,633	0
Poland	1,407	4,820	3,224	509	3,086	109
Chile	925	456	703	956	5	1,058
Total	801,934	34,838	678,013	24,423	579,095	13,263

1/ Averages for 1925-29 and 1930-34 comprise exports of domestic wheat and all flour; imports comprise all wheat (including for milling in bond and export) and all flour, annual 1938, exports comprise domestic wheat and flour made from "wholly United States wheat"; imports for consumption comprise a "wheat unfit for human consumption", "wheat, other" (42 cents dutiable), and all wheat flour, except flour "imported in bond for export".

2/ 3-year average.

3/ 1 year only.

Source: Wheat Situation, WS-64, Feb. 1942. Bur. Agr. Econ., U. S. Dept. Agr.

As indicated by the data presented in table 25, wheat used for seed for the period 1930-41 averaged 12 percent of the total domestic disappearance; feed (fed on farms where produced), averaged 16 percent; food uses averaged 69 percent; and the balancing item averaged 3 percent. The quantity of wheat used for seed and food, or approximately 81 percent of the domestic disappearance, varies only slightly from year to year. Since obviously the use of wheat for seed and food may not be expanded to any considerable extent, if there is to be any increase in domestic utilization it must necessarily be accomplished by other means. Efforts are now being made through scientific research in the Northern and Western Regional Research Laboratories to increase the industrial utilization of wheat for assisting in the solution of the surplus problem, and also the United States Department of Agriculture is now (1942) urging the feeding of more wheat to livestock.

Table 25. Distribution of the United States Domestic disappearance of wheat, 1930-41

Year	Food	Feed (fed on farms where produced)	Seed	Balancing item 1/	Total
	1000 bushels	1000 bushels	1000 bushels	1000 bushels	1000 bushels
1930	488,170	157,188	80,886	20,893	747,137
1931	485,381	173,991	80,049	14,421	753,842
1932	493,916	124,912	83,513	17,241	719,582
1933	450,088	72,261	77,832	26,911	627,092
1934	462,918	83,700	82,585	27,043	656,246
1935	471,707	83,168	87,555	16,455	658,885
1936	479,517	88,272	96,593	23,787	688,169
1937	475,831	112,860	94,146	20,180	703,017
1938	486,531	125,591	75,454	35,417	722,993
1939	485,581	91,487	72,853	23,991	673,912
1940	490,511	98,622	74,350	11,342	674,825
1941	502,000	97,987	64,236		

1/ Includes wheat used in mixed commercial feeds and wheat fed on farms other than where grown.

Source: Wheat Situation, WS-64, Feb. 1942 and subsequent revisions. Bur. Agr. Econ., U. S. Dept. Agr.

Storage Facilities

An inventory of commercial grain storage capacity in the United States as of February 16, 1942, made by the Agricultural Marketing Service, U. S. Department of Agriculture, revealed a total capacity of 1,602,258,000 bushels, of which 1,272,078,000 bushels were bulk storage, 315,313,000 bushels were bag storage, and 14,867,000 bushels were crib storage. New construction either underway or planned as of February 1, 1942, totaled 34,838,000 bushels.

Several rough estimates of farm storage indicate a total capacity of about 2 billion bushels.

USES

The principal uses of wheat in the United States consist of seed, feed, and food, with the latter accounting for about two-thirds of the total (see table 25). The use of wheat or its products for industrial purposes has been relatively very small in the past, but there is a possibility that in the future larger and larger quantities may be utilized for such purposes.

Seed

Total United States annual wheat requirements for seed (see table 25) ranged from 64 to 96 million bushels for the period 1930-41. Of the quantity so used approximately 22 percent consisted of Hard Red Spring, 6 percent of Durum, 41 percent of Hard Red Winter, 22 percent of Soft Red Winter, and 9 percent of White wheat.

Feed

Definite data on the total quantity of wheat fed annually in the United States are not available. Data, however, are available showing the quantity fed (see table 25) on farms where produced. For the period 1930-41 this varied considerably, ranging from 72 to 174 million bushels. That this quantity represents the major portion of the total fed is apparent from the fact that in table 25 the "balancing item," in which is included all other wheat used for feed, in no year, for the period covered, exceeded 35 million bushels.

The general use of wheat for feed is prevented owing to its relatively high price in relation to other grains. However, frequently situations in respect to supply arise which make its use either necessary or desirable. When corn is cheap and plentiful, farmers rarely use much wheat for livestock feed. Yet when drouth reduces the corn crop, when the price of wheat is lower than that of corn, or the corn crop fails to keep pace with the production of young animals, the value of wheat as a feed is rediscovered. Also, whenever there is a considerable proportion of damaged wheat, the quantity used as feed is likely to increase for the reason that such wheat is unsuitable either for food or for seed and consequently usually is utilized for feed.

The most consistent use of wheat as feed is in the feeding of poultry. Practically all scratch and mash feeding mixtures contain from one-third to three-fourths wheat or some product of wheat. No particular quality or type of wheat is demanded for this purpose; consequently, the cheaper grades and types are used. Red Durum wheat, owing to its relative cheapness, is one of the types so used.

In the feeding of livestock 16/, wheat is not considered an essential element in the ration, although in a general way, it is of equal feeding value, pound for pound, with corn. It is better in most respects than barley or oats. It contains somewhat more digestible protein than corn, a little less fat, and slightly more carbohydrate. It is definitely higher than corn in energy value. It is also higher in net energy, total digestible nutrients, and carbohydrate than either oats or barley. Its low crude fiber content gives it an advantage in digestibility over barley and more especially over oats.

In the feeding of wheat to hogs the following outstanding facts are important: (1) it may be substituted for corn and has about the same or slightly higher feeding value than corn; (2) when fed it should be supplemented by the use of some form of protein concentrate; and (3) grinding increases its feeding value 15 to 20 percent. In most cases wheat has shown a greater advantage in the feeding of hogs than of other classes of livestock.

For beef cattle feeding wheat is less palatable than corn but not less nutritious. Best results are obtained when the wheat is fed in a coarsely ground or rolled form. It is practicable to substitute wheat for some, if not all, of the corn in the feeding ration.

In the feeding of dairy cows best results are obtained if the wheat is used to an extent of not more than 33-1/3 percent in the feed ration.

In the feeding of sheep, wheat may be substituted for the other grains in the feed ration, but should be crushed or coarsely ground.

16/ Practical Experiences in Feeding Wheat. Fed. Farm Bd. Bul. No. 2, Nov. 1930.

Feeding Wheat to Livestock, U. S. Dept. Agr., Misc. Pub. No. 86.

Feeding Dairy Cows. U. S. Dept. Agr., Farmers' Bul. 1626.

Wheat is only fairly suitable as feed for lambs. It may be fed to horses with good results, although caution is necessary on account of its highly concentrated nature and, therefore, it should be fed only when mixed with other grains. In table 26 are shown the relative values per bushel of wheat, corn, and barley for feeding poultry, sheep, hogs, and beef cattle.

Besides the use of whole wheat for feeding purposes, the annual output of bran and shorts, byproducts of wheat flour milling, amounting to over 4 million tons, is used for feed. These byproducts are an important source of livestock feed.

Food

Approximately two-thirds of the annual United States domestic consumption of wheat, or roughly 480 million bushels, is for food. Some of this is consumed in the form of breakfast foods, macaroni, and spaghetti, but the large portion of it is converted to flour and used in making bread and pastry products. Table 27 shows the census reports for 1929, 1937, and 1939 giving the types and amounts of wheat flour and breakfast foods produced.

Because of substitution of other foods and reduced calorie requirements for many persons relieved of arduous labor through technologic advancements, the per capita consumption of flour has been declining over a period of years. This decline has been so great that even the considerable increase in population that has taken place has been unable to prevent a decline in total consumption. Table 28 shows the per capita consumption of wheat flour at 10-year intervals, 1879-1880 to 1909-1910 and the annual consumption of wheat and other cereals for the years 1919-20 to 1939-40.

Industrial Uses

It is fairly safe to say that up to 1941 not more than one million bushels of wheat were used annually for industrial purposes, including the making of starch, gluten, distilled spirits, malt, paste, and core-binder flour. In 1941 there was a slight increase, and in 1942 a substantial increase is expected.

Starch and Gluten

Starch and gluten are products generally derived jointly from wheat flour. The production of wheat starch is the oldest branch of the starch industry. Since about 1910 its importance, however, has declined relative to cornstarch owing to the fact that it was found that the latter made from a cheaper material was satisfactory for many purposes. Nevertheless, because wheat starch possesses special characteristics which give it superiority over other starches for certain uses, it is still being produced in the United States and in many countries of Europe and the Orient.

Table 26.- Relative values per bushel of corn, wheat, and barley, based on their relative worth for different feeding purposes

When price of corn is -	Relative feeding value (not including cost of grinding) for -				
	Poultry	Sheep		Hogs and beef cattle	
	Wheat	Wheat	Barley	Wheat	Barley
Cents	Cents	Cents	Cents	Cents	Cents
50	53.5	53.5	40	56	40
70	75	75	56	79	56
75	80	80	60	84	60
80	86	86	64	90	64
85	91	91	68	96	68
90	96	96	72	101	72
95	102	102	76	107	76
100	107	107	80	112	80
105	113	113	84	118	84
110	118	118	88	123	88
115	123	123	92	129	92
120	128	128	96	134	96
125	134	134	100	140	100

Source: Feeding Wheat to Livestock. U. S. Dept. Agr. Misc. Pub. 96. 1930.

* * * * *

Table 27. - U. S. Production of flour, bran and middlings, and breakfast foods made from wheat, 1939, 1937, and 1929

Product	1939	1937	1929
	1,000 bbls.	1,000 bbls.	1,000 bbls.
Wheat and prepared flours - total	111,369	105,274	120,094
White flour, for sale as such	95,891		
Blended flour, plain	403		
Phosphated flour	3,381		
Self-rising flour	5,395	1/ 101,416	1/115,773
Other prepared flours (biscuit cake, doughnut, pancake, etc.)	718		
Semolina flour	3,394	2,479	2,959
Graham and whole-wheat flour	2,187	1,379	1,362
	1,000 tons	1,000 tons	1,000 tons
Bran and middlings	4,500	4,184	4,682
	1,000 lbs.	1,000 lbs.	1,000 lbs.
Breakfast foods made from wheat:			
Ready to serve	299,539	297,334	2/
To be cooked before serving	153,453	149,161	

1/ Not broken down on 1937 and 1929 census schedules.
2/ Not available.
Source: Manufacturers Census, Grain-Mill Products, 16th Census, 1939.

Table 28. - United States apparent per capita consumption of wheat and other cereals, 1879-80 to 1939-40

Year 1/	Wheat flour	Corn meal and corn flour	Rye flour	Buckwheat flour	Cleaned rice	Cereal breakfast foods	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1879-80	224.0						
1889-90	224.0						
1899-1900	224.0	2/	2/	2/	2/	2/	2/
1909-10	210.0						
1919-20	175.0	35.0	3.1	1.0	4.9	(10.0)	229.0
1920-21	176.0	34.4	2.7	.8	6.0	(10.0)	229.0
1921-22	176.0	36.3	2.6	.7	4.4	(10.0)	230.0
1922-23	176.0	35.9	2.9	.6	5.1	(10.0)	226.8
1923-24	176.0	32.5	2.4	.6	5.3	(10.0)	224.5
1924-25	176.0	29.6	2.8	.6	5.6	9.9	224.6
1925-26	176.0	29.3	2.8	.5	5.6	10.4	224.8
1926-27	176.0	28.9	2.9	.5	5.6	10.9	226.4
1927-28	176.0	29.9	2.8	.5	5.8	11.4	226.4
1928-29	176.0	30.5	2.8	.5	5.6	11.8	227.2
1929-30	172.0	28.2	2.7	.5	5.0	11.8	220.2
1930-31	167.0	26.5	2.6	.4	5.6	11.8	213.9
1931-32	162.0	26.4	2.6	.3	5.0	10.9	207.2
1932-33	159.0	25.6	2.8	.2	5.9	10.0	203.5
1933-34	154.0	25.1	2.8	.2	4.9	9.6	196.6
1934-35	154.0	24.6	2.5	.3	5.9	9.0	196.3
1935-36	154.0	24.5	2.4	.4	5.3	9.0	195.6
1936-37	154.0	23.6	2.3	.5	6.7	9.0	196.1
1937-38	154.0	23.4	2.3	.3	6.4	9.0	195.4
1938-39	154.0	23.4	(2.3)	(.3)	5.5	(9.0)	194.5
1939-40 3/	154.0	2/	2/	2/	2/	2/	2/
1940-41 3/	154.0						

1/ Year beginning July 1 for wheat, rye, buckwheat flour; August 1 for rice; and January 1 of the second year indicated for corn meal and breakfast food.

2/ Not available.

3/ Preliminary estimates.

Source: Wheat figures for 1879-80 to 1909-10 based on data in Wheat Studies, Volume 4, No. 2; other figures from 1919-20 to 1938-39 from Northwestern Miller, April 17, 1940. Figure for 1939-40 to 1940-41 from Northwestern Miller Almanack, April 29, 1942.

Note: The figures in parentheses are probably estimates based on figures immediately preceding or following.

Low-grade wheat flours are chiefly used in the production of wheat starch and gluten, but these flours must be selected with care in order to assure the gluten being of proper quality. According to one source of information, usually "soft" wheat low-grade flour is used for this purpose.

Yields vary considerably according to the flour used, but on the average one hundred pounds of flour will produce about 50 pounds of starch, 10 pounds of gluten, and 22 pounds of "middlings." Since these are the only products, the difference between their total weight and the weight of flour represents a shrinkage or invisible loss of 18 pounds. The price relationship of these products is fairly well represented by the following wholesale factory prices reported as prevailing in March 1936: Starch $4.17, gluten $13.00, and "middlings" $2.17 per 100 pounds. On July 8, 1942, the F.O.B. price of starch was $8.00, that of gum gluten $25.00, and of devitalized gluten $15.00 per 100 pounds.

Two wet-milling companies in the United States produce wheat starch and gluten. One is located at Harbor Beach, Michigan, and the other at Columbus, Ohio. Both use wheat flour as a raw material. Eight companies are reported to have operated prior to World War I, but because of economic conditions during and after the war, six of them withdrew from business. For the years 1919-35 for which data are available annual United States production of wheat starch varied from 4.7 million to 16.3 million pounds and production of gluten from 0.6 million to 3.6 million pounds. During the last few years (1939-41) it is probable that the quantity of wheat starch produced annually has been somewhere between 15 and 18 million pounds.

As indicated in the preceding paragraph the method used in the United States for wheat starch production is at the present time based on the use of flour as the raw material source. The process used consists in preparing a dough from either first or second clear flour and then kneading this dough under a spray of water which washes the starch from the gluten. The gluten is dried either in vacuum or drum driers, and the starch slurry, after screening for the removal of fibrous material, is settled out on tables. It is reported that under normal operating conditions the following approximate yields are obtained from the use of this method: first grade starch, from tables 51 percent; starch tailings, 22.5 percent; and gluten, both gum and devitalized, 11.5 percent. Losses based on the original flour consist of - moisture, 7 percent; solubles, 5 percent; and fibrous material, 3 percent.

Wheat starch is utilized chiefly in the laundry and textile industries--consumption in the former predominating. It is also used to some extent in adhesives. It does not possess the stiffening properties of corn, potato, or tapioca starch, but is more flexible and moisture resistant and consequently advantageous for certain finishes. Used in conjunction with other starches, it is of value in stabilizing the finish. In laundry work it is used on linen collars, shirts, etc. Its moisture resistance, good spreading properties, and strong adhesiveness make it desirable for adhesive use.

Gluten is marketed for food purposes and as a substitute for albumen in the textile industry. Much of the gluten produced in the United States is exported or is further processed into mono-sodium glutamate, known in the Orient where it originated as "ajinomoto." This secondary product is used chiefly as a condiment for seasoning foods, particularly soups, gravies, and stews. Four pounds of wheat gluten are required to produce one pound of mono-sodium glutamate.

Wheat starch, rice starch, and white and sweet potato starches together constitute only about one percent of the total United States production of starch (including that converted into sirup and sugar); they are dutiable when imported. Wholesale prices in cents per pound reported in May 1942 for the various starches were as follows: Wheat (thick boiling) 5.00; corn, pearl 3.47, powdered 3.57; rice 9.43; white potato 6.37; sweet potato 6.25; arrowroot (powdered) 9.50; sago (flour) 5.38; and tapioca 5.50.

Gluten - Procea Process 17/

In addition to the methods of gluten extraction referred to in the section immediately preceding, there is one known as the Procea Process invented by an Australian named Bellingham. By this process the gluten is extracted from flour in a manner which permits adding this gluten to flour dough used for baking bread. It is claimed the process can be operated in the usual bake shop.

In extracting the gluten a dough is formed by mixing flour and water together. A little yeast is used with the water to aerate the dough. Then a "simple" chemical is mixed with the dough and the whole left for 2 or 3 hours, after which it will be found that the starch and gluten have separated - the starch on the bottom and the gluten on the top with a layer of water between. The gluten may then be lifted out of the water en masse.

The benefits from the use of this process, as claimed by its promoters, are as follows: (1) Bread dough made from almost any type of flour can be modified by the addition of gluten extracted either from the same or from other flour; (2) by thus increasing the gluten content of a dough, the possibility is greatly increased of obtaining good quality bread; (3) the gluten itself may be used in producing starch-free or low-starch breads for "slimming" and health diets; and (4) the process makes possible the utilization of low-grade flours in bread production by using them as sources of gluten to be added to bread doughs made from other flour.

No mention is made in published articles concerning the possible use of the starch separated from the gluten by the use of the Procea Process but it is probable that this product could be utilized in the production of cakes.

17/ Sources of information: Food Manufacture, October 1935, and Bakers Helper, October 5, 1935.

Alcohol and Potable Spirits

Until recently wheat has been used only to a small extent in the production of industrial alcohol and potable spirits. In the production of the latter only sound wheat is used, but in the production of the former unsound wheat might be used. According to official reports 18/, the quantities of wheat used in the production of alcohol and other distilled spirits for fiscal years 1901-40 were as follows:

Year (ending June 30)	Bushels	Year (ending June 30)	Bushels	Year (ending June 30)	Bushels
1901	24,171	1914	10,582	1927	--
1902	29,391	1915	4,550	1928	--
1903	32,197	1916	3,373	1929	--
1904	23,915	1917	2,533	1930	11,990
1905	12,481	1918	--	1931	28,379
1906	11,366	1919	--	1932	331,631
1907	21,452	1920	--	1933	6,480
1908	11,756	1921	--	1934	44,000
1909	9,648	1922	--	1935	51,000
1910	10,316	1923	--	1936	--
1911	21,765	1924	--	1937	51,000
1912	25,505	1925	--	1938	39,000
1913	2,756	1926	--	1939	56,000
				1940	30,000

The reason such small amounts of wheat have been used in past years for alcohol production has been mainly that its price was higher than the prices of other grains. In 1942, however, the serious wheat surplus problem (crop carry-over of 627 million bushels), the greatly increased demand for alcohol for use in the production of munitions, synthetic rubber, and other essential supplies, and the scarcity of black strap molasses, previously the chief raw material for alcohol production, created a situation which made it advisable for the Commodity Credit Corporation to offer some of its holdings of wheat for distilling purposes at relatively low prices.

The possibility of any expansion in the use of wheat for the production of potable spirits has not been explored until recently. From recent trials it has been found that the characteristic flavor of the alcoholic spirits produced from wheat is not significantly different from corn spirits, under modern distillation and fermentation procedures.

18/ Statistics for fiscal years 1901-1933, with blanks for the Federal Prohibition years, are from U. S. Treasury Department, Bur. of Ind. Alcohol report of Dec. 1933, "Statistics Concerning Intoxicating Liquors". Statistics for 1934-1940 are from U. S. Dept. of Agr., Bur. Agr. Econ. Feed statistics supplement No. 2, table 21.

The alcohol yield from wheat compares very favorably with those from other starchy farm crops as is shown in table 29. Whatever yield advantage it has, however, is usually offset by inverse price relationships which favor the use of other materials; this accounts for the relatively small quantity of wheat used for this purpose in past years.

Table 29. - Potential yields 1/ of alcohol and dried distillers' grains from wheat--and the quantity of malt required--in comparison with other crops as alcohol sources

Kind of material	Weight per bushel	Approx. yield 1/ of 95% alcohol per specified bushel weight	Approx. yield 1/ of distillers' grains on total-material weight
	Pounds	Gallons	Percent
Wheat	60	2.8 2/	26.9
Corn	56	2.5	22.3
Grain Sorghum	50	2.1	24.4
Rye	56	2.3	27.1
Rice (rough)	45	1.9	26.0
Oats	32	1.1	42.3
Potatoes	60	.8	3.8
Sweet potatoes	55	1.0	4.0

1/ Based on mixtures of 88 percent grain and 12 percent malt.
2/ Wheat has a greater variation in carbohydrate content than corn. Commercial wheat, therefore, may give lower alcohol yields than commercial corn, for the grades ordinarily used.

Source: Use of Alcohol from Farm Products in Motor Fuel. Senate Document 57, 73rd Congress, 1st session.

Malt

Most malt is made from barley and rye. It may also be made from wheat, but that grain has not been used for malt to any appreciable extent until quite recently, principally because of its higher price in relation to barley and rye.

The principal use of malt is in the distilling and brewing industries for saccharifying starch in order to make it available to micro-organisms which convert the sugar to alcohol and carbon dioxide. For this purpose barley and rye malts are very satisfactory. There is another use, however, which has been gaining in importance, namely, that of being mixed with wheat flour for increasing diastatic activity in order to obtain improved quality in bread baking. For this use barley and rye malts are not so satisfactory as wheat malt for two reasons, (1) undesirable color effects and (2) legal prohibitions on flour mixtures. One maltster who was using wheat in 1940 stated there was a potential United States market for 5 million bushels of wheat annually for malting purposes.

The use of wheat malt for improving the baking quality of flours may be accomplished in three different ways. The wheat malt as grain may be mixed with the mill grist of wheat before milling; it may be milled separately and the flour therefrom mixed with other flour at the mill where the latter is produced; or the malt flour may be mixed with other flour at the bake shop. Millers who add wheat malt to their mill grist before grinding add it in amounts up to 0.2 percent.

Soft starchy wheats have been generally used in the making of wheat malt but it is reported that malt made from hard wheats has a higher diastatic activity.

Paste

Pastes for use in bookbinding and paper hanging are sometimes made from wheat flour. For these purposes soft wheat "low-grade" and "clear" flours are usually preferred. Formerly, practically all paste used for paper hanging was made from wheat flour, but in recent years professional paper hangers have been using a prepared paste made chiefly from cornstarch. Some low-grade flour is used in the manufacture of plywood adhesives.

Core-Binder Flour

Wheat flour is frequently used in iron foundries as a core binder in the preparation of molds for castings. Flour of any grade or degree of soundness is suitable for this purpose; consequently, low-grade and damaged flours which are the cheapest are generally used.

FLOUR MILLING PROCESSES

Modern Process

In the milling of wheat it is generally the aim to separate the branny covering and germ from the endosperm with as little contamination of the latter as possible and then pulverize the endosperm into flour. The present or modern process is one of gradual reduction of the kernel with subsequent sifting operations after each reduction. The reductions are accomplished between chilled iron rolls revolving in opposite directions at different rates of speed.

Before wheat is ground into flour it must be thoroughly cleaned and properly conditioned. The cleaning, owing to the varied kinds of weed seeds, other grains and other foreign material which may be present, requires the use of a variety of methods and devices. These include magnetic separators for removing iron and steel objects, washers for removing smut spores and other loose dirt, combination screening-and-fanning machines called receiving-and-milling separators for removing loose, coarse, and fine materials, scourers for removing fixed surface dirt and the fine hairs (referred to collectively as the "brush") which occur on one end of the wheat kernel, and other machines of a special character for the removal of small stones, garlic, cockle, mustard,and oats.

The modern milling process used in the production of flour is designed to take advantage of the natural physical characteristics and susceptibilities of the component parts of the wheat kernel. Maximum milling efficiency is attained only when the grain is in proper condition when milled. The branny covering of the kernel is tougher than the other components, a characteristic permitting the breaking up of the other components without materially reducing the bran and thereby making possible their separation on the basis of difference in size of particle. This toughness varies according to the amount of moisture present. The embryo or germ is oily and when of the right moisture content is soft and pliable, which characteristics enable it to be easily flattened into sizable particles that can be readily separated from the endosperm. The endosperm or flour component of the kernel is friable when it contains the proper amount of moisture, and is then capable of being fractured to angular particles of various sizes according to the will of the miller. If the endosperm has too much moisture it has a tendency to flake, whereas if it has too little moisture its resistance to pulverization is increased; efforts to overcome such resistance to pulverization cause the endosperm to pulverize into flour too early in the process. The conditioning of wheat for milling, therefore, is largely a matter of adding or taking moisture from the wheat in a manner that will result in the proper moisture content for each of the component parts of the kernel. To accomplish this, either drying or wetting with subsequent storage in tanks for a number of hours to allow for penetration, or proper distribution, may be necessary depending upon the original condition of the grain. In some instances the application of heat may be essential to attaining the optimum condition for the grinding and subsequent sifting operations.

Starting with the cleaned and conditioned grain the modern process of milling consists of a series of grinding operations, some known as "breaks" and the remainder as "reductions," each followed by a sifting operation or operations combined in some instances with air aspiration. The "breaks" are accomplished by use of corrugated rolls, whereas the "sizings" and "reductions" are generally all done on smooth rolls. However, on sizings and on certain reductions finely corrugated or scratch rolls are sometimes used.

The principal milling product is flour. Ordinarily the byproducts are bran and shorts but occasionally include wheat germ which is used as a health food. Bran and shorts are used as feed for livestock. Shorts, which is composed of fine particles of bran and germ and unseparated portions of the endosperm, is sometimes divided into flour middlings, or gray shorts, and standard middlings, or brown shorts. The flour product if undivided is called "straight" but frequently it is divided into "patent," "clear," "low-grade," and sometimes "red dog" flours. Theoretically, "straight" flour is the total flour product, but generally from 2 to 5 percent of the poorest flour is excluded. The "patent" flour is that portion of the total flour freest from bran particles and best in quality. This name was originally applied to flour resulting from the reduction of granular endosperm particles which had been purified of bran particles by use of the middlings purifier, a patented device. Patent flour is of the "short," "fancy," "long," or "standard" variety according to the percent (30 to 95) it represents of the total volume of flour milled. "Clear" flour, also called "bakers," is the second grade flour fraction and may represent from 5 to 55 percent of the total volume of the flour. It is sometimes subdivided into "first" and "second" clear with first clear being superior to second clear. "Low-grade," representing 1 to 5 percent of the total, is the poorest grade of flour unless a longer than average extraction of flour is made in which case a still lower grade known as "Red Dog" is produced.

In case a short or low percent patent flour is made, the remaining flour, if not further divided, is called "cut-straight." Another grade sometimes produced is "filled-" or "stuffed-straight" consisting of a straight flour from one run of wheat to which has been added "clear" or "cut-straight" flour from another run.

The yield of flour from a bushel (60 pounds) of wheat varies somewhat according to milling efficiency and to its grade and weight per measured bushel (see table 30). In the United States, on the average, 4.6 bushels of clean wheat are used to produce a barrel (196 pounds) of white flour, representing a flour yield or extraction of approximately 71 percent. Bran yields generally run from 9 to 16 percent of the weight of clean wheat, and shorts yields from 12 to 16 percent. Commercial wheat germ yields run from one-half to one and one-half percent.

Other Milling Processes

The modern or roller milling process which was adopted about 1870 displaced the buhr-stone process. The main differences between these two processes are in the duration of processing and the type of grinding machines used. The roller process includes more reduction operations than the buhr-stone process and more sifting and purification refinements which make it more efficient. The type of grinding machines used in each process is implied by its name. The efficiency of the roller process, although higher than

Table 30. - Average flour ("straight" grade) yields 1/ from wheats of various weights per bushel

Wheat weight per bushel 2/	Yields 1/ by wheat class				
	Hard Red Spring	Durum	Hard Red Winter	Soft Red Winter	White
Pounds	Percent	Percent	Percent	Percent	Percent
63	73.8	72.9	73.3	72.4	70.3
62	72.8	72.4	73.5	71.6	70.8
61	71.8	71.0	72.5	70.7	70.4
60	71.0	70.3	71.8	69.6	70.3
59	70.8	69.2	71.3	69.6	69.7
58	69.7	68.7	70.8	68.3	69.2
57	69.0	66.8	70.7	67.9	68.3
56	68.0	65.1	70.5	67.3	66.9
55	66.4	64.3	69.1	67.0	66.3
54	65.8	62.5	68.3	66.3	65.1
53	64.5		66.6		64.4
52	63.6		67.1		64.3
51	62.8		65.5		63.2
50	62.1				
49	61.2				
48	60.7				

1/ Percentage that weight of total ("straight") flour product is of weight of dockage-free wheat before tempering.

2/ Winchester bushel.

Source: Averages from experimental milling tests performed in the U. S. Dept. Agr., Bur. Agr. Econ. Milling and Baking Laboratory 1915-24. Total number of tests involved, 5383.

that of the buhr-stone process, is nevertheless not as high as is desired. This is apparent from the fact that, whereas the yield of flour by this process averages 71 percent of the weight of the wheat kernel, the actual endosperm (floury portion) content of the kernel is about 85 percent. Thus there is an apparent waste of 14 percent of flour in the present milling process. This inefficiency shows the need for improvement in the present milling process. A number of attempts at improvement either in efficiency of production or in quality of product have been made, but all thus far have either failed to give the desired improvement or have been impracticable for general milling purposes. The more important of these in recent years are the "Steinmetz" and "Earle" processes.

The "Steinmetz" and "Earle" processes are based on the principle of removing the outer coating from the kernel by soaking before beginning its reduction into flour. A special feature of the Steinmetz process which originated in Germany about 1920 is that it requires the immediate use of the flour by a special baking process.

The Earle process 19/, invented in 1941 by an American mining engineer, permits the production of a flour that requires neither immediate use nor baking by unconventional methods. In this process the wheat, immersed in water, is conducted through a series of flotation units or tubs in which it is churned by impellers. A small amount of sodium carbonate is introduced into the first tub to keep the pH of the water at a suitable figure. Also, a small amount of pine oil is added to assist with the formation of foam essential to flotation of the outer coating particles peeled from the wheat kernel by the churning action of the impellers.

Much importance is attached to the retention in flour of vitamins by the recent nutrition trend which emphasizes the need for a higher vitamin content in foods. Promotion of the Earle process has been largely on this basis and, whether or not it succeeds, this trend in nutrition is likely to have some effect on future milling processes.

The so-called Morris milling process patented in 1935 is primarily a modification of the conventional modern roller process having to do with pulverization of the wheat germ (embryo) and its incorporation in the flour in such a manner that the keeping qualities of the flour will not be impaired. The modifications used in accomplishing these results have to do with the grinding and aeration of those mill stocks containing most of the germ. Such stocks are ground much finer and aerated to a much greater extent than is customary in the conventional process.

19/ Sources of description: Peeled Wheat. By Maurice Johnson. The Northwestern Miller, April 9, 1941, and Food Indus., 13 (1941).

Geographical Distribution of Milling Capacity and Flour Production

There were an estimated 3,001 flour mills in the United States on January 1, 1942, with a total flour-producing capacity of 709,768 barrels per 24-hour day; corresponding estimates on January 1, 1941, showed 3,337 mills with a production capacity of 727,398 barrels. The trend toward a smaller number of mills and a reduction in milling capacity has been apparent since the turn of the century. This decline has been due largely to the abandonment of small custom mills, the consolidation and enlargement of terminal merchant mills, and a reduction in the per capita wheat flour consumption. In table 31 are shown the number of mills, milling capacity, and the quantity of wheat ground and flour produced for the period 1914 to 1941.

Table 31. - The number of flour mills, milling capacity, quantity of wheat ground, the amount of flour produced, and wheat ground per barrel of flour; 1914-1941

Year	No. of 1/ mills 2/	Wheat flour milling capacity 1/	Wheat ground 3/	Flour produced 3/	Wheat per barrel of flour
		Barrels per 24-hour day	1000 bushels	1000 barrels	Bushels
1914	7780	1,013,318	545,728	116,404	4.69
1919	7983	1,005,700	612,562	132,466	4.62
1921	7603	1,085,700	521,234	110,846	4.70
1923	7348	1,058,000	538,312	114,439	4.70
1925	6971	1,000,000	530,593	114,690	4.63
1927	5303	984,610	544,054	118,132	4.61
1929	4777	983,921	546,242	120,094	4.55
1931	4718	926,821	526,098	115,419	4.56
1933	3934	842,073	4/	4/	4/
1935	4255	840,615	470,533	102,327	4.60
1937	4063	811,452	485,869	105,274	4.62
1939	3865	788,740	508,054	111,369	4.56
1940	3423	737,391	5/(506,708)	5/(111,345)	(4.55) 5/
1941	3337	727,398	5/(505,597)	5/(111,103)	(4.55) 5/
1942	3001	709,768			

1/ On January 1 of designated year. Taken from Northwestern Miller, January 21, 1942.

2/ Active wheat and rye flour mills with daily capacity of 25 barrels or more.

3/ From Biennial Census of Manufacturers.

4/ Data for 1933 not comparable with other years because of differences in census schedule.

5/ Calculated from Current Statistical Service Releases of the Bureau of Census.

Buffalo, Kansas City, and Minneapolis, in the order named, are the leading flour-producing centers; Kansas, New York, and Minnesota are the leading flour-producing states; the Southwest, which includes mills located in Kansas, Oklahoma, and Nebraska, and in Kansas City and St. Joseph, Missouri, is the principal flour-producing district; and General Mills, Incorporated, Pillsbury Flour Mills Company, and Commander-Larabee Milling Company are the largest milling companies. Data showing the production of flour by principal districts and centers are presented in table 32. In table 33 are listed the 10 leading flour milling companies of the United States.

Shifts in the geographical center of the flour-milling industry have occurred intermittently since early in the nineteenth century, following changes in population, shifts in wheat producing areas and types of wheat produced, technological advances in milling methods, changes in freight rates, and changes in many other factors.

During the early 1800's, Philadelphia, Baltimore, and Richmond, Virginia, were in turn the most important milling centers and by 1850 Rochester, New York had assumed leadership in the amount of flour produced. The latter city's milling activities declined in importance, however, as the vast soft wheat producing territory of the Mississippi and Missouri Valleys came into production creating a new source of supply. This and the advantage of water transportation projected St. Louis and Cincinnati to preeminence as milling centers. However, their leadership was short-lived with the introduction in 1878 of the technological advancements in milling methods--the roller mill and purifier. These improvements permitted hard spring wheat, with its superior quality for breadmaking, to be processed to better advantage, thereby revolutionizing the industry and creating a market for northwestern wheat. As a consequence, Minneapolis became the milling center of the country and remained so until superseded by Buffalo in 1929. Since 1937 Kansas City has been second to Buffalo in the production of flour.

Buffalo's ascendency to first place in milling importance was largely the result of its favorable location. Being situated at the eastern terminus of the lake transportation route, which permits low water rates on wheat shipped from the West and short rail hauls for flour shipped to the large eastern consumption centers, was a contributing factor. Also, Buffalo is so situated between export markets and Canadian producing areas as to be able to take full advantage of the milling-in-bond privilege on Canadian wheat.

Table 32. - Production of flour by principal flour milling districts and cities and total for the United States, 1933-1941

District and city	Flour produced in -								
	1933	1934	1935	1936	1937	1938	1939	1940	1941
	1000 barrels	1000 barrels	1000 barrels	1000 barrels	1000 barrels	1000 barrels	1000 barrels	1000 barrels	1000 barrels
Northwest:									
Minneapolis	7,283	7,082	6,636	6,453	5,681	5,737	5,559	5,242	5,622
Outside mills	9,773	9,569	8,943	9,552	8,266	9,152	9,840	9,671	9,959
Total	17,056	16,651	15,579	16,005	13,947	14,889	15,399	14,913	15,581
Southwest:									
Kansas City	6,091	5,857	6,070	6,203	7,332	7,480	7,246	6,213	6,842
Atchison	1,406	1,405	1,353	1,493	1,458	--	--	--	--
Wichita	2,075	1,799	1,893	2,163	2,396	1,927	2,046	1,776	1,986
Salina	1,647	1,767	1,855	2,114	2,257	2,349	2,635	2,302	2,285
Outside mills	11,067	11,675	11,262	12,136	12,413	12,757	13,068	14,034	15,322
Total	22,286	22,503	22,433	24,109	25,856	24,513	24,995	24,325	26,435
North Pacific Coast:									
Seattle-Tacoma	1,034	1,220	1,081	1,260	1,172	3,159	3,461	3,253	3,248
Portland	1,126	1,143	1,647	1,848	1,860	2,004	2,142	1,890	1,717
Total	2,160	2,636	2,728	3,108	3,032	5,163	5,603	5,143	4,965
Other:									
Buffalo	9,781	9,625	9,635	10,425	10,252	10,200	10,188	9,803	10,180
Chicago	1,361	1,298	1,362	1,360	1,234	1,608	1,339	1,256	1,300
Central States	6,274	6,451	5,638	5,938	5,543	6,535	7,969	8,197	7,987
Grand total	58,918	58,891	57,375	60,945	59,864	62,908	65,493	63,637	66,448
U. S. total	96,975	97,852	96,743	101,179	100,275	102,589	105,374	102,994	105,992

Source: The Northwestern Miller Almanack, April 29, 1942, page 27.

Table 33. - The ten largest wheat flour milling companies in the United States in 1942

Company	Headquarters	Daily capacity
		Barrels
General Mills, Incorporated	Minneapolis, Minn.	70,650
Pillsbury Flour Mills Company	Minneapolis, Minn.	39,000
Commander-Larabee Milling Company	Minneapolis, Minn.	22,200
Russell-Miller Milling Company	Minneapolis, Minn.	18,500
Colorado Milling and Elevator Company	Denver, Colo.	16,700
Tex-O-Kan Milling Company	Dallas, Tex.	15,200
International Milling Company	Minneapolis, Minn.	14,500
Standard Milling Company	Chicago, Ill.	12,700
National Milling Branch of National Biscuit Company	Toledo, Ohio	8,500
Flour Mills of America, Inc.	Kansas City, Mo.	8,400

Source: The Northwestern Miller Almanack, April 29, 1942.

WHEAT UTILIZATION RESEARCH

Under Section 202 of the Agricultural Adjustment Act of 1938 the Secretary of Agriculture was authorized and directed to "establish, equip, and maintain four Regional Research Laboratories, one in each major farm producing area, and at such laboratories to conduct researches into and to develop new, scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and byproducts thereof. Such research and development shall be devoted primarily to those farm commodities in which there are regular or seasonal surpluses and their products and byproducts." In accordance with these provisions research in wheat utilization is being conducted by the Northern and Western Regional Research Laboratories, located at Peoria, Illinois, and Albany, California, respectively.

These researches include determination of composition and structure of different varieties produced under various environmental conditions; quantitative recovery, fractionation, purification, and modification of wheat protein; fractionation, recovery, chemical constitution, and modification of the starch constituent; and investigations on fermentation of wheat and wheat derivatives. No special study of the oil constituent is planned owing to the fact that wheat germ, the portion of the kernel containing most of the oil, already finds ready sale at relatively high prices in comparison with other component or constituent parts of the wheat kernel. The researches on wheat protein are being conducted by the Western Regional Research Laboratory, while the researches on the other wheat constituents are being conducted by the Northern Regional Research Laboratory.

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