WHEAT STUDIES

OF THE

FOOD RESEARCH INSTITUTE

VOL. IV, NO. 5 MARCH 1928

RYE IN ITS RELATIONS TO WHEAT

ASIDE from wheat, rye is the only cereal from which yeast-leavened loaf bread can be made. Rye is used for bread-making, for feed, and for distillation of alcohol; but only in Europe north of the Alps is production or consumption of large volume. Before the war, the per capita disappearance of rye was about 360 pounds in Germany and only 22 pounds in the United States. Since the war disappearance in both countries has declined, to about 245 pounds in Germany and 17 pounds in the United States. There has been a tendency to abandon rye bread in favor of wheat, though rye is as digestible as wheat except for the bran. Europe has always produced the bulk of the world crop of rye but not of wheat, and has therefore imported much more wheat than rye.

For an equivalent number of calories, the price of wheat usually exceeds the price of rye both in the United States and in Europe. This results largely from consumers' preference for wheat; rye bread has always been the bread of poverty in Europe, and rye tends to be regarded merely as a flavoring medium for wheat in the United States. Demand for rye seems sufficiently inelastic, however, to elevate rye prices above wheat prices in years of marked shortage of rye crops. So long as consumers everywhere continue to prefer wheaten bread and suitable land is available in the world for further expansion of wheat production, and so long as American farmers prefer other grains for feeding stuffs, the prospect for profitable continuous expansion of rye production in the United States is not bright.

STANFORD UNIVERSITY, CALIFORNIA

March 1928

WHEAT STUDIES

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The central feature of the series is a periodic analysis of the world wheat situation, with special reference to the outlook for supplies, requirements, trade, and prices. Each volume includes a comprehensive review of the preceding crop year, and three surveys of current developments at intervals of about four months. These issues contain a careful selection of relevant statistical material, presented in detail in appendix tables for reference purposes, and in summary form in text tables and charts.

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Entered as second-class matter February 11, 1925, at the post-office at Palo Alto, Stanford University Branch, California, under the Act of August 24, 1912.
Published by Stanford University for the Food Research Institute.

RYE IN ITS RELATIONS TO WHEAT

In the dietary of most nations the primary foodstuffs, plants and products of plants, exceed secondary foodstuffs, the edible products of animals. Among the primary foodstuffs, cereals are the most important. As a rule, except in the United States and a few other countries exceptionally situated, cereals contribute in terms of calories over half the food supply of a people. The reasons for the predominance of cereals lie both in agriculture and in the characteristics of the grains. The prominent cereals are wheat, rye, corn (maize), barley, oats, the grain sorghums, and rice.

The cereals are primarily carriers of carbohydrate and protein, the fat content being subordinate. Starch forms the outstanding component of all cereals, usually over 70 per cent of the dried weight. The proteins are important, naturally, but particularly so in countries making lesser use, or no use, of animal products. The starch of cereals is the most important fuel-food supporting the body heat and the physical work of domesticated animals and human beings. Since the starches of all cereals yield identical sugar when digested, the grains are directly substitutive. External characteristics may serve to limit substitution to some extent; but for the most part, both for human beings and domesticated animals, any one of the farinaceous cereals may be substituted for any other one. They are substitutive agriculturally to less extent than nutritionally.

The potato deserves to be classed with the cereals because starch is the chief component of the potato. To the extent, therefore, that any cereal represents a source of starch, the potato may be employed as substitute. Agriculturally, also, potatoes are substitutive with cereals over a considerable range.

In each continent are three main groups of grains which, though substitutive, stand somewhat detached from each other in agriculture, trade, and consumption. But though detached, they overlap and their relations are important. The three groups are the bread grains (wheat and rye), the coarse grains (oats, barley, corn, and the grain sorghums), and rice. Rice is widely used in countries bordering on the Mediterranean Sea, in the West Indies, and in Central America, but is a secondary or incidental cereal elsewhere in the Americas, in Africa, in Europe, in Australasia, and in Asiatic Russia. In all of these regions the chief groups of cereals are bread grains and coarse grains. But in Asia (outside of Siberia) and in the East Indies, bread grains, coarse grains, and rice are all prominent as cereal staples in the diet.

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Wheat and rye owe the name bread grain to the familiar fact that yeast-leavened bread is made from their flours. Yeast-leavened loaf breads cannot be made from the flours of corn, barley, oats, and rice, though baked preparations of the biscuit type and quick breads can be made. In mixed breads, coarse grains are often used to stretch the bread grains. But in household and commercial practice, the distinction is fundamental between bread made of flours of gluten-containing bread grains and bread made of meals of gluten-lacking coarse grains.

The relations of wheat and rye to each other are numerous and important. Europe, the largest importer of wheat, is also the largest consumer of rye. North America is a rye-growing continent, with a population of descendants from European stock. A study on rye therefore finds an appropriate place in WHEAT STUDIES. The following statement is not designed to be exhaustive on any point, but is purposed to serve as a general orientation on rye to those who are interested in the agriculture, the food uses, trade practices, and economic relations of wheat.

I. PRODUCTION AND MARKETING OF RYE

Agricultural Relations of Rye

Rye is a more hardy and rugged crop than wheat. It has a wider geographical range, both as to latitude and altitude. In the northern agricultural areas of Europe, Siberia, and in Canada and Alaska, rye matures where wheat cannot make a crop. South of the Equator, rye matures under otherwise favorable conditions in the southernmost parts of South Africa, Tasmania, and Argentina. Rye may successfully be sown in the fall throughout a wheat belt of North America where wheat must be sown in the spring; spring-sown rye, like oats, makes a crop in a belt of considerable width lying north of the spring-wheat belt. At the same time, rye does surprisingly well southward in our temperate zone, in the sub-tropical regions bordering on the Mediterranean Sea and the Gulf of Mexico. Since rye succeeds relatively everywhere that wheat thrives, and over large regions where wheat fails, the potential rye belt of the world is much larger than the potential wheat belt.

It has indeed been suggested that rye became a cultivated crop because it was so hardy a weed-grass that it could not be exterminated and finally became the major crop in some localities. Vavilov has reported[1] that in southwestern Asia wild rye still occurs as a weed in fields of wheat and barley. With increasing altitude, the rye withstands the adverse conditions better than wheat and barley. Long ago wheat and rye were planted together in Russia (and to some extent the practice still persists), the rye tending to predominate with unfavorable climate and on poor soils.

For marginal lands, rye is generally preferred over wheat. The soil requirements of rye are less exacting than those of wheat, and the adaptability is wider. Rye is not so good a crop as wheat for the first breaking of a prairie; but it does better on old and exhausted soils. Rye succeeds on the peaty soils of moors where wheat fails. Rye tolerates acid soils better than wheat; it may be grown on the same land year after year with a less marked decline in yield. Rye does surprisingly well on sandy soils, even if shallow. This explains the widespread distribution of rye over northern Europe; also, rye does well in the sandy soils adjacent to the Mediterranean Sea and widely distributed over our southern states. Larger crops of rye are of course secured on good land than on poor land, but not enough larger to favor the raising of rye if the land is good enough for wheat. Rye is called the "grain of poverty" in Europe as much because it lives on poor soils as because it is the bread of the poor classes.

Rye thrives under a lower mean summer temperature than is necessary for wheat. Rye endures cloudy weather better than wheat, requiring fewer hours of sunshine. The dormant plant stands a lower temperature during the winter, requires less snow cover, tolerates alternate freezing and thawing better; but it is sensitive to excessive moisture near the freezing point, and to freezing at blossom time. Under unfavorable winter conditions, rye makes a half-crop where wheat would fail entirely; under the coolest of summer conditions, rye will produce a part crop where wheat would hardly head at all.

Rye tolerates excessive moisture better than and endures deficient moisture as well as wheat; the newly planted grain makes less demand on subsoil moisture. A rank growth occurs with excessive moisture, with deficient moisture a stunted growth; but under both circumstances, the tendency to head is relatively pronounced. In terms of yield, the outturn is less affected by extremes of moisture than in the case of wheat, and the fluctuations are less. Rye does well in the humid areas of the states adjacent to the Great Lakes and in the subhumid regions of the northern Great Plains area.

Outside of ergot,[2] rye suffers less from parasitic diseases than wheat and is less

[1] *Bulletin of Applied Botany and Plant Breeding*, XXVI, No. 2, 1926.

[2] Ergot is a poison and a drug, as well as a pest of rye. Ergot poisoning, long associated with rye, holds now little more than historical interest except in a few countries of Europe (notably Russia and Spain) where control is still necessary. The condition is due to a parasitic fungus, *Claviceps purpurea*, that infests many grains and grasses but particularly rye. The fungus settles in the blossom of the growing grain, largely replacing the kernels as the head develops and ripening into a dormant stage, the *Sclerotium*

sought out by larger pests. Rust, smut, scab, cinch-bugs, the Hessian fly, the joint worm, and grasshoppers are less feared by growers of rye than by growers of wheat. Under these circumstances, it is sometimes practicable to plant spring rye in the winter-wheat area where spring wheat would stand little chance.

The yield of rye, in pounds per acre, is less than that of wheat under conditions favorable to wheat. But the minimum yield of rye is usually more than the minimum yield of wheat. In northwestern Europe before the war, usual yields were close to 30 bushels per acre; in southern and eastern Europe the usual yields were under 20 bushels; in Russia the yield was not much over 10 bushels per acre. In the Lowlands, France, and Germany, the yield of rye falls substantially below that of wheat. This is not true in Canada and in the United States. But under conditions relatively unfavorable to wheat, rye usually makes a larger yield than wheat. The usual yield of rye is larger under marginal conditions; it is a safer crop, less abandonment is observed, and the average yield therefore better. Since the kernel is smaller, a lower weight of rye is used in seeding than in the case of wheat, which means a relatively larger net yield from the crop. In many regions relatively adapted to both wheat and rye, but not conspicuously favorable to wheat, rye will produce more pounds per acre than wheat; whether more dollars per acre (even though the cost of raising rye is probably somewhat less) is of course another question.

Rye possesses several incidental advantages over wheat, or at least may offer them. When a field of fall-sown wheat offers a too-disappointing yield, it may be used as pasture, plowed for summer fallow, or plowed under for a spring-sown crop. Both wheat and rye, fall-sown, may be cropped in the spring without injury to the later harvest of grain if the condition is good and the cropping not excessive; apart from this, a stand of wheat is not used for fodder except to salvage an abandonment. Practically speaking, wheat is planted only for the purpose of harvesting wheat. But rye is often planted without intention to harvest rye—for pasture, cover crop, ensilage, and hay. Indeed, such use of rye, in rotations, is one of its prime advantages. Rye ripens a week or two earlier than wheat in the same region; it tends to shell out during harvest less than wheat (except Marquis), and demands less prompt attention when ripe for cutting; it sprouts less than wheat in the shock. Rye has a longer straw than wheat, yields more straw to the acre, and therefore furnishes more straw

clavus, which the following spring reinfects the next crop. The intensity of infection and spread of the parasite is favored by high humidity and wind. The parasite in its dormant stage, clumped in the head of the grain-stalk and called by Europeans "the mother-corn," has a waxy consistency and a sweetish taste, which attracts bees and other insects to it, this leading to dissemination of the infection. It may be restrained by the cutting of grasses in infected fields before the dormant stage of the parasite has developed, by adequate preparation of the soil and crop rotation, and by sterilization or cleaning of the seed. The extirpation of the fungus is made impracticable by the fact that the mother-corn brings a high price as raw material for pharmaceutical manufacture of preparations used as drugs. It is not difficult to remove the mother-corn by appropriate cleaning, though traces are likely to remain with the grain and appear in the flour. For the most part, infected rye flour has come from country mills not properly equipped for cleaning the grain, especially in localities where it is customary to grind rye without preliminary cleaning and scouring. European authorities generally regard two-tenths of one per cent of mother-corn in rye flour as the safe limit of tolerance; in some well-studied epidemics of ergot poisoning, the rye flour has been shown to contain over 5 per cent. Large amounts of the spurred rye are revealed in a sticky and semi-fluid consistency of the bread. Chemical, spectroscopic, and microscopic tests are available for application to the flour, but are unsatisfactory when applied to bread. The diagnosis may be confirmed by tests on animals. The prominent symptoms of ergot poisoning are peripheral gangrene (*Ergotismus gangraenosus*) due to the action of one constituent of the ergot on the peripheral blood-vessels, and spastic contractions or convulsions (*Ergotismus convulsivus*) due to the action of another constituent upon the central nervous system. Prior to the Napoleonic Wars, extensive epidemics occurred in various parts of Europe and small isolated epidemics have occurred during the present century. The crop of 1890–91 was the last instance of a generalized appearance of groups of ergot poisoning in Europe, though a sharp localized appearance was noted in Kursk and Tomsk in 1903. A review of the older literature suggests that ergot poisoning was confused with, or associated with, nutritional diseases, since some of the symptoms described, particularly cutaneous lesions, resemble those observed in pellagra. Indeed, some writers regard the historical ergotism as possible of occurrence only in association with inanition.

The parasite of ergot is generally disseminated over our northern states, but the intensity of infection is low. The usual limit of tolerance is three-tenths of one per cent. The routine methods of cleaning rye eliminate all but the very finest particles of ergot, so that American rye flour contains only insignificant traces. Commercially, ergot is more feared in durum wheat than in rye, since the trade standards for semolina are more rigid than for rye flour.

for farm use. Also, the straw has superior qualities for industrial uses, a matter of more importance in Europe than in North America.

Winter rye has definite advantages in rotation in some regions. In the upper Mississippi Valley, when a small grain is used for rotation, the choice often lies between rye planted in the fall and small grains planted in the spring. Being fall-sown and requiring little preparation of the soil (it is usually stubbled in), winter rye offers a better distribution of labor than spring wheat. Both in planting and harvesting, rye distributes farm labor well. Rye, with barley, lends itself well to the demand for concentrates in the northern dairying states. In many sections, therefore, rye has favorable relations in agriculture, despite its lower rating as foodstuff and feeding stuff. Good judges of agriculture believe that progressive farm practice in the United States could make advantageous use of 10 million acres planted to rye if the returns of rye as a cash crop were relatively remunerative. Raising rye is agriculturally advantageous, but selling the crop tends to be economically disadvantageous.

Characteristics of Rye as Grain

According to the official grain standards of the United States Department of Agriculture, "Rye shall be any grain which, before removal of dockage, consists of 50 per cent or more of rye, and when free from dockage contains not more than 10 per cent of cereal grain of a kind or kinds other than rye." Four grades of rye are established (Nos. 1, 2, 3, 4), weighing respectively 56, 54, 52, and 49 pounds minimum per Winchester bushel, and containing respectively not over 13, 14, 15, and 16 per cent of moisture. Grades 1 to 3 inclusive must be cool and of natural odor, i.e., sound; No. 4 rye must be cool, but may be musty or slightly sour. The four grades are permitted to contain, respectively, not over 2, 4, 7, and 15 per cent of damaged kernels, of which those with heat damage may not exceed respectively 0.1, 0.2, 0.5, and 3.0 per cent. The total foreign material other than dockage permitted is limited respectively to 3, 6, 10 and 10 per cent of the whole, of which the foreign matter other than wheat is limited respectively to 1, 2, 4, and 6 per cent. There is nothing in the grading of rye corresponding to vitreous kernels in the case of wheat. Ryes circulating in the channels of trade, and especially those passing into export, are likely to bear regional designations. Thus, No. 2 Western is probably the most common grade of rye exported.

The ryes of the United States incline to be of one type, though improved strains have been developed at home and introduced from abroad. Improved ryes are Dakold, Rosen, North Dakota No. 9, Advance, and Swedish. Before the war our production of rye was so small that agronomists felt little incentive to improve the grain. Since the war there has been scanty time, and little occasion, for improvement. Naturally, our mills select the best rye for grinding, according to high American standards for rye flour. Therefore, just as in the case of wheat, the poorer ryes go abroad. Under these circumstances, it is not surprising that Europeans have rated American ryes rather low in the scale.

In Europe, on the other hand, rye has received more attention from cerealists and improved strains have been adapted to particular regions. The ryes of Europe are of two types, depending largely on soil and climate. The one type is soft, usually with high moisture content, often tough even when sound, and low in protein. Such are the ryes usually grown on the poorer sandy soils of northern Europe. Other areas, especially in Russia and the Danubian region but including parts of Germany and the other western and southern European countries, produce a hard rye, of low moisture content and fairly high protein content. The soft rye meets the needs of distilleries and feeding yards; the hard rye is adapted to the manufacture of flour. The two are commonly referred to as bread rye and feed rye—analogous to malt barley and feed barley. Before the war, international trade consisted largely of bread rye; since the war Europe has imported all kinds of rye.

All commercial rye is more or less dark-colored. Plant breeders in rye countries have long sought to produce a white rye, and every so often the evolution of a white rye is reported. Such a rye has never reached commercial production. There are, however, improved varieties of rye having less color than common kinds.

Rye is a seed covered with a coat (also called testa or spermoderm) under which lies a thin layer called the nuclear layer, with the embryo (the germ of the young rye plant) lodged at one end while the bulk of the interior is occupied by the endosperm. In milling the operation is to free the endosperm more or less completely from the germ, the nuclear layer, and the husk or coat.

The kernel of rye is usually rather smaller than the kernel of wheat and of a less plump contour. It has a relatively thicker coat and larger embryo; the endosperm is smaller. This corresponds to a difference in the proportions of coat, germ, and endosperm; the endosperm of wheat comprises a larger proportion of the kernel than that of rye, and therefore wheat yields more flour than rye. The endosperm of rye amounts usually to less than 75 per cent of the weight of the grain, and to make a bran-free rye flour the extraction must usually be below 68 per cent. The endosperm of wheat comprises around 82 per cent of the weight of the grain, and a bran-free flour can usually be secured with an extraction of 74 per cent. In general, therefore, wheat can be extracted to 74 per cent and rye to 68 per cent with production of comparable straight flours. In Germany a rye flour of 70 per cent extraction is regarded as comparable in fiber content with a wheat flour of 77 per cent extraction. These relative positions tend to be maintained upward and downward. Wheat is therefore naturally a higher-priced grain partly because it holds more higher-priced flour and less lower-priced offal.

Rye and wheat of comparable water content differ sensibly in composition. Both are poor in fat, but rye has still less fat than wheat. The starch content of rye is somewhat higher than that of wheat. It is in the protein, however, that the important difference is found. Wheat contains much more protein than rye. The best ryes rarely contain over two-thirds as much protein as the best wheats; the poorest wheats do not contain as little protein as the poorest ryes. In the soft type of rye the protein content may run as low as 6 per cent; the hardest may yield over 10 per cent. Comparable German flours of rye and wheat carry respectively from 8.5 to 11 and from 11 to 14 per cent of protein, from which the protein contents of rye and wheat as grain may be adjudged. American ryes run on the average considerably lower in protein than the ryes of Europe.

The caloric content of rye tends to run slightly less than that of comparable wheat. This is not enough to make any difference in judging ryes for the manufacture of flour. The higher starch content of rye is an advantage in the manufacture of alcohol; but on this point rye is to be compared not with wheat, which is rarely used for distillation, but with corn, potato, and molasses.

Acreage and Production of Rye

The group of bread grains contains numerous wheats, and rye. The wheats belong to the genus *Triticum*. Many wheats are newer or older hybrids. Classed under wheat are several varieties of emmer and spelt. Polish wheat and durum wheat are regarded as mutations of emmer; the common bread wheats (*Triticum vulgare*) are believed to have been derived from spelt. Rye is *Secale cereale;* it is not closely related to the wheats. The grains of Polish wheat sometimes resemble those of rye and have been erroneously classed as such. Wheat and rye have been crossed, both naturally and experimentally, wheat being the mother plant. The hybrids are commonly sterile, though in a few instances fertile descendants have been propagated over a number of generations. Both spring and winter rye exist, but winter rye is much the more common.

Wheat was grown in pre-Christian times by Aryans and Chinese. It must have been brought into northern and western Europe in the earliest centuries of the Christian era. Rye is supposed to have been cultivated from, or was a mutation of, *Secale montanum,* a grass indigenous to the foothills around the Mediterranean Sea. We have no records of rye grain in pre-Christian times. It became distributed during the medieval period and after the Renaissance was more prominent than wheat. Indeed, rye was the predominating bread grain up to the nineteenth century. In this sense, considering the development of modern agriculture, rye may be said to have been the older bread grain. Prior to the nineteenth

century, rye was prominent in Great Britain and widespread over Spain, France, and Italy, the Danubian regions, and European Russia. Rye and corn were planted earlier than wheat by English settlers in Massachusetts, by Dutch settlers in New York, and by Swedish settlers in Delaware; it was planted early in Maryland, Virginia, and Georgia. In early colonial times rye was the staple flour of New England. The prominence of wheat is largely a matter of the last century. The outstanding wheat regions of southern Russia, North America, South America, and Australia are mostly of relatively recent origin. The wheats that now make up the largest part of the international trade in wheat are less than a half-century old. Wheat culture has been vastly improved, while that of rye has lagged; in consequence, wheat has outstripped rye.

To furnish a background, the reported acreage and production of wheat and rye in the world since 1909 are shown in Table 1. The data are incomplete because of the absence of information for China and Asia Minor; and Russian figures are probably not trustworthy for pre-war years.[1] According to these incomplete figures, world rye production in terms of bushels runs, on the average, slightly larger than two-fifths of world wheat production. Rye production would appear relatively smaller if data on both crops were available for China and Asia Minor, since these regions are known to be large producers of wheat but small producers of rye.

As will be pointed out later, the present acreages planted to wheat and rye do not represent the potential acreages. No emphasis is to be laid upon the absolute figures; it is quite as much the relative positions that interest us. When world acreages of bread grains are viewed by geographical subdivisions[2] it is observed that the distribution of wheat acreage is conspicuously world-wide, while rye is prominent only in Europe and European Russia. Indeed, for many years Russia and Germany have probably furnished over 70 per cent of the rye of the world. The relative position with respect to acreage has not been significantly modified since the war;

TABLE 1.—ESTIMATED WORLD WHEAT AND RYE ACREAGE AND PRODUCTION, 1909–27*

Year	Acreage (million acres)		Production (million bushels)	
	Wheat	Rye	Wheat	Rye
1909	...	...	3,665	1,772
1910	...	...	3,613	1,689
1911	...	...	3,606	1,593
1912	...	...	3,894	1,909
1913	...	...	4,126	1,900
Average	278	109	3,781	1,773
1914	...	...	3,668	1,631
1915	...	...	4,324	1,597
1916	...	...	3,265	1,430
1917	...	...	3,196	1,158
1918	...	...	2,911[a]	586[a]
1919	...	...	2,821[a]	682[a]
Average	...	...	3,364[a]	1,181[a]
1920	...	...	3,268	983
1921	262	91	3,374	1,254
1922	249	93	3,468	1,432
1923	258	102	3,800	1,474
1924	270	110	3,523	1,421
1925	288	116	4,102	1,828
1926	300	114	4,231	1,709
1927	310	116	4,289	1,855
Average	277	106	3,757	1,494

* Data of U.S. Department of Agriculture. Dots (...) indicate that comparable estimates are not available. Estimates include all Russian territory reporting for years named, but exclude China and Asia Minor.

[a] Excluding Russia in 1918 and 1919.

but, on account of the relatively greater concentration of rye production in Europe, the smaller post-war yields per acre both of rye and wheat in Europe have resulted in a decline in world rye production not apparent in world wheat production.

RYE PRODUCTION IN EUROPE

The following rough figures, in million bushels, may be taken to represent the normal crops of wheat and rye in the several European countries under usual conditions of weather, our purpose being not to illustrate total bread grain production but rather to contrast production of wheat with that of rye.[3] Russia, Germany, Poland, Czecho-

[1] Soviet authorities assert that the 1909–13 average of wheat production based upon official data is too low by about 150 million bushels, while rye production is some 175 million too low.

[2] See Appendix Tables I–IV, which show rye acreage and production by countries.

[3] These figures are not averages, but merely rough approximations to representative figures of production.

Slovakia, Austria, Scandinavia, Finland, the East Baltic States, Belgium, and Holland produce more rye than wheat. The preponderance of rye is partly the expression of soils and climate, but partly the result

Country	Wheat	Rye
Russia	700	900
Germany	100	300
Italy	200	7
France	330	40
Spain and Portugal	150	30
Poland	50	225
Czecho-Slovakia	35	50
Austria	10	20
Hungary	70	30
Jugo-Slavia	70	10
Bulgaria	40	8
Roumania	100	10
Scandinavia	20	35
Finland and East Baltic	5	50
Belgium	15	20
Holland	5	15

of established crop rotations and of industrial uses for rye. It is hard to believe that the acreage planted to wheat and rye respectively in the European countries expresses for consumers the most economical division of land and labor when viewed in the light of import requirements and of the respective prices of wheat and rye. It is probably as much an agricultural heritage as an economical arrangement.

In Europe north of the latitude of the Alps, and in northern Russia, the acreage of rye is determined by soil, climate, and existing systems of crop rotation. Wheat is planted by preference whenever possible. Where the prospects for wheat are poor, then rye, oats, or barley is planted in accordance with customary rotations. In Europe south of the latitude of the Alps, and in southern Russia, the acreage of rye is limited by consideration of relative returns. In effect, rye is planted only to the extent dictated by customary crop rotation and on soils not locally adapted to wheat.

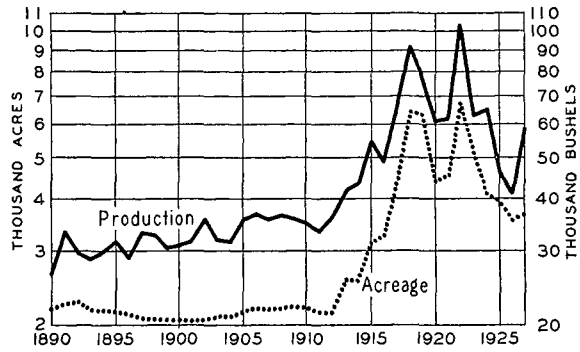
Rye grows more or less everywhere in European Russia, from the tundras to the steppes. In the so-called "northern soils," with the short summer, rye is with oats the chief crop; flax, barley, and wheat are variously prominent in different regions. In the so-called "southern soils," wheat is more prominent than rye, at least in certain regions; barley and oats are also commonly raised, and corn to the southward. Of the cultivated area of Russia before the war, about two-thirds was planted to cereals. Of the total acreage planted to cereals, over a third was in rye (both spring and winter), about a fourth in wheat, a fifth in oats, and a tenth in barley. Ordinarily, rye was cultivated in Russia with primitive methods, and it often fell heir to soils exhausted by wheat and flax. Quite consistently the yields per acre were low. Siberia has large regions available, under climatic difficulties, for growing wheat and rye. Wheat has been preferred; and it is worthy of note that in Siberia have been developed quick-maturing strains of wheat that seem to stand drought and cold almost as well as rye.

Rye Production in the United States

Chart 1 presents the data on acreage and production of rye in the United States from 1890 to 1927.[1] The acreage reported was harvested acreage; we do not possess reports of abandonment of rye acreage. If the figures for planted acreage were available, these would diverge from harvested acreage more than in the case of wheat. The reason would not be larger abandonment on account of winterkilling, but larger use for pasture, cover crop, ensilage, and hay.

Chart 1.—Acreage and Production of Rye in the United States, 1890–1927*

(Logarithmic vertical scale)



* Official data. See Appendix Table II.

From 1890 to the outbreak of the war the rye acreage of the United States varied

[1] See Appendix Table II for detailed annual data, including yield per acre.

little, never below 2 million acres and never above 2.3 million acres until 1913. The per capita acreage declined over the period. The yield per acre rose gradually from about 12 bushels per acre to about 16.

The war provided to rye growers an extraordinary incentive for expansion. As indicated in the chart, the acreage rose progressively to 6.4 million acres in 1918 and 6.3 million in 1919. There was a sharp drop in 1920 and 1921, with a sudden rise to the peak of 6.7 million acres in 1922. From this point the acreage has declined and in 1927, in spite of a small increase over 1926, was only 3.7 million acres. The yield per acre was not maintained during the war and has since declined progressively, the reported yields for 1925 and 1926 being the lowest reported since 1890, though a high yield was obtained in 1927. Thus since 1909–14 production rose from around 35 million bushels to the peak of 1922, 103 million bushels, since when the reported crop rapidly declined to some 41 million bushels in 1926.[1] A large part of the increase in acreage occurred in the two Dakotas and was due quite as much to discouragement over the wheat crop as to the attraction of war prices for rye.

The principal rye-producing states, those that usually have over 100,000 acres in rye, are Pennsylvania, Indiana, Michigan, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Nebraska, and Montana, with Colorado and North Carolina approaching this acreage. These states have over 80 per cent of the rye acreage of the country, and one state, North Dakota, has about a third of the rye acreage. The reasons for cultivation are not the same in all regions. In many of the states rye fits into a system of diversified grain culture with oats, barley, and wheat; it is prized for green fodder and used on the poorer soils. In the Dakotas, Montana, and Colorado, however, it is commonly a poor-land alternative for wheat in one-crop farming.

From 1890 to 1912 a downward trend in per capita rye acreage was in evidence. Over this period the harvested acreage was almost constant at around 2.1 million acres. During 1913 and 1914 the acreage rose to over 2.5 million acres. Thereafter the war expansion carried it rapidly upward. This trend can be expressed in units representing one one-hundredth of the acre. In the first five years after 1890, the average per capita rye acreage unit was 3.38, in the next five years it was 2.93; in the next five years 2.60; in the next five years 2.49; and during the three years 1910–12, it was 2.28. Had this trend persisted it is clear that at the present time the per capita rye acreage unit would be below 2, which would make the actual acreage something in the neighborhood of 2 million acres. Adjusted for the loss in the market demand of some 5 million bushels of rye as the result of prohibition, 2 million acres looks generous. The actual acreage is at present around 3.5 million acres. How is the difference to be explained?

Some of it may be regarded as unliquidated acreage of war expansion. Some growers may find the export price of rye relatively remunerative. For the most part, however, a different explanation must be sought. To some extent rye acreage is a choice of evils, oats and barley being the other evils. This might explain the persistence of rye acreage in Illinois, Minnesota, and Indiana. But the difference in rye acreage in the Dakotas is in itself enough to account for the difference between 2 and 3.5 million acres. Practically speaking, if one would subtract from the present rye acreage the increase in rye acreage that has taken place in the Dakotas since 1912, the remainder would about correspond to the pre-war rye acreage. In other words, while there have been increases and decreases in numerous other states, the increase in rye acreage, as compared with 1909–13, has taken place in the two Dakotas. In these two states, rye may have replaced either wheat, oats, or barley; for one reason or another, farmers raising wheat, oats, and barley operate under difficulties. The rye acreage in these two states has varied from 1.3 to 1.6 million acres during recent years; the combined acreage of wheat, oats, and barley has varied from 16 to 19 million acres. A shift of a million acres could readily occur, with small effect on the acreage of wheat, oats, and barley in these two states, but with a large relative effect on the rye acreage of the entire country.

[1] Rye furnished an illustration of war expansion equaled by few commodities. Judged by production, the expansion was nearly threefold. Judged by exports, the expansion was about thirtyfold.

Rye Production in Canada

Before the war rye was an insignificant crop in Canada.[1] A small acreage was planted to rye in the Maritime Provinces, Quebec, and Ontario, to meet the needs of descendants of rye-eating nationalities. Since there was no purpose in raising rye on good wheat land, rye was not planted in the Prairie Provinces except for special reasons.

The war stimulated the planting of rye in Canada as in the United States. The acreage expanded from 116 thousand acres, the five-year pre-war average, to the peak of 2,105 thousand acres in 1922–23. Since 1922 the acreage has been steadily contracting and in 1927 only 743 thousand acres were harvested. The average production for the five years before the war was a little over 2 million bushels. The peak production in 1922–23 was 32.4 million bushels. With contraction of acreage the crop in 1927 fell to some 15 million bushels. Some of the increase in the past two decades may of course be attributed to the general increase in the area of land under cultivation.

The rye crop of Canada resembles that of the United States. The type of rye is much the same, the average yield a little heavier. Rye has not attained in Canada the position it occupies in the United States as a rotation crop. The farmers of Canada are accustomed to feeding small grains to domesticated animals and this might be expected to favor the growing of rye; but with the free availability of oats, barley, wheat screenings, low-grade wheat, and mill-feed, it is doubtful whether rye will receive much attention as a feeding stuff in the near future. So long as Canadian distilleries make whiskey, a certain amount of high-grade rye will be required for that product; but this demand will not support much of a crop. Canada has a very large potential rye acreage, resembling northern Europe in this respect. Winter rye does well over large parts of the Maritime Provinces, Quebec, and Ontario. The poorer lands in the wheat belt of the three Prairie Provinces are adapted to rye, and north of the wheat belt lies a stretch in which rye and oats mature fairly well. There is in British Columbia also considerable land adapted to rye but not to wheat. But the very weight of wheat exports from Canada tends to operate against rye, and under these circumstances, further contraction of rye acreage, rather than expansion, is to be expected in the immediate future. In all likelihood, the war boom of rye in Canada will subside more quickly and more completely than in the United States.

Rye Growing in the Southern Hemisphere

South America, south of the 25th parallel, has large regions naturally adapted to the growing of rye, mostly on the east side of the Andes, but also on the west. In Argentina particularly is a large potential rye acreage. Rye is known to do well everywhere within the "Wheat Crescent" and also outside of it, especially to the west and to the south. Before the war there was no incentive for raising rye in Argentina; there was little domestic demand and no export prospect. The area sown was less than 100 thousand acres, and the total production less than a million bushels.[2] In Argentina as in North America, the war provoked an expansion of rye acreage. Since the war, the rye planting has risen to over half a million acres, with a maximum production approximating 4.7 million bushels. Yield per acre has been lower even than in the United States. Rye does not fit particularly well with established rotations, except where alfalfa does not thrive. The population of Argentina is largely of Latin rather than of Teutonic derivation; therefore there is only a small demand for rye bread in a country where the growing and milling of wheat is a major industry. Argentina has a huge husbandry of cattle and sheep and a small though growing count of swine. But in the face of the large corn crop, favorable conditions for the growing of oats and barley, and a large acreage in alfalfa, the prospect of demand for rye as a feeding stuff seems negligible. The rye of the Plate as it appears in European markets is a high-grade bread rye; it is hard, and of relatively high protein content, used like the best Russian rye to strengthen the softer ryes of

[1] Appendix Table III shows acreage, production, and yield per acre of rye in Canada, 1890–1927.

[2] See Appendix Table IV.

northern Europe. The extent of rye production in Argentina in the near future would seem to be conditioned upon the recovery of Russian export of rye and upon the costs of producing rye in particular regions of Argentina contrasted with that of wheat. Apparently rye has found a small niche in the agriculture of Argentina. There seems little question that, quality considered, rye can be produced in Argentina and delivered in Europe at a price that would not be regarded as remunerative in North America. Whether this is enough to make it worth while in Argentina to plant rye rather than other crops remains for future development to make clear.

In South America, outside of Argentina, insignificant amounts of rye are grown in Chile and other countries. In New Zealand and Australia also a few thousand acres are planted to rye. In South Africa before the war rye had a greater prominence than in Argentina, due in part to the rye-eating habits of the Europeans who had come mostly from lower Rhine stock and to the characteristics of the soil and climate which were not particularly favorable to wheat. But in absolute terms acreage has always been small, less than 150 thousand acres. The entire rye acreage of the Southern Hemisphere does not exceed a million acres, and under these circumstances a minute tabulation may be dispensed with.

Rye Marketing

The marketing of rye in the United States before the war was very simple. There were nine important primary markets—Minneapolis, Duluth, Milwaukee, Chicago, Omaha, Kansas City, Peoria, St. Louis, and Toledo; since the war Indianapolis has been added to the list. Minneapolis, Duluth, Milwaukee, and Chicago outranked all others and handled close to 90 per cent of the merchandised crop. Records exist of receipts to, and shipments from, these primary markets; also of the visible supply of the United States (commercial and unofficial), including all reported markets, but by no means complete.[1]

Since most of the merchandised rye was raised in the northern states, the seasonal course of receipts, shipments, and visible supply was relatively uniform. May–July were ordinarily the low months. With the harvest, transactions would rise to the peak in September–December (in one season earlier, in another season later), gradually declining to the end of the year, with variations from season to season. Usually the peak of the visible supply lagged one, two, or even three months behind the peak of receipts and shipments. The visible supply consisted largely of stocks in the hands of, or awaiting deliveries to, millers and distillers.

For the highest pre-war year (1912–13), the total receipts at the primary markets were 16.4 million bushels, with the highest receipts for any month not as much as 3 million bushels; the total shipments for 1912–13 were 11.4 million bushels, with the highest shipments in any month at 1.8 million bushels. The highest visible supply during any month of the five-year period was 2.3 million bushels. The carryover of rye in terminal markets was insignificant, since in no year did the visible supply of rye on July 1 equal half a million bushels. To what extent mills carried stocks of rye into a new crop year, or stocks of rye flour, was unknown.

Trading in rye futures was an established practice in "the good old days" of the Chicago Board of Trade. It was for the most part of a desultory character, the specialty (or sport) of a few individuals. The smallness of the crop and scantiness of visible supplies, however, occasionally presented opportunity for manipulation, and corners in rye were several times attempted. Terminal grain dealers and some rye millers hedged their transactions, though the volume of speculative trading was often too low to sustain any hedging. Under such circumstances, grain dealers and millers would sometimes hedge their rye transactions either in wheat or in corn. If the price of rye was high relative to that of wheat, spot rye would be hedged in wheat futures; if the prices of coarse grains were high relative to that of rye, cash transactions in rye would be hedged in corn, or occasionally oats, futures. On account of the small volume of desultory speculation, brokers gradually gave up handling rye accounts, and finally the business centralized in the

[1] See Appendix Tables V–VII.

hands of one man, named McDermott, who specialized in the business. For a time, he executed on the Chicago exchange practically all orders for buying and selling futures in rye, i.e., he acted both for sellers and for buyers, and was therefore familiarly known as "the rye pit." About 1912 trading in rye futures died out.

With the greatly increased crops of rye since the war, the marketing of this grain has assumed a much enlarged importance, accentuated by the heavy amount of rye passing to export and by the re-establishment of trading in rye futures.

Trading in rye futures was formally reopened, under modern regulations, in 1918. The active exchanges are in Winnipeg, Minneapolis, Duluth, and Chicago. When the New York Produce Exchange formally opened trading in grain futures with delivery in Buffalo, rye was included, but this has since been suspended. The only active market for trading in rye futures in Europe is in Berlin.

Cash transactions in rye, when hedged, are now usually hedged in rye futures. Sometimes, however, it is better to hedge cash rye in wheat futures or in corn futures; also, a hedge in rye futures may sometimes be advantageously transferred into wheat or corn futures. In view of the much larger crop, the substantial volume of visible supply, and the relatively big volume of trading, with only the same small volume of milling, the weight of rye hedging ought nowadays to be relatively light. The volume of transactions is small compared with wheat, corn, and oats, but nevertheless substantial when compared with the size of the crop.[1] The large millers of rye flour now hedge their rye transactions; speculators buy rye futures "for investment," and sell short when they think the price too high; elevator companies lay in stocks of rye in the fall and hedge them; and spreaders watch the rye quotations on the different exchanges and buy and sell in the different markets — just as with wheat. In short, since the war rye has again become a full-fledged cereal in the market sense.

The largest post-war figure for receipts came in 1922–23, when 73.9 million bushels of rye were received at the ten primary markets, with shipments of 58.7 million bushels. The month of highest receipts for the year 1922–23 was August, with practically 14 million bushels; the highest shipments for this year were during the same month, 12.1 million bushels. This record was surpassed in a year of smaller crop, 1924, with receipts of 17.6 million bushels and shipments of 16.4 million bushels in October. The highest visible reported in any month since the war was 23.5 million bushels on February 1, 1925, but visible supplies have frequently been over 20 million bushels in different months during the past five years. These large accretions in receipts, shipments, and visible supply have been related to exports and not to domestic movements and disposition.

Before the war, the practices in the marketing of rye in Europe were relatively simple and primitive. Although a large part of the wheat imports of Europe represented interstate traffic and another large part came from Russia, the trade was dominated by shipments from overseas. Thus, interstate European wheat trading, and to a considerable extent domestic trade, had the complexion of international world trade. This was accentuated by the preeminence of Liverpool in the wheat trade, and by the fact that international merchants dealt in the export wheats of all countries. In the case of rye, however, there was little more than interstate trade between Germany and her neighbors in northern Europe, border trade between adjoining countries, and Russian exports into northern and western Europe. In fact, German and Russian imports and exports and the imports and re-exports of the lowland countries were the largest elements in European international trade in rye. With the net imports of the continent, ex-Russia, amounting to some 40 million bushels of rye annually, contrasted with over a half a billion bushels of wheat, the differences in merchandising practices become understandable. Though future trading in rye existed at different times in different continental cities, it had little importance. The imports and exports of rye from country to country were practically on a sample or arbitration basis.

Since the war, European practices in the

[1] See Appendix Table VIII.

marketing of rye have tended more to approach those used with wheat. This has resulted from the greater proportion of rye secured from overseas. With the same importers in Europe and the same exporters in overseas countries handling both rye and wheat, the trading practices have naturally become identical. Russian rye has not appeared on the markets of Europe in the same way that overseas rye has appeared. The export of rye is a state monopoly in Russia. The Russian export association, like the Canadian Pool, has desired to deal with millers rather than with traders. Russian rye has been sold to international traders, but the Russians have preferred to sell it to millers in importing countries and the purchases of rye in importing countries have sometimes been associated with agreements for export of manufactured goods. In a sense, Russian rye exports have tended toward barter, while those of other countries have been conducted on the routine basis of bills of exchange.

II. USES OF AND TRADE IN RYE

Utilization of Rye

Before the war rye had three uses in the United States: as foodstuff, as feeding stuff, and as industrial raw material. Little was exported. The least important commercial use was apparently as feeding stuff, owing to the free availability of coarse grains and the general prejudice held by husbandmen against rye. Before the war rye was raised as a cash crop like wheat, since little was fed on the farm. If one applies the available census data on the milling of rye, it follows that about 30–35 per cent of the rye production was milled. Apart from a certain amount of rye flour used in foundries, the principal industrial use of rye was in the manufacture of alcohol and whiskey. By many, rye whiskey was preferred over corn whiskey. Rye was used in the manufacture of commercial yeast, of which the residue was used in the manufacture of gin, so that rye entered into this beverage also. The amount of industrial alcohol manufactured from rye was relatively small, since other forms of starch and sugar were usually cheaper. Before the war, rye had a large demand in distilleries. Between 1901 and 1914, inclusive, the average amount of rye used in distilleries was 5.3 million bushels, compared with 20.6 million bushels of corn, and 32.8 million gallons of molasses. Contrasted with the size of the crop and the amount of rye ground into flour, the rye used in distilleries was therefore a substantial fraction of the commercial demand. Since the war, the picture has been totally changed. Potable spirits are no longer made out of rye, and cheap molasses has replaced rye in the manufacture of industrial alcohol. During the years 1921–27 the average amount of rye used by distilleries was only 69,321 bushels, contrasted with 5.6 million bushels of corn and 171.7 million gallons of molasses. There is no prospect of revival in use of rye by distilleries. Existing stocks of potable alcohol suffice to cover medicinal use of whiskey for some time, and when new manufacture is begun the amount required will be trivial in terms of rye. So long as cheap molasses is available, largely duty-free from Cuba, rye remains too expensive to be used in the manufacture of industrial alcohol.

The present situation in the United States is quite different. Export has become a major disposition; the use of rye as foodstuff stands almost unchanged; the use as a feeding stuff is increasing; but the industrial use is insignificant.

In Europe, on the other hand, the use of rye as a feeding stuff has always stood next to the use of rye as a foodstuff, above the use of rye as industrial raw material. There has always been some manufacture of rye whiskey in Europe, especially in Great Britain. The Latin countries preferred brandies; the northern countries had cheaper whiskies than rye. Industrial alcohol was rarely made from rye, unless unfit for use by animals, because potato, beet sugar residue, brewery residue, and corn were considerably cheaper. Since rye fitted in with European agriculture so admirably, husbandmen learned early to fit rye into effective feeding practices. Feed rye was almost a distinct trade variety from bread rye; it meant merely the softer grain, low in protein and high in moisture, grown on poor soils in a moist climate. Rye was often

grown on soils that would produce a good feeding rye but that would not produce a passable bread rye. To some extent, the European countries imported feed rye from Russia and occasionally from overseas; but the best policy was to raise feed rye and import bread rye. A relatively large fraction of the millable rye crop was always fed to animals in Europe; for example, in the Eltzbacher report on the German food supply before the war, 25 per cent of the rye crop (outside of seed) was assigned to animals and industry, while only 10 per cent of the wheat crop found corresponding disposition. Everywhere in Europe tail wheat and tail rye have gone largely to animals, but the definition of tail rye was everywhere less strict than the definition of tail wheat.

With prosperity, and with comparable crops of wheat, rye, and potatoes, more rye and potatoes will be fed to animals and less wheat; with a short rye crop, little rye will be fed to animals (unless unmillable) if potatoes and coarse grains are available. Just as adaptations between wheat, rye, and potatoes occur for the food supply, so the peasants make similar adaptations in respect of feeding wheat, rye, and potatoes to domesticated animals.

Characteristics of Rye as Foodstuff and Feeding Stuff

The value of rye in a diversified human diet and in a mixed feeding ration, contrasted with the other cereal gains, may be fairly adjudged according to calories. The nutritional values of the celluloses, starches, and sugars, and of fats in the several cereal grains, are qualitatively practically identical. There are differences in the mineral content and in the fiber, of which the importance is not clear. Apparently the coat of rye is somewhat less digestible than the coat of wheat. Of rye and wheat flours of the same percentage extractions, rye is less digestible and leaves a larger unresorbed residue. But when rye and wheat flours are compared on the basis of identical proportions of bran and germ in the flours, this difference apparently disappears and rye flour is as digestible and well utilized as wheat flour.[1] Apparently, therefore, so far as protein, carbohydrates, and fat are concerned, rye flour is as digestible as wheat flour; the difference lies in the coat. Since the coat of rye is less digestible than the coat of wheat, it follows that whole rye flour is less digestible than whole wheat flour. This may be the expression solely of the difference in quantity of bran, though possibly the bran of rye itself is less digestible than that of wheat.

The protein of rye in a mixed diet is comparable with that of wheat. The plant proteins are judged by their content of, and balance in, amino acids. Of the proteins of the several grains, that of corn is the least well balanced and competent—a point of no importance in a diversified diet containing the customary intake of milk and meat. It becomes important in the diet of the vegetarian and is therefore important in

[1] Considerable discussion has been held over the relative digestibility of wheat and rye. There is no advantage in entering here into a minute analysis; but for the purpose of clarification, some statement seems necessary. The following is presented as reasonable intepretation of the probable truth contained in the conflicting data.

The common experience has been that rye bread is less digestible than wheat bread. Is this due to the flour, to the characteristics of the loaf, or to the type of fermentation? The protein, starch, fat, and cellulose of wheat and rye are apparently of equal digestibility. Short extraction flours (representative of the endosperm and containing neither coating nor germ) seem alike in digestibility. Possibly rye bran may be even less digestible than wheat bran. Widespread confusion has arisen from the fact that wheat and rye breads have been compared without the flours having been themselves initially comparable. One cannot compare a rye flour of 70 per cent extraction with a wheat flour of 70 per cent extraction, because the former contains far more fiber and is less digestible in consequence. One must compare wheat and rye flours of equal fiber content. A straight wheat flour of 74 per cent extraction is from this point of view comparable with a straight rye flour of 66 per cent extraction. Such flours are found to be equally digestible and resorbable. Certainly a white patent rye flour is as digestible and resorbable, or more so, than straight and first clear wheat flour with which it is commonly blended.

But the digestibility of bread may be influenced by other factors than the digestibility of flour. A heavy and soggy bread is not penetrated with the digestive juices as readily as a light and fluffy bread; this would favor the digestibility of wheat bread. Finally, the acids and the other products of the prolonged fermentation used in making rye bread might tend to reduce digestibility. Whether commercial rye breads purchased at random on the market are as digestible and resorbable as commercial wheat breads similarly purchased, is one question; whether rye bread needs to be less digestible than wheat bread is another and different question. It is probably fair to say that commercial rye breads are as a rule less digestible and resorbable than commercial wheat breads; but it is equally true to hold that a rye flour is as digestible and resorbable as a comparable wheat flour.

the feeding of domesticated animals. To the extent that bread occurs in the diet of Americans, it is quite immaterial from what grain it is made so far as the protein is concerned. In the American diet bread is practically a carrier of calories, a fuel.

Rye as a feeding stuff is regarded as somewhat inferior to wheat and slightly inferior to barley and oats, but better than corn. The superiority of rye over corn lies in the protein. Animals fed heavily on corn require supplemental protein to an extent that does not hold for wheat, rye, barley, and oats. Some disadvantage attends the use of any grain fed as an exclusive ration, and this holds for rye just as it holds for wheat and the other grains. Fed in the natural state, the use of rye as a feeding stuff is attended with disadvantages. The gliadin gums in the mouth when masticated; the uncrushed grain escapes digestion. The taste of straight rye is not relished by animals. Rye should be fed ground and preferably mixed with other grains. Thus used, rye is comparable with the other grains in terms of calories, as has been conclusively demonstrated abroad. Rye is commonly used as horse feed in Europe, especially in mixed grain rations. Rye may be hogged down, as corn is, but the practice is wasteful of grain and it is probably better practice, whenever harvesting is not found desirable, to cut for hay or for ensilage. The use of rye has sensible disadvantages with dairy cattle; green rye gives a poor flavor to milk and rye grain makes a butter harder than desired. In the case of bacon hogs, on the contrary, the hardness of the fat is an advantage. In short, the value of rye as a feeding stuff is largely a question of management. When it is advantageous to raise rye, advantageous ways of feeding rye can be worked out. Whenever feed concentrates are purchased on the basis of protein content, rye bran must sell below wheat bran since it is poorer in protein.

Rye is more scientifically used as a feeding stuff in northwestern Europe than in the United States. The feeding yards are more carefully controlled by experimentation and the margin on operations is closer. Bacon pigs, dairy cows, and baby beef steers are fed on rations whose contents in protein and carbohydrate are adjusted closely to the prices of the several feeding stuffs, on the basis of the qualities of products desired. The principal concentrates are skim milk and buttermilk; wheat tailings, screenings, and bran; rye, rye screenings, and bran; feed barley, screenings of malt barley, and malt products; corn; potatoes; expressed meal or oil seeds (cottonseed, linseed, rapeseed, sunflower seed, peanut seed, coconut); tankage and fish meal. These are adaptable within a range of prices; they are substitutive within a range determined by yield and quality of product. The animals are given almost individual attention; the standards of farm management are high; the concentrates are carefully prepared to secure the best digestability, with avoidance of untoward behavior; the prices of concentrates are adjusted from day to day on the basis of protein content; and the animal products are scored and marketed under a system of high official standards. In such a system neither prejudice nor predilection find much place. Under these circumstances, rye finds its proper position as a feeding stuff; it is fed, on the price basis, in such a way as to secure the best return from it. Such an advanced system of animal husbandry is the result of collective action and this is lacking in this country. The majority of American husbandmen are individualists; and since the above system lies outside of the capacity of the single farm, the lessons of European husbandry and the preachments of experts in American agricultural colleges in favor of rye, barley, and oats have had little result.

The Milling of Rye

The milling of rye in the United States and Canada follows current practice in the milling of wheat, though with less refinement. In the older sections of the country some rye is still milled with primitive equipment such as has passed out of use in the milling of wheat except in customs mills. In the large milling centers rye is ground like wheat, but is more simply treated. Rye is usually scoured and brushed, but not tempered, since added moisture is apt to make the kernels tougher. The flour tends to adhere to the bran more tenaciously than in the case of wheat, and a clean separation is more difficult. Rye is

usually crushed on what are known as scratch rolls; smooth rolls do not give satisfactory results. The flour is separated from the bran by plain bolting, the separation depending on the fineness of the mesh, without making use of an air current in the sieve purifier or of aspirators as is done with wheat. The result is an imperfect removal of the bran, even in short patent rye flour. The extractions vary widely from mill to mill and from season to season, as is to be inferred from the census reports on the milling of rye. The mills naturally select the ryes with the largest yield of flour and the lightest color. Recently introduced varieties, such as Rosen and Abruzzi, seem distinctly superior to the older domestic ryes in flour yield.

The principal rye-milling states are Minnesota, Wisconsin, Illinois, Michigan, New York, and Pennsylvania. These six states mill over 80 per cent of the rye ground in the country. The principal quotation points for rye flour are Minneapolis, Chicago, Buffalo, Boston, Philadelphia, and Baltimore. Most of the rye is apparently milled during the autumn and winter. The rye offal finds its way into the feed market with the offal of wheat, the relative prices varying slightly from season to season. Since rye offal is lower than wheat offal in protein and fat, it is less highly prized, and this finds reflection in the price.

Our information on the milling of rye is scanty, fragmentary, and unsatisfactory. The Bureau of the Census does not include rye in its monthly and annual reports on flour milling. The milling journals pay little attention to rye, either currently or annually, as may be noted by reference to reports on rye in the *Millers' Almanac*. For information we are therefore restricted to trade reports and to the reports in the decennial censuses and in the biennial censuses of manufactures.

The scanty information we possess on the production of rye flour is in the censuses of 1899, 1904, 1909, 1914, 1919, 1921, 1923, and 1925.[1] The rye milled and output of rye flour are reported for merchant mills above a capacity that was not identical from census to census. Customs mills were included in some years and excluded in others. Rye flour was sometimes reported in a mixed group with other grains. The data are unquestionably less accurate than the data on wheat. Commercial reporting of flour production, such as has long been practiced for wheat flour, does not exist for rye flour. The data are given in Table 2.

TABLE 2.—RYE GROUND AND OUTPUT OF RYE FLOUR IN MERCHANT MILLS OF THE UNITED STATES, CENSUS YEARS 1899–1925*

Census years	Rye milled (*thousand bushels*)	Output of rye flour (*thousand barrels*)
1899	10,088	1,443
1904	11,480	1,503
1909	11,504	1,532
1914	12,814	1,937
1919	15,952	2,528
1921	7,708	1,335
1923	9,246	1,635
1925	8,126	1,561

* Compiled from reports of the U.S. Census. These figures imply what seem to be impossible inferences. In 1899, 7 bushels of rye were required to secure one barrel of flour, in 1914, 6.6 bushels were required. But in 1923, only 5.7 bushels of rye were required to secure one barrel of flour, and in 1925 only 5.2 bushels were required. In other words, rye flour was whiter and shorter patent twenty-five years ago than is the case today. This is so improbable, so opposed to observation, as to be unbelievable.

The amount of rye ground increased gradually from 10.1 million bushels in 1899 to 12.8 million bushels in 1914. Since export of rye flour was negligible, it is apparant that the milling of rye expanded no more than the population increased. The sharp increase to 15.95 million bushels in 1919 may be regarded as a part of post-war European relief. The sharp decline reported in the census of 1921 may be regarded as the result of the return to patent flour wheat bread, both corn bread and rye bread retreating per capita. The grindings reported for 1923 and 1925 were somewhat larger but were still below the level of the years just preceding the war. The reported rye flour outputs tell the same story, though the extractions vary somewhat from year to year.

Minnesota, Wisconsin, New York, Michigan, and Pennsylvania were the prominent rye-milling states at the beginning of the century. In 1914 Minnesota led, followed by Wisconsin, Pennsylvania, New York, and Illinois, which had superseded Michigan.

[1] It is worthy of remark that our information on the milling of corn is equally scanty.

In 1921 Wisconsin and Minnesota stood in a class by themselves, producing nearly 70 per cent of the rye flour of the country. In the report of the last census of manufactures, for 1925, these two states were credited with approximately 73 per cent of the total outturn of the country. This distribution of rye milling corresponds both with the distribution of rye acreage and of the population of north European extraction.

In many countries of Europe, particularly in eastern Europe, is still to be found considerable milling of rye by primitive methods. The uncleaned and also untempered rye is ground between stone plates driven by water-wheel or windmill and yielding a coarse rye meal. A partial advance on these primitive methods, to be found in central and eastern Europe and in Russia, consists in what is known as plain grinding of rye. This is carried out on corrugated rolls and stone plates. In some instances the rye is ground to flour, bran and all; about 5 per cent of the bran is separated in the cleaning, and the remaining flour is called a scoured flour. In other instances the rye is passed over several breaks, and the bran is sifted away to give a flour of some 85 per cent extraction. This is known as break flour and is not only whiter, but the particles are finer. Most modern mills operate with corrugated rolls, the products being separated into several graded fractions that are known as dressed, sifted, and bolted rye flours. The dressed rye flour is about a 74 per cent extraction; the sifted flour is still finer; the bolted flour corresponds to a patent, and may be as low as, or below, 60 per cent extraction.

The best rye flours, known in Germany and Scandinavia as white ryes, are produced on rolls quite after the current practice in the milling of wheat. These mills produce several grades, corresponding to a series of patent and straight flours, of which the finest is usually less than a 50 per cent extraction. Thus, in the European milling of rye we find flours corresponding to short patent, standard patent, long patent, bakers' patent, straight, clear, and whole rye flour, ground in ancient and modern mills.

The finest rye flours are made in western Europe, the coarsest in eastern Europe; the largest proportion of whole rye flour is made in Russia. The finest rye flour, the shortest extraction, goes mostly to the cities; the coarsest rye flour, the longest extraction, is most used in the country. To this general statement, however, important exceptions exist. For example, the industrial workers in the Rhineland cities are heavy users of coarse and whole rye flour.

Per Capita Consumption of Rye

Consumption of a cereal has either a broad or a narrow meaning. The broad meaning of consumption corresponds to disappearance; it means crop, minus net exports, adjusted for differences between carryover in and carryover out. The narrow meaning of consumption corresponds to ingestion, plus domestic waste. The per capita consumption of rye in the United States can be estimated only in rough figures. Estimates of rye acreage have not received the attention accorded to wheat and are less trustworthy. There is no reliable estimate of carryover. Since the food use of rye is practically confined to rye flour, consumption in the narrow sense is to be arrived at by adjusting flour production of the year for carryovers and net exports.

To estimate gross consumption, or disappearance, the best we can do is to add the figure for visible supply on July 1 to the crop of that year;[1] and from this figure to subtract the visible supply on the first of July following, also the net exports during the year, also seed at the rate of six pecks per acre, without further adjustment for stocks in any position, either in the form of grain or flour. The remainder, including all the plus and minus errors, corresponds to disappearance in all ways, in country and city.

Table 3 contains the figures for the five years before the war and the past six years. During the five years before the war, the highest per capita disappearance was 20.2 pounds, the lowest was 17.5 pounds, and the average was 18.8 pounds. To what extent the concordance was fictitious cannot be guessed.

[1] The visible supply of course does not comprise the total carryover; but other data are not available. There is reason to believe that the rye visible constitutes a larger fraction of the total rye carryover than is the case with wheat.

Since human use of rye in the form of flour was about 6 pounds per person per annum (see below), it follows that two-thirds of the disappearance of rye must have been accounted for by industrial use, animal feed, and seed for planting rye used as pasturage, ensilage, and hay.

Since the war the variations in disappearance of rye have been more pronounced, but the figures have been lower. The highest figure for per capita disappearance was 17.4 pounds, the lowest 8.7, the average 12.6 pounds. The absence of use of rye in distillation accounts for part of the reduction. Beyond that, the figures suggest that less rye has been fed directly, and less rye sown for pasture, ensilage, and hay, or both.

The consumption of rye in the narrow sense, ingestion plus domestic waste of rye flour, is to be measured directly from the milling figures. Pearl[1] included in his estimation of the food supply for the years before the war a computation for rye that was as good as the data permitted. Recomputing his figures for the years 1911–16 into a composite, and using the population of the middle of the period, we find that the consumption of rye flour was a shade under 4 pounds per person per year. This would correspond to something like 6 pounds of rye, as against a disappearance of something approaching 19 pounds, during the same period.

For the post-war period we have three reports of rye flour milling in the biennial censuses of 1921, 1923, and 1925. These are of course incomplete, since the reports exclude merchant mills below a certain outturn and also customs' mills. Let us make an arbitrary guess that the volume of rye flour thus excluded has been 5 per cent and raise the reported totals of rye flour by that amount. Taking the estimated population of the same years, we secure figures for the per capita consumption of rye and rye flour in pounds as follows:

	Rye	Rye flour
1921	4.18	2.54
1923	4.88	3.02
1925	4.15	2.79
Average	4.40	2.78

The figures in the second decimal places have of course no meaning; indeed, the first decimal place is doubtful. Contrasting these figures with those computed from Pearl, one arrives at the inference that the per capita consumption of rye flour since

TABLE 3.—PER CAPITA DISAPPEARANCE OF RYE IN THE UNITED STATES, PRE-WAR AND POST-WAR*

July-June	Crop (thousand bushels)	Visible July 1 (thousand bushels)	Seed (thousand bushels)	Net exports of rye and rye flour (thousand bushels)	Net supply (thousand bushels)	Population[a] (thousands)	Per capita disappearance (bushels)	Per capita disappearance (pounds)
1909-10	35,406	157	3,277	212	31,696	91,530	.346	19.4
1910-11	34,897	378	3,191	(188)[b]	32,257	93,165	.346	19.4
1911-12	33,119	15	3,175	(103)[b]	29,635	94,458	.314	17.6
1912-13	35,664	427	3,835	1,853	29,954	96,144	.312	17.5
1913-14	41,381	449[c]	3,811	2,234	35,416	98,213	.361	20.2
Average	36,093	285	3,458	802	31,792	94,702	.336	18.8
1921-22	61,675	587	10,008	29,934	20,685	109,135	.190	10.6
1922-23	103,362	1,635	7,756	51,654	30,486	110,688	.275	15.4
1923-24	63,077	15,101	6,225	19,816	34,903	112,684	.310	17.4
1924-25	65,466	17,229	5,961	50,229	17,799	114,311	.156	8.7
1925-26	46,456	8,706	5,367	12,641	26,343	115,940	.227	12.7
1926-27	40,795	10,811[c]	5,505	21,694	23,152	117,600	.197	11.0
Average	63,472	9,012	6,804	30,995	25,562	113,393	.226	12.6

* Data from *Agriculture Yearbook, 1926; Wheat and Rye Statistics* (U.S. Department of Agriculture Statistical Bulletin 12), January 1926; and *Monthly Summary of Foreign Commerce.*

[a] Figures for January 1, as estimated by National Bureau of Economic Research.

[b] Net import.

[c] The visible supply on July 1, 1915, was 369 thousand bushels; and 1,255 thousand on July 1, 1928.

[1] *The Nation's Food*, pp. 252–58.

1921 has been somewhat lower than before the war, 4 pounds per capita before the war, 3 pounds per capita since.

These figures illustrate how insignificant is the American consumption of rye. According to Ballod,[1] before the war the ingestion of rye flour per person per year corresponded to 240 pounds in Russia, 133 pounds in Germany, and 94 pounds in Austria-Hungary. According to the report of the Eltzbacher Commission, the German consumption approximated 172 pounds.[2] Post-war data on rye flour consumption are lacking, but incomplete statistical evidence suggests that a decline has occurred in northern Europe. The following data show, for five European countries, the domestic disappearance of rye per capita per year in the pre-war and post-war periods, in pounds:[3]

Country	1909–14	1921–26
Belgium	210	155
Denmark	510	325
Germany	360	245
Netherlands	250	151
Sweden	280	220

Domestic disappearance of course includes seed, feed, and industrial use as well as human consumption. Nevertheless the reductions appear rather large to be attributable to reduced use for these purposes only, or to errors in crop estimates; one may reasonably infer what common observation corroborates—that throughout northern Europe the use of rye flour is declining. These figures compare with an American average domestic disappearance (similarly computed, without allowance for carryovers or seed) per capita in pre-war years of about 22 pounds, in post-war years of about 17 pounds.

International Trade in Rye

Before the war, 95 per cent of the rye of the world was produced and consumed in Europe and Russia; Russia, Germany, and Austria-Hungary produced five-sixths of it. Russia exported rye to Europe and imported from Europe. The United States and Canada had a border trade in rye; the United States shipped a trifling quantity overseas. Argentina also made small shipments overseas. The amount of rye secured by Europe, ex-Russia, from Russia, and overseas sources of supply averaged around 40 million bushels per annum during the five pre-war years. The trade between the several European countries was in larger volume. The imports of the United Kingdom were largely for purposes of distillation, those of the other northern European countries largely for foodstuffs.

In years of normal rye crops, Germany was a net exporter of rye. She exported rye to portions of northern Russia, most of which are now incorporated into Poland, Finland, Esthonia, Latvia, and Lithuania; also, to Scandinavia and to Switzerland. She was at the same time an importer of rye, sometimes of cheap feed rye from Russia, but more often of hard bread rye from Russia and from Argentina. Belgium and Holland were net importers, largely from overseas; Holland was also an active re-exporter of imported rye. The portion of the old Austro-Hungarian Empire that is now Czecho-Slovakia was a net rye importer. The region south of Budapest shipped out varying amounts of rye to the northern countries. The volume of imports of rye depended somewhat upon the proportion of unmillable rye in the domestic crops of the European countries, the tail rye going to animals and being replaced by imported rye. A tabulation of imports and exports among the several states before the war, adjusted to the boundaries of the new states since the war, is impractical for reasons of lack of detailed and trustworthy information.[4]

After 1915, failing to secure grain from Russia, the Allies turned to North America for rye. Before the war, we had exported little rye to Europe, except insignificant parcels for distillation. The rye exports rose promptly to nearly 15 million bushels and remained in that neighborhood during the war. In 1919–20 export rose to 42 million bushels, in 1920–21 to 47 million, from

[1] Karl Ballod, "Die Volksernahrung in Kreig und Frieden," *Schmollers Jahrbuch, 1916*, pp. 77–112.

[2] The striking difference in estimates for Germany was due to differences in production and in rye fed to animals. The true figure lies somewhere between 133 and 172 pounds.

[3] Crops plus net imports or minus net exports, divided by population.

[4] Data on imports and exports of European countries for post-war years, with pre-war averages in part comparable with post-war figures, are given in Appendix Table IX.

which point it has tended to decline to 20 million bushels or less, though exports in 1922–23 and 1924–25 were over 50 million bushels.[1] These exports were provoked by shortage of bread grains in Europe. As was the case during the war, since the war rye has been imported into the countries of the ex-Allies to serve as stretching material for wheat. It has been imported by ex-neutrals and by ex-enemy countries as straight bread flour and as stretching material for wheat flour. Apparently, during the war or since, little American rye has been used in Europe as feeding stuff or material for distillation.

European statistics on rye are believed to be less secure than in the case of wheat, on account of lower accuracy in estimation of acreage, larger use on farms and in rural districts, and smaller proportion passing through the channels of trade. In addition, the changes in the western boundary of Russia have brought into Europe (ex-Russia) countries that before the war were in European Russia. These include Finland, Latvia, Esthonia, Lithuania, Congress Poland, Bessarabia, and a few other small parcels of territory. These were rye-producing and rye-consuming areas, with the exception of Bessarabia where the use of corn was more prominent. Consumption, however, exceeded production for these areas as a whole. Europe, ex-Russia, is therefore a heavier rye importer (or wheat importer) at present than was the case before the war.

The important potential rye-exporting countries of Europe are Hungary, Poland, Roumania, Jugo-Slavia, Bulgaria, and of course Russia. The net-importing countries of note are Scandinavia, Finland, the three east Baltic states, France, Italy, Belgium, Holland, Czecho-Slovakia, Austria, and the United Kingdom. The future position of Germany is unclear. Before the war she was a net rye exporter; since the war she has been alternately a net importer and exporter. Some rye is produced in Alsace and Lorraine, still more in Posen that is now a part of Poland. If Germany could secure the Russian rye available before the war, she might again become a small rye exporter; otherwise, Germany would probably do with rye as Spain does with wheat, import or export a small amount, depending on circumstances.

We regard the present Poland as a potential net exporter of rye, but in fact she is not yet in that position. This is due to a number of factors lying outside the grain-raising capacity of the country in relation to population of human beings and animals. Peasants sell rye and feed oats and barley or feed rye and sell oats and barley, according to prices. Rye is exported in the fall and reimported in the spring, usually in larger amount. The government is now building a rye reserve for protection of supply and control of price.

The relations everywhere have been highly irregular since the war, on account of trade barriers and disorganization of currencies, and are just becoming restabilized. It is, however, noteworthy that while the volume of rye imported into the present Europe from Russia and overseas has tended to be larger than the imports of the pre-war Europe from Russia and overseas, the volume of trade between the different states of Europe has been substantially smaller.

Striking has been the increase in the overseas trade, and in some years in the shipments of Russia. Both have been irregular, high in some years, relatively low in others. In 1923–24 Russia exported over 53 million bushels of rye, a figure not equaled in the five years prior to the war; in the following year, the Russian exports sank below 3 million bushels. In 1924–25, the year of lowest Russian exports, the United States exported over 50 million bushels, largely to Europe; in the following year only a fourth as much was exported. The exports of Canada, insignificant before the war, exceeded 6 million bushels in each of the past five years, and reached nearly 10 million in 1922–23. The exports from the Plate, averaging less than 300 thousand bushels in the five years before the war, have risen to ten times that figure. Holland continues to be an importer of rye for purposes of consumption, but is no longer prominent as a re-exporter of imported rye. Scandinavia and the countries east of the Baltic Sea, which used to secure a part of their rye from Germany, now secure it largely from overseas. International trade in rye, both as to routes and quantities, has

[1] See Appendix Table II.

been strikingly changed since the war; but to a large extent it has been an abnormal development.

Russian exports and imports of rye since the war may fairly be termed incidental or accidental episodes, rather than the expression of agricultural potential. The combination of dictatorship of the proletariat, disorganization of currency, breakdown of transport, crop failure and famine, and state control of import and export trade has prevented Russia from contributing to Europe anything like the amounts of wheat and rye that were to have been expected on the basis of pre-war experiences. Russia has lost northwestern provinces that were rye importers; therefore her failure as a rye exporter is all the more notable. Rye is raised more or less all over Russia, but the distribution of the crop was more to the northward, with wheat and maize to the southward. Rye is the staple cereal of Russia and is raised as food for peasants even in the areas of the Volga and in the Ukraine. Under pre-war Russian landlordism, rye was raised for domestic foodstuff and wheat was raised for export. With parcellation of the land this has ceased to be true; the peasants consume more wheat and less rye relatively, but absolutely more of both combined. It seems likely that the same effect is everywhere to be expected in Central Europe—parcellation of the land is followed by improvement in the country standard of living, favoring wheat as against rye.

The question of prospective Russian exports is as important for rye as for wheat. Before the war average Russian net exports of rye were around 27 million bushels and of wheat around 165 million bushels.[1] Is there a prospect (and if so at how early a date) that European Russia of the present boundaries will again export as much rye and wheat as was exported before the war from the same area? Or have the changes in Russian agriculture since the war conduced to a changed level of exports?

The exports of wheat and rye from Russia before the war were mostly the expression of the outturn of large estates and to a substantial extent represented exploitation of tenants, land workers, and small peasants. Today, title to the land rests, in theory, in the state; but occupancy, use, and tenure rest in the peasant. Occupancy includes control over farming, and tenure may be transmitted to the next generation. Russian peasants apparently regard the status as equivalent to possession. In effect, therefore, parcellation of the land has been accomplished in Russia. This has been accompanied by changes in agriculture, with the trend toward animal husbandry and in the direction of a higher standard of alimentary subsistence.

The Soviet state has every incentive to favor exportation of cereals. Indeed, with each year the purchasing power of exported cereals becomes increasingly more important. Therefore, the "procurement" of exportable surpluses, their expedition from points of collection to dispatching points for export, and their sale in the importing markets of Europe, are a first concern of the Soviet government. They have failed to bring out the available supplies, through inexpert management; but they have not relaxed on the project of exports through lack of incentive.

From the standpoint of the peasants, however, the incentives of cash sale seem not to be maintained. The peasants are building up their animal husbandry; thus more grain is consumed on the farms. Russia has the traditional practice of carrying large stocks. The importance of these stocks is intensified in the peasant mind by the recollection of the famine of 1921; it is accentuated by the increase in the count of domesticated animals. With each year, the peasants seem to find themselves able to get along with fewer of the city-made articles to which they had become accustomed before the war. They are returning to more primitive farm implements. Household industries are being revived; the family of the peasant is becoming more self-sufficing. Perhaps most important of all, the peasants have found during recent years a striking disparity between the amount of grain they sold for export and the amount of goods and implements received in return. In short, the effective incentives of the peasant class for export of wheat and rye are, for the time being, apparently on the decline.

[1] These figures would be different when adjusted to conform to the changed boundaries of Russia on the west.

The export program for the present crop year has fallen down badly; nothing like the amount of wheat and rye that came out of Russia last season will come out of Russia this season. In explanation, in addition to official estimates of a smaller crop of wheat but a larger crop of rye,[1] we are told that the peasant is building up stocks, is disinclined to sell at current prices, and that larger exports are to be expected only in the event that several large crops shall have filled the farm stocks to overflowing. Furthermore, if Soviet authorities are right in adjudging standing estimates of pre-war crops as far too low, Russian domestic consumption may not have recovered as yet to a level permitting considerable exports.

If this statement of the situation in Russia, in itself reasonable and plausible, is correct, then it does not seem likely that an early return of Russian exports of wheat and rye to the pre-war level is to be anticipated. Fear of famine is ingrained in the Russian peasant. A crop failure is expected every so often (rather often) in southern Russia, especially in the region of the Volga. Just as squirrels, according to popular belief, hoard for a hard winter, so Russian peasants hoard for the year of crop failure. It is not unreasonable to infer that the reported building up of stocks, if it is actually taking place, is in part the result of widespread fear that another crop failure is about due.

The expansion in United States export trade in rye since the war has been one of the most striking of the post-war expansions. This is made evident by contrasting the average export of the five years before the war, 800 thousand bushels, with the average export during the years 1921–27, which was around 31 million bushels. Though clearly forecast in post-war conditions in European agriculture, the trade came to the United States almost unheralded, a direct continuation of our expanded war agriculture. Since 1922 the acreage has gradually declined, with little agitation over the rye surplus problem. Our exports of rye to Europe have held on long and heavily, largely because of the delay in Russia's return to the export trade.

We are advised by responsible European importers that the ryes shipped into Europe from the United States since the war have been consistently disappointing in quality, and have often sold for 4–5 cents per bushel below Russian rye. They have been soft, low in protein, and gave a low yield of flour. It is the experience of mills in Scandinavia, Holland, Belgium, and Germany that average No. 2 Western rye has been distinctly inferior to the ryes secured from Poland, the Danubian area, Russia, and the Plate, adapted better for use in distillation and as feeding stuffs than to the manufacture of flour.

At the beginning of the crop year, or as soon thereafter as crop estimates become available, tables of European wheat import "requirements" are prepared in Europe and in the several exporting countries. These tables are revised month after month, as additional information becomes available. Discussions of such tables are frequently to be found in WHEAT STUDIES. The European rye crop is one of the elements in setting up the table for European wheat import requirements. No corresponding tables of European rye import requirements are set up, except in a desultory and fragmentary manner. The variables are numerous, the fluctuations wide. Predicating stated wheat and rye crops in Europe, and stated exportable surpluses of wheat and rye available to Europe, and setting up a figure for gross wheat requirements, one might forecast a probable figure for import of rye. For example, on the basis of the present crop reports, it has been suggested that during the crop year 1927–28 European wheat requirements would be around 640 million bushels and rye requirements 50 million bushels. The forecast for rye would be the more hazardous. If one were to forecast European wheat requirements at 640 million bushels and European rye requirements at 50 million bushels, and the actual outcome were to be 620 million bushels of wheat and 30 million bushels of rye, the miss of 20 million bushels would be a small matter in the case of wheat but a large mistake in the case of rye.[2] It cannot

[1] The wheat crop of 1927 is estimated at 750 million bushels as compared with 810 million in 1926; the rye crop of 1927 at 968 million as against 897 million in 1926.

[2] During the present season, European imports of rye will probably be modified more by European imports of barley than by European imports of wheat.

be assumed that Europe needs a fixed (computable) amount of bread grain, and, if less wheat is secured than planned, the difference will be made up with rye. We have therefore not felt it justifiable or advantageous to attempt to set up in advance a table of importers' requirements and exporters' supplies of rye, corresponding to the tables that play such a prominent rôle in the study of wheat.

III. CHARACTERISTICS AND CONSUMPTION OF RYE FLOUR AND RYE BREAD

Characteristics of Rye Flour

As we have seen, the larger commercial mills in the United States sometimes make as many as four grades of flour called respectively white, pale, dark, and straight rye flour. The extractions vary from season to season, and from region to region. White rye flour is often of a lower extraction than 50 per cent of the grain; a straight rye flour is rarely as much as 70 per cent. The pale and dark gray flours stand between the white and straight flours. Clear flours are usually not separated, but go into millfeed. There is little production of whole rye flour in this country; what passes as such is usually straight flour with bran added. Rye grits and groats[1] are practically unknown in this country. The most common flours are white and (medium) dark, these being most widely quoted. White rye flour is a short patent, dark rye flour practically a (low) straight flour. The standards for color, ash, fiber, acidity, and protein content are not so well developed as for wheat flour; also, they are less important. Rye is usually ground in separate mills; but there are advantages if the rye mill is one of the units in a wheat milling company, since this facilitates the disposition of the offals.[2]

In rye milling there is less blending practiced than with wheat. For the most part, mills grind the rye of the region and do not draw rye from distant sections in order to produce a uniform flour. In other words, quality and uniformity are less important with rye flour than with wheat flour.

Rye flour has a specific odor and taste, and these extend to baked products. The taste and odor are so penetrating as to be obvious in bread made of wheat flour containing only 5 per cent of rye flour. It is therefore possible to make bread with a rye taste out of wheat flour with a relatively

[1] Cracked, crushed grains, sometimes hulled, grits being finer than groats.

[2] It may not be out of place to comment on flour grades. Milling practice and terminology vary from locality to locality, from mill to mill, and from season to season. In effect, though not in direct operation, the mill divides the berry of wheat into two fractions—flour and millfeed. The flour is commonly called straight flour and represents from 70 to 74 per cent of the weight of the cleaned wheat. During the war, for example, the American mills manufactured a uniform straight flour of about 74 per cent extraction. There is considerable marketing of straight flour, but for the most part patent flours are prepared from it. The straight flour is divided into two fractions—patents and clears. The patent flours represent purifications, particularly reduction of color, acidity, ash, and fiber. Patent flours are short or long, depending upon the amount secured from the straight flour. A long patent flour, for example, is one secured with the removal of, say, 5 or 10 per cent of the straight flour. A short patent flour is one secured with the removal of, say, 20 or 30 per cent of the straight flour. The fraction removed from straight flour, when purified in the making of patent flour, is called clear flour. When a short patent flour is manufactured, a fine clear flour is secured. Large mills manufacture several grades of patent flours, representing various degrees of refinement. Correspondingly, they produce two or even three clear flours. Usually the third clear flour, and sometimes the second clear flour, goes with the red dog into feed. The first clear flour goes largely to export, into rye blends, into self-rising and cheaper bread flours, and into industrial use. The finest, shortest patent goes mostly into the family trade. The terms are rather loosely used. Thus, the straight flour of one mill may be practically identical with the long patent flour of another mill.

By extraction is meant the percentage of weight of wheat recovered in a particular flour. A straight flour of 70 per cent represents 70 per cent of the weight of the wheat used in grinding it. A patent flour of 50 per cent extraction represents a short patent in which half the weight of the wheat is recovered.

The practical miller, in defining patent flour, applies the percentage to the straight flour, not to the original wheat. Thus, "90 per cent flour" and "70 per cent flour" represent respectively patent flours containing 90 and 70 per cent of the straight flour, 10 and 30 per cent of clear flour being recovered. If the straight flour were a 70 per cent extraction of the wheat, then a "90 per cent flour" would represent a 63 per cent extraction of the wheat and a "70 per cent flour" would represent a 49 per cent extraction of the wheat.

The same technical and grading expressions are applied to rye flour, but with less precision and refinement. Correspondingly, there is with rye flour less precision and refinement in the determination of color, acidity, ash, and fiber.

small admixture of rye flour. The taste and odor of rye are such as seem to lend themselves naturally to use with meat, cheese, and vegetables, rather than with fruits and sugar. In consequence, rye lends itself poorly to the manufacture of breakfast cereals, cakes, pastries, and confections. This holds true even in the European countries that consume rye extensively; their sweet baked goods are usually made of wheat. Nevertheless, one sees on the American market such combinations as raisin rye bread, orange rye bread, and others. Millers of wheat flour advocate the use of fruit breads in the hope of increasing the consumption of flour; growers of fruits support this in striving to increase the consumption of fruit. Wheat having set the example, rye follows suit. In Europe caraway seed is commonly added to rye bread, a practice also followed in this country; this is done, supposedly, less for the flavor than for the stimulating effect of the essential oil of caraway on fermentation!

The public does not associate whiteness with rye flour as with wheat flour. Also, the conditioning and maturing of rye flour are not so important as with wheat flour; rye flour does not gain as much relatively by being matured as wheat flour does. Rye flour, however, is the more perishable.

In Europe the rye flours vary from country to country. The shortest white ryes may be as low as 50 per cent extraction. Straight rye flour is commonly 68 per cent extraction. Between the short patent and the straight flour appear several grades of gray flours. Clear rye flour also is common in Europe. Since the war there is considerable milling of whole rye flour in different European countries; straight rye flour mixed with bran is also manufactured. Before the war, the manufacture of rye grits and groats was widespread. Since the war this is on the decline, apparently in favor of whole rye flour. What is called whole rye flour is rarely over a 94 per cent extraction, since about 6 per cent of the weight of the kernel is removed in the act of cleaning.[1] With the decline of manufacture of grits and groats and increase in the milling of whole rye flour, bakers of whole rye bread in Europe have learned that to meet public taste whole rye flour must be ground fine. Finding it difficult to make an acceptable rye flour of over 84 per cent extraction, unless the endosperm is milled fine, the European mills now incline to the practice of preparing their so-called "graham-rye" flour by sifting rye bran back into a finely ground straight flour.

Before the war the most popular single rye flour in northern Europe was a finely ground flour of about 82 per cent extraction. Since a straight rye flour in Europe—using the term as comparable with their straight wheat flour—was around 68 per cent extraction, the popular flour of 82 per cent extraction represented a half-way product between straight and whole rye flour. A somewhat lighter flour remains the favorite post-war rye flour in Europe. As a rule, darker flours are preferred in country districts and lighter flours in the city. The proportions of these several flours vary from country to country and from season to season. They also vary with the size of the domestic crop, the price level of bread grains, and the prosperity of the country.

The European mills try to turn out uniform rye flours and, in order to do this, import ryes to blend with domestic ryes. In this sense, the manufacture of rye flour in Europe compares with the manufacture of wheat flour in the United States. Buffalo mills sometimes import hard Canadian wheat to blend with domestic wheats, and Pacific Coast mills import hard wheat from Montana and Kansas to blend with local wheats; just so the large mills in northern European cities import ryes from neighboring countries, from Russia, from North America, or from Argentina. They endeavor to secure hard rye rather than soft rye. From Russia and the Plate hard ryes are to be secured; from North America come ryes rarely better and often not so good as the usual ryes of northern Europe. The harder type of rye is generally used in making flour for consumption in cities; soft rye suffices for the making of country flour. The criteria of and public taste for rye flours are better established in Europe than in the United States.

The protein content of rye flour is substantially lower than that of wheat. In this

[1] Rye is scoured and brushed in machines of varying construction (in Europe, the cleaning is often done between stones), whereby the outside of the husk is removed, 5 or 6 per cent of the weight being lost.

country, rye flour is often stated to have only half the protein content of wheat flour. Such a wide difference is not to be found in European analyses. Corresponding European analyses give a much higher protein content for rye flour and a somewhat higher protein content for wheat flour, the difference between the two, therefore, being less than in the American analyses. This is partly due to difference in extraction, in part however to the fact that American ryes are not so good as European ryes. For both wheat and rye flours, American chemists use a lower factor for conversion of nitrogen into protein, so that all American analyses give lower results for protein than European analyses. It is safe to state for comparable flours that the protein content is always higher for wheat than for rye; it may be a fourth higher, a half higher, or twice as high, depending on circumstances in milling and on the grains from which the flours have been derived.

When wheat flour is moistened, worked into a gummy mass, and washed with water, a crude protein is isolated that has long been called gluten. When rye flour is manipulated in the same manner, no corresponding recovery of gluten occurs. But since the dough of rye flour behaves under fermentation like the dough of wheat flour, it must contain a gluten-like material. When, in isolating gluten from wheat flour, rye flour is added, the yield of gluten is reduced; something in the rye operates against the isolation of wheat gluten. When, however, the isolated gliadin (see below, p. 204) of rye flour is added to wheat flour, this does not operate against the isolation of the gluten, but increases it proportionately, just as if one added gliadin isolated from wheat flour. Therefore, the inhibitory factor in rye flour lies outside of the gliadin. Not only does rye flour behave like wheat flour in dough under fermentation; but when the proteins are isolated from the two flours, it is found that the principal protein of rye is very similar to one of the two principal proteins of wheat. It is therefore natural to speak of rye containing gluten, even though it cannot be isolated by washing; and since it is advantageous to use the term gluten in this general sense, we invoke the indulgence of the cereal chemists for so doing.

The bread grains, wheat and rye, are thus characterized by the presence of gluten. Maize, barley, oats, rice, and the sorghum grains contain no gluten or gluten-like proteins. Suspended in water, gluten forms a gum-like mass, tough, elastic, and distensible. Inflated with gas, glutens form sponge-like masses, the volume of which is enormously larger than that of the original material. Under distension, gluten will expand to twenty times the original volume. The gluten of wheat contains two proteins, glutenin and gliadin. Glutenin and gliadin are difficult of quantitative determination, but enough is known to indicate that they make up the largest part of the protein of wheat flour, being present in approximately equal amounts. Rye contains gliadin. The gliadin of rye is not identical with the gliadin of wheat, though very similar. In quantity, gliadin is present in rye flour to much less extent than gliadin and glutenin in wheat flour. Also, qualitative differences in the glutens of the two flours exist, with superiority on the side of wheat.[1]

[1] In order that the efforts made above to present the subject untechnically may not lead to misinterpretation, certain amplifications and qualifications seem desirable. Gluten is the name applied to the elastic protein that may be obtained from wheat flour through the action of water. One cannot isolate gluten from rye flour by washing. But on the basis of behavior in dough, rye flour contains a colloid that has the right to be called a gluten even if it cannot be isolated by washing, and we shall use the term here. Like all proteins, gluten is a colloid—an emulsion colloid with special characteristics. Crude gluten may be purified by appropriate methods. As components of gluten, two proteins may be identified called glutenin and gliadin. Glutenin is now classified as a glutelin, while gliadin is regarded as a prolamin. Wheat flour contains both glutenin and gliadin in variable but usually about equal proportions; rye flour contains also a glutelin, but not identical with the glutelin of wheat and not present except in traces. The gliadins of wheat and rye are apparently not identical chemical individuals.

The qualities of glutenin and gliadin are modified by their behaviors when suspended in water, depending on the presence, and concentration, of acids, alkalis, and salts. All colloids when mixed with water form phases that are modified (*a*) by acidity or alkalinity, (*b*) by the degree of acidity or alkalinity (concentration or hydrogen potential), (*c*) by the presence of electrolytes, regarded merely as carriers of electrical charges, and (*d*) by the presence of electrolytes whose cations or anions exert specific influences as elements aside from their electrical charges. All phase reactions take time for development: within limits, increase in temperature hastens developments. Also, the velocities of phase reactions are modified (temperature constant) by changes in the media related to acids, alkalis, and salts. These time relations possibly correspond to the so-called "development" of the dough. These several relations are only partly ex-

Rye dough expands less than wheat dough; other things being equal, wheat bread is always lighter than rye bread.

When wheat or rye flour is mixed into a dough, following the addition of yeast we have the familiar rising of the loaf consequent on the evolution of gases of fermentation. The individual air-cells of the sponge-like mass do not as a whole communicate, and the loaf is thus distended. Breads made from the other grains cannot be raised with yeast in the same way, because they do not contain the elastic glutens. Breads made with baking powders are sometimes called quick breads, as distinguished from yeast-risen breads. Quick breads can be made with the flours of maize, rice, oats, barley, and millet, but not yeast-risen dough breads. Both yeast-risen and quick breads may be made from wheat and rye flours. Nowadays most quick breads are made with the addition of enough wheaten flour to make the use of baking powders practicable; but in earlier times corn pone, rice cakes, and oaten scones were made straight. Commercial bread-making rests upon the adsorption of water by gluten and distension of the loaf in the fermentation of the dough.

Both wheat and rye are poor in fat, but rye flour is the poorer. Rye flour is slightly more starchy than wheat flour. So far as heat values are concerned, the larger content of starch practically balances the smaller content of protein and fat; therefore, comparable wheat and rye flours differ but slightly when rated by calories. Wheat flours run from 1,620 to 1,700 calories per pound, with rye flours 20 to 50 calories poorer (with standard moisture).

plored for the best-known colloids, and are less well known for gluten than for some other colloids. Not only does a particular colloid exhibit strikingly varying behavior under different concentrations of acids and electrolytes in the system, but two colloids may behave in a manner different from that which either would exhibit alone, other things being equal. This point is of particular importance in relation to the bread grains, since it is not unreasonable to expect that gliadin alone would behave differently than when mixed with glutenin. To some extent, other things being equal, the different behaviors of wheat and rye flours might be due to the fact that rye contains largely gliadin while wheat contains glutenin and gliadin, thus modifying the phase.

When studied in the isolated state, the gluten of rye behaves like that of wheat, only to lesser extent. The emulsion of rye gluten is less viscous, more soluble in water, takes up less water in the phase reaction and displays less swelling. The sponge structure is less elastic, and has a softer feel, resembling, by way of comparative illustration, a soap suds rather than whipped white of egg. These varying behaviors of the isolated proteins find their counterpart in the behaviors of wheat and rye doughs. While rye gluten is less viscous than wheat gluten, watery suspensions of rye flour are more viscous than those of wheat flour. Because this viscosity of rye flour is little affected by acidity, and for other reasons, it is inferred that it may be due to the influence of components of the carbohydrate fraction of the flour.

At the present time, investigators seem to be divided in their views. According to one view, the qualities of glutenin and gliadin are inherent, predetermined in the seed, and therefore subject to modification by plant breeding. In particular, the bilateral relations of the two colloids to each other in the phase system are regarded as determined largely by the glutenin. The other view finds in the acids and electrolytes in the kernels of wheat and rye the principal causes of the varying behaviors of glutenin and gliadin. Under this view, the colloidal properties of wheat and rye flours might be modifiable in the act of milling and baking. That the addition of electrolytes in certain proportions and of acidity to a certain extent would modify the behavior of the gluten in the dough, fits in with either view. These two views are of course not exclusive; there is probably truth in both. We may expect future investigations gradually to separate those qualities of glutens that are inherent in the chemical constitution of the molecule from those referable to environment in the phase system.

The Characteristics of Rye Bread

The characteristics of a bread are both physical and chemical. They depend upon the grain used, the type of flour employed, the ingredients other than flour, salt and yeast, the type of fermentation, and the method of baking. Once baked, breads become stale or retain their freshness, depending on circumstances. Rye breads are unlike those of wheat as a result of differences on all the points mentioned.

A loaf may have a thick or a thin crust; it may be light or heavy, fluffy or tough; it may be relatively wet or dry. It may have large holes or small holes; it may have a dense or a light texture; it may be crummy or sticky. On all of these points, variations are less important for rye than for wheat bread, both in Europe and in the United States.

To the baker the number of loaves to be secured from the unit of flour is important. On account of the larger content of gluten, and better quality, wheat flour absorbs more water in the dough than does rye flour. At the same time, a rye bread is usually more soggy than a wheat bread, the sogginess being due to the texture rather than to the absolute water content. Cer-

tain rye breads, however, have a high water content, due possibly to the action of lactic acid.

The flavor of a bread is the composite result of many factors. Naturally, the flavor of a plain bread, such as is almost universal in Europe, differs from the flavor of a bread containing milk, shortening, and sugar, such as is becoming universal in the United States. As a witty American baker has put it, it is the difference between plain bread and poor cake. The flavor of a plain bread includes both taste and odor. The flour of each grain has its particular flavor, brought out when the flour is mixed with water and baked. The yeast itself develops a flavor, as may be determined if a cake of yeast is spread thin and baked. The action of yeast on the flour in the act of fermentation produces a flavor, different in wheat and rye. Incidental products of the fermentation, such as lactic acid, contribute a flavor of their own and seem also to develop a flavor in the loaf. Finally, the flavor of bread is influenced by texture, since the taste of bread is brought out by mastication. Naturally, a bread eaten straight tastes different from a bread used as a vehicle for spreading materials.

Breads are of two types—sweet and sour. Sour means acid; sweet means merely lack of acid taste—blandness, not the sweetness of a sugar. Sour wheat breads are liked in some countries, for example in some parts of Scotland and France. Wheat bread does not so readily become sour as rye bread. American bakers try to keep rye bread sweet, or at least only faintly sour. In Europe rye bread is usually sour, except the palest rye-wheat breads; indeed, sourness is sought in certain types of rye bread and sour buttermilk and skim milk are added to accentuate the acidity.

Bread dough may be fermented by the addition of a culture of yeast. Fermentation may also be started by the use of sour dough, usually saved over from the previous batch. (Sour dough is *Vorteig* in German, *levain du chef* in French.) In some countries cheese, buttermilk, and sour milk are used as sources of yeast in the preparation of bread. The use of yeast cakes has almost entirely superseded the use of sour dough in the United States. In Europe, on the contrary, sour dough is widely used in all countries, not merely as continuation of an old custom, but because certain types of bread can apparently be made more cheaply and uniformly with sour dough.

The acids commonly present in bread are lactic, acetic, and occasionally butyric. When one studies the products of fermentation induced with yeast, alcohol and carbon dioxid are seen to be the products of one group of fungi, while lactic acid is the product of another. Thus we speak of alcoholic fermentation and lactic acid fermentation. It is the yeast of alcoholic fermentation that lies at the basis of bread-making. In the fermentation of sugar to alcohol, lactic acid is an intermediary stage; but under normal conditions it remains among the end-products in traces only. In addition, in the fermentation of the loaf fungi are also encountered normally producing acetic acid, probably out of alcohol. Occasionally, fungi which produce butyric acids are also present and active, but this is to be regarded as adventitious and abnormal. Butyric acid is highly undesirable in bread, on account of its disagreeable odor. Bread bakers once obtained their yeast from breweries. Later, the manufacture of bakers' yeast became a specialty, in order to obviate the dark color and taste likely to contaminate brewers' yeast, and to secure high and uniform activity. Bakers' yeast contains organisms producing both alcohol and lactic acid. Indeed, the acid is regarded as a stimulant to the fungus of alcoholic fermentation. A sour dough contains cultures producing alcohol, lactic acid, and acetic acid; also butyric acid, when the sour dough goes bad, as is frequently the case. Even where sour dough is saved out of the last batch and remains uncontaminated, it is likely to lose its strength and every so often a fresh start must be made with the use of commercial yeast. In modern times some bakers prepare sour dough for each batch of rye bread. Fermentation with yeast cakes that have been prepared under carefully controlled conditions of culture yields fewer adventitious products than does sour dough.

The water content of bread depends upon many factors, including ingredients and procedures. The commercial standard of moisture is the maximum amount of water consistent with the customary and desired

characteristics of the loaf. Other things being equal, rye flour absorbs less water than wheat flour and the dough expands less. But rye bread retains moisture longer than wheat bread with the same kind of a crust; and rye flour lends itself to the baking of a crust that will retain moisture in the loaf over a long period.

The digestibility of bread and the absorption of the products depend upon the extraction of the flour, the type of fermentation, and the texture of the loaf. Naturally, digestibility depends in part upon mastication. Some types of bread seem to require more mastication, other types are easily bolted. Bread eaten straight is masticated more than bread eaten with butter or conserves.

The food value of bread, in terms of calories, depends upon the grain from which the flour is obtained, the extraction of the flour, the presence of other nutritive ingredients than flour, and the water content of the loaf. Although the pound of rye flour has slightly less food value than the pound of wheat flour, the pound of average plain rye bread may contain as many calories as the pound of average plain wheat bread, due to difference in water content.

Rye Bread in the United States

Rye consumers in the United States have drifted a long way from, or advanced a long way ahead of, their European forebears. Slavs, Germans, and Scandinavians would regard conventional American rye bread as a nondescript foodstuff, adapted neither to workdays, Sundays, nor feastdays. Our rye breads incline to be imitations of American wheat breads rather than imitations of European rye breads.

The customary rye bread of the United States is not straight rye but mixed rye and wheat. It is made for the most part of so-called "rye blend" flour, containing 25, 33, 40, 50, and rarely over 60 per cent of rye flour. Depending on the bakery, the rye flour used is white, medium gray, or dark. The wheat flour in the blend is usually clear or straight, preferably strong, that is, made from hard wheat. Occasionally bakers' patent flour is used; rarely a short high-grade patent hard flour is blended with a white rye to produce an almost white, light-textured bread with just a faint odor and taste of rye. American bakers try to make the mixed rye breads as bland (not acid) as possible.

Rye flour is marketed just as manufactured, and is also blended with wheat flour. For the household trade there are advantages in merchandising a rye-wheat blend. To what extent rye bread is baked in the home is unknown, but it must be slight. Also unknown is the extent to which home-baked rye bread is made of rye flour alone, of commercial rye-wheat blends, or of a flour mixture prepared in the home. Bakeries naturally prefer to make their own blends, partly because they understand the tastes of their customers, but also because they can thus take advantage of varying prices of the several wheat and rye flours.

Straight rye bread appears on the market to a limited extent in some cities. It is made either of white or gray rye flour. It is heavier and more soggy than rye breads containing wheat flour, and is distinctly more acid. On the basis of flour prices, the ingredient cost may be no less for straight rye bread than for mixed rye bread, since clear wheat flour may cost less than rye flour. Furthermore, the yield in loaves is larger in the case of the mixed bread.

A small amount of rye bread is made of whole rye flour, carrying with doubtful justification the name of pumpernickel. In a few out-of-the-way places, pumpernickel is still made of crushed rye instead of rye flour. Indeed, it is still possible "way down East" to find occasional examples of a coarse rye and corn bread of a type that dates back to pre-Revolutionary times. Modern American pumpernickel is rather a concession to the whole grain cult than a continuation of the German prototype.

Rye bread in the United States is not favored with the additions of shortening and sugar commonly used in the baking of wheat bread. It is usually fermented with yeast, the extent of the fermentation being sometimes controlled with salt; it is a short fermentation process, controlled to avoid acidity. The flavor of rye bread seems to come from the fermentation as well as from the flour. With the same amount of yeast, rye flour tends to ferment more acidly than wheat flour, resembling whole wheat flour rather than patent wheat flour. Since Amer-

ican bakers restrain the fermentation, they thereby reduce the so-called rye flavor of the bread. Most bakers use the sponge method rather than straight dough. Since rye flour contains much poorer gluten than wheat flour, expansion of the dough is only moderate.

Rye bread may be baked either on the hearth of the oven or in tins and is usually baked with steam in the oven. The loaves are usually baked separately in order to have a complete crust. As a rule, bakers endeavor to have a heavier and a darker crust for rye than for wheat bread. The short one-pound loaf is the common loaf, though the two-pound loaf is also baked. Rye breads are usually not wrapped. The more wheat flour in the blend, the quicker the loaf dries out.

Rye bread is not consumed in the United States to any extent as a substitute for wheat bread. Our small consumption of rye rests on taste. Consumption is heaviest in the northern states. Immigrants and first-generation descendants from Slavic, Scandinavian, and Teutonic countries use rye bread from choice. The second generation of immigrants is apt to regard rye bread as carrying a social stigma. Rye bread has acquired since the war a rather widespread use in public eating houses, including the best hotels and clubs. This is the result of the urge for variety. It has become the custom in public eating places and clubs to have several kinds of bread placed before the patron, and rye bread is commonly among them. Before the war, the rye sandwich was associated with beer; since the war it seems to hold its own without beer, as witness the cheese sandwich and the hot corned-beef sandwich. The rye bread used in public eating houses, however, is largely wheat bread with a trace of rye color and flavor, and not much of the rye crop goes into this bread.

Rye Bread in Europe

For a long time home baking of bread has been almost obsolete in most European countries; commercial baking is the rule. Before the war, the bakeries were usually small; large-scale baking, according to American practices, was little seen outside of a few large cities in Great Britain and western European countries. The bakery was essentially a neighborhood shop. Since the war, large-scale baking is on the increase and up-to-date bakeries are being installed. These bakeries, however, work especially with wheat. Rye bread has lagged behind in large-scale manufacture and for the most part is still the product of the small bakery. In short, wheat bread tends to be made with modern methods, while rye bread tends to be made with older methods. This difference continues because wheat and rye breads in Europe are for the most part supplementary rather than competitive; the public has different standards for the wheat loaf ("white bread") and for the rye loaf ("black bread").

Before the war, the bread standards in continental countries, especially in Germany and Austria-Hungary, were greatly influenced by military regulations. What might be called the standard rye bread of the Teutonic countries was made with a flour of an extraction of 82 to 84 per cent. This was the composition of the bread of the military barracks, the *kommiss* bread, and was the customary bread of the working classes. Since able-bodied males served as recruits for several years, and thus became accustomed to the bread of the barracks, this became the controlling taste of the common people. Since the war this is less the case, and the rye bread tends to appear in more diversified forms than before the war.

While rye has for centuries been the common bread of Europe, important shifts and trends have taken place. Rye bread is naturally far more important north of the latitude of the Alps than south. Long ago, barley was widely used in Russia and in Europe in the making of unleavened bread and mixed with wheat and rye. It was replaced by rye and is now rarely used in bread, except as a stretching material. Following the introduction of rice and maize into southern Europe, these replaced rye to a considerable extent; latterly, especially since the war, wheat is replacing them, especially maize. Once common in Great Britain, rye bread is now practically extinct in that country. Rye has always been more the bread of the country than of the city. Everywhere it has been the bread of the working classes rather than of the classes

better situated. Rye was always called the bread of poverty; in the poorest classes wheat bread was known as the bread of the sick-room, of Sunday, and of the feast day. There has long been social difference between the two breads; rye and wheat breads were literally in different castes. Since the war, with replacement of monarchies by democracies, following the decadence of the aristocratic classes and the political supremacy of the working classes, a trend of revulsion against rye is clearly discernible.

This revulsion against rye in favor of wheat is devoid of nutritional basis; under the circumstances it is sociologically foolish and economically unsound. Nevertheless, it exists, and is not to be argued away. The trend against rye and in favor of wheat is intensified by the recollections of war bread. The war breads of Europe were for the most part highly undesirable and unsatisfying. They were also widely regarded as unnecessary. They were loaded with dilutions, stretchings, and sophistications of one kind or another, and these were inflicted on rye bread much more than on wheat bread. These war breads were much more prominent in the countries of the Central Powers, i.e., in rye-eating countries, than in the countries of the Allies.

During the war the Germans maintained an extensive propaganda in favor of rye. The foolish attempt was made to dress up rye as an aristocrat. Assisted by university professors, the food administration of the Empire conducted a widespread and intensive campaign in favor of rye. Rye was pictured as the source of the basal Teutonic virtues, superior to wheat in the building of bone, brawn, and brain. The purpose of this propaganda was to make the German people content with the poor rye bread they were receiving. The effect was negative. Since the war the reaction against war bread has survived, to the injury of rye and to the gain of wheat. Similar reactions against rye are to be observed in Scandinavia, in the low countries, in the succession states of Austria-Hungary, in the Balkans, and in Russia. The European may have always felt that wheat was better than rye; since the war this has become a trend in favor of the higher priced wheat.[1]

The predominating rye bread of Europe is made of straight rye flour without other ingredients than ferment, salt, and water. Mixed rye breads are made in all countries; but straight rye bread is now, and was before the war, the predominating type. The color of rye bread was never dodged in Europe, and all rye breads were commonly known as black breads. There were lighter breads made of flours of shorter extraction, as short as 50 per cent; but when breads were made of short-extraction rye flour, the tendency was to add wheat flour. Rye breads made of whole rye flour were also known in all countries before the war, but the amount was small.

Since the war, the commonest rye bread remains a rye bread from flour of 82–84 per cent extraction, but more and more appears the tendency to use lighter flours and to add wheat flour. Considerable city bread is made of 70 per cent flour. On the other hand, the modern movement for so-called health breads has found expression, more or less all over Europe, in the manufacture of whole rye breads of various types.[2] Some of these are made literally of whole rye, i.e., uncleaned rye; others are made from flours ground from cleaned rye, representing about a 94 per cent extraction. Others are made from finely ground straight flour, or even clear flour, to which bran has been added. Some of these breads are not made from flour at all, but from crushed or cut rye or from grits and groats.

The mixed breads of Europe are important, both nutritionally and economically. Mixed bread has in Europe a totally different meaning than in the United States. Rye may be mixed upward or downward, so to speak. Mixed upward, wheat is used as a strengthener; the product is improved and the price is increased. Mixed downward, barley, oats, corn, and potatoes are used as stretching materials; the product is degraded and the price is lowered. Sometimes bean meal (usually soya) is added to enrich in protein. The mixed rye breads are in the broad sense adaptations between crops on the basis of relative prices.

The mixed wheat-rye breads of Europe are consistently richer in rye than those in the United States. They are made more

[1] This follows from common observation in Europe, but incomplete statistical evidence lends support.

[2] E.g., the "health" rye breads of Steinmetz, Simon, Gelinck, Avedyk, and others.

after the fashion of wheat bread, but they remain rye bread. The hotels serve fairly light rye bread; but for the most part, if a European can afford a better bread than standard rye bread of the region, he is apt to go to wheat bread and not stop off at the half-way station of wheat-rye bread. The motives that induce Americans to affect rye bread, made mostly of wheat, do not exist in Europe. Nevertheless, the use of mixed breads is steadily increasing, and commercial bakers favor mixed breads rather than straight rye bread. One form of mixed bread in Germany is made of left-over wheat bread dough mixed with rye flour.

Notably important are the mixed breads made by degrading rye (sometimes with wheat flour included) with corn, oats, barley, and potatoes. Some of the oldest of these mixed breads are made of grits or groats of rye, oats, and barley combined. Others contain corn. Pumpernickel is the best-known illustration of this type of bread, though in modern times pumpernickel is made out of flours, as well as out of grits and groats. The potato is not usually used in groat bread. Pumpernickel may be either straight rye or a mixed bread, baked or steamed.

Biscuits of rye have long been made in Europe, of straight rye or of mixed flours or groats. The Swedish flatbread is a familiar illustration. These biscuits, properly stored, will keep for months.

Whenever wheat flour is mixed with rye flour to make rye bread, various wheat flours may be used. Whole wheat flour is rarely used except in a few traditional breads. As a rule, clear wheat flour is used in making the cheaper rye bread. Indeed, this is the common method of dumping clear wheat flour, and imported clears are widely used for this purpose. Straight wheat flours are also employed, usually with rye flours of shorter extraction. Some of the lightest rye breads are made of rye and wheat patents.

Usually the flours are blended after being milled, but there is sometimes a sowing of mixed grains, which are then milled together. This, however, is dying out, through the opposition of the mills, since wheat and rye require different tempering and a different arrangement of the breaks in milling. The blending of rye and wheat flours, to make the accustomed loaf at the lowest cost, is a highly developed art in European countries.

Not only is wheat mixed with rye to improve rye bread, and oats, barley, and corn mixed with rye to cheapen rye bread, but potato also is widely used as a stretching material. The use of potato in bread, both rye and wheat, is very old in Europe. It was not originally, and is not necessarily, a stretching material. Potato starch is an excellent pastry material and finds its way into the most delicate confections in European pastry shops. When discreetly used in rye bread, potato improves the quality, particularly if the bread is made with sour dough. The loaf is somewhat lighter, of a finer texture and less soggy, and no flavor is added. Such use of potato ought not to exceed 5, or at most 10 per cent, in terms of dry weight of potato to dry weight of rye flour. Originally the potatoes were cooked and mashed for the occasion, since the use of raw potato pulp proved disadvantageous in several ways. Latterly potato flakes, made from cooked potatoes, have come into general use. Dried raw potato works better than fresh potato pulp, but it is easier to dry cooked flakes than raw potato flakes.

In hard times, or when rye is scarce and potatoes plentiful, larger amounts of potato are used to make mixed potato-rye bread. Under extreme circumstances, the pulp of fodder roots has also been employed. During the war a great deal of rye bread was made in central Europe containing a third and even a half weight of potatoes. Such breads were not good; they were very moist and soggy, highly acid, prone to decompose, and low in protein. War experience with bad potato-rye bread has been followed by revulsion against use of potato in bread. At present, when potatoes have to be used to stretch rye, most Europeans prefer to use them separately and not to mix them into a poor bread.

Rye-wheat breads are usually made with yeast instead of sour dough. It is difficult to make a conventional straight or whole rye bread with yeast. Sour dough seems necessary, but yeast works satisfactorily with mixed flour. With sour dough, long fermentation is the rule. The modern bakeries naturally prefer yeast to sour dough, and this leads them to add enough wheat flour to a rye dough to make the fer-

mentation readily workable with yeast. This procedure of the bakeries, therefore, works in favor of mixed wheat-rye bread, as against straight rye bread. With the use of yeast and mixed flour, a rapid fermentation is sought, but at the expense of acidity and highly developed rye taste. The net result is that in Europe at present city bread tends more and more to contain some wheat and to be fermented with yeast, while country bread tends to remain straight rye and is fermented with sour dough.

Rye bread in Europe is usually made with the straight dough method. The sponge method, however, is coming into favor in large bakeries, especially with mixed breads. Rye loaves are usually baked on stones or on the hearth of the oven, rarely in tins. Baking is usually with dry heat, not with steam in the oven, as is common practice in this country. Most European bakers, especially in the country, try to give their loaves a very hard crust, so that the bread will keep for weeks or even months. The common rye loaf of Europe is the two-kilo or quartern loaf, but one sees loaves up to ten pounds weight.

In judging the rye breads in Europe, Americans must not employ American bread standards. For both wheat and rye, the average bread of the United States is much lighter than in Europe. The common wheat bread of Europe is made of flour of a longer extraction than the average used in the United States, a long fermentation is customarily employed, neither milk, shortening, nor sugar is routinely used, and the bread is heavier. European rye breads are therefore not so far below European wheat breads, so far as the mass of people is concerned, as might be imagined by Americans judging European rye bread by American wheat bread. Breads in Europe, both wheat and rye, are staples in the diet, not vehicles for spreading, as in the United States, and are to be judged accordingly.

IV. PRICE RELATIONSHIPS OF RYE AND WHEAT

The prices of the several cereal grains, relative to each other, are based, on the side of demand, on caloric values and special qualities; and, on the side of supply, on the varying amounts available in the crops. Over short periods, variations in supply are the most influential factors in the determination of relative prices. Over long periods of time, costs of production and consumers' criteria would seem to be the effective factors in modifying relative prices. Demand for cereals for foodstuffs is based more on special characteristics than on energy values, but is influenced by special circumstances on the side of supply or by untoward developments in the channels of trade. Demand for cereals for feeding stuffs ought to be based largely on energy value, modified to some extent by special characteristics. But expert knowledge on feeding values is not the common property of animal husbandmen. Indeed, experience would seem to indicate that farm practice lags behind expert knowledge and may even oppose it.

The several cereal grains are roughly comparable in their uses. As carriers of calories, as sources of energy for human beings and domesticated animals, they are substitutive within a range. They are substitutive in the manufacture of alcohol. Their prices therefore should be relatively comparable, somewhat in the same sense that the prices of different industrial fuels are comparable. The grains are least comparable in their food relations; they are much more comparable in their feed relations. That a relationship tends to exist between the prices of the several grains is axiomatic on the grain exchanges. In street parlance, the grains pull each other up or drag each other down.[1] Fixed differentials between the prices of the different grains might be expected to be more closely approximated in western Europe than in the United States, since foodstuffs and feedstuffs are computed more closely than in this country.

The subject of the price relations of the several grains on the calorie basis contains three separate, though overlapping, questions: the relations of the bread grains to each other, of the coarse grains to each other, and of the bread grains to the coarse grains. Despite the fact that the coarse

[1] No comprehensive study of these price relations, conducted with competent mathematical methods, seems to exist.

grains influence the bread grains, we shall here consider only the relations of the bread grains to each other, since the larger question lies outside the scope of this study.

The price relations of the bread grains in the United States would be one thing if the country were on a strictly domestic basis and something different with the country on the export basis. Before the war we were practically a non-exporter of rye but a heavy exporter of wheat. The foreign influence on domestic prices was therefore large for wheat and insignificant for rye, and of course varied from year to year. Since the war, we have been a heavy exporter of both grains, with corresponding effect upon prices. For rye, particularly, the difference is of importance. Before the war, the rye price was determined largely by domestic influences; since the war, with heavy exports of rye,[1] foreign influences have been of much greater importance.

During the past eighteen years, the price of 60 pounds of No. 2 rye at Chicago has equaled the price of No. 1 Northern Spring wheat at Minneapolis in only one year, 1917–18.[2] The price of 60 pounds of No. 2 rye at Chicago has equaled the price of 60 pounds of No. 2 Hard Winter wheat at Kansas City twice, in 1911–12 and in 1914–15. The price of 60 pounds of No. 2 rye at Chicago has three times equaled or exceeded the price of 60 pounds of No. 2 Red Winter wheat at Chicago, in 1911–12, in 1914–15, and in 1917–18. Over the eighteen years the price of 60 pounds of No. 2 rye at Chicago was 81.1 per cent of the price of 60 pounds of No. 1 Northern Spring at Minneapolis, 85.1 per cent of the price of No. 2 Hard Winter at Kansas City, and 83.9 per cent of the price of No. 2 Red Winter wheat at Chicago. The relations in individual years are of course much wider, but judged by individual years as well as by the average, pound for pound, rye inclines to be worth something between three-fourths and five-sixths of the price of wheat.

For purposes of comparing the relative prices of rye and wheat, it is desirable to employ some common denominator, as the experienced grain trader unconsciously does in a rough way. Rye weighs less per bushel than wheat; and a pound of rye contains fewer calories than a pound of wheat. On the caloric basis, a bushel of wheat is equivalent to 1.06 bushels of rye. We have therefore recomputed terminal prices per bushel, so as to show terminal cash prices for one million calories of No. 2 rye at Chicago, compared with similar prices of No. 1 Northern Spring wheat at Minneapolis, No. 2 Hard Winter wheat at Kansas City, and No. 2 Red Winter wheat at Chicago.[3] Table 4 shows these prices for five pre-war and six post-war crop years.

Between 1914 and 1917 the practices of European grain buyers in the United States subjected prices to abnormal influences. Following the entrance of the United States into the war, allocations of wheat were made to mills. There were no allocations of rye corresponding to those of wheat, but European buyers of rye and rye flour could secure it only through governmental channels. Rye flour was for a time a compulsory purchase with wheat flour. After the close of the war, the Grain Corporation operated until May 1920, but wheat was not allocated to mills and rye was free. Because of these abnormal influences on both wheat and rye prices, we have omitted price data from July 1, 1914, to July 1, 1921.[4]

To revert to the statement that, other things being equal, the relative prices of the different grains depend partly on their energy values and partly on their special qualities, what ought one specifically to expect with the bread grains? As between wheat and rye, the larger amount of gluten and its superior quality in wheat would place the price of wheat above that of rye. The margin between wheat and rye ought

[1] In relation to size of crop, the exports of rye have exceeded those of any other grain.

[2] See Appendix Table X.

[3] Our computation is based upon the assumption of a 56-pound bushel for rye and a 60-pound bushel for wheat, and upon caloric values as per analyses of rye and wheat, as given in W. A. Henry and F. B. Morrison, *Feeds and Feeding* (Madison, Wisconsin, 1917). One million calories corresponds to 9.91 bushels of wheat of 60 pounds; and to 10.53 bushels of rye of 56 pounds. The procedure is not strictly accurate because caloric values vary slightly from variety to variety and from year to year. But the computed prices per million calories may be regarded as more satisfactory than the crude price data. The crude data appear in Appendix Table X. This table also shows rye prices converted to a basis of 60-pound bushels, approximately the conversion roughly followed by experienced traders in comparing rye and wheat prices.

[4] The crude data appear, however, in Appendix Table X.

to be substantial, expressing public preference for wheat bread over rye bread, but width of margin would not be unvarying. The two bread grains ought to stand apart from the coarse grains and on a higher price level, i.e., the commercial value of the gluten should bring a premium. Rye occupies a position between wheat and the coarse grains. It contains a gluten-like protein and therefore is a bread grain strictly speaking; as such, it stands above the coarse grains for human consumption. But it is an inferior bread grain, and the per capita consumption is low.

Let us first consider the pre-war prices; it will suffice to confine our attention to the five crop years 1909–14.

TABLE 4.—TERMINAL PRICES OF ONE MILLION CALORIES OF HARD SPRING, HARD WINTER, AND RED WINTER WHEAT, AND RYE, WITH RELATION OF RYE TO WHEAT PRICES, PRE-WAR AND POST-WAR*

Crop year July–June	Wheat			Rye	Relation of rye price to prices of		
	No. 1 Northern Spring at Minneapolis *(dollars)*	No. 2 Hard Winter at Kansas City *(dollars)*	No. 2 Red Winter at Chicago *(dollars)*	No. 2 at Chicago *(dollars)*	No. 1 Northern Spring wheat *(per cent)*	No. 2 Hard Winter wheat *(per cent)*	No. 2 Red Winter wheat *(per cent)*
1909-10	10.80	10.60	10.90	8.00	74	75	73
1910-11	10.41	9.71	10.11	8.85	85	91	88
1911-12	10.60	9.61	8.92	9.58	90	100	107
1912-13	8.62	8.72	10.21	6.84	79	78	67
1913-14	8.72	8.32	8.72	6.74	77	81	77
Average	9.83	9.39	9.77	8.00	81	85	82
1921-22	14.17	11.80	12.39	10.21	72	86	82
1922-23	11.89	11.20	11.30	8.53	72	76	75
1923-24	11.59	10.41	10.11	7.37	64	71	73
1924-25	15.46	13.38	15.66	13.16	85	98	84
1925-26	15.96	16.15	16.25	10.11	63	63	62
1926-27	14.47	13.38	13.68	10.64	74	80	78
Average	13.92	12.74	13.23	10.00	72	79	76

* These prices are obtained by multiplying the cash sales prices (as given in the *Agriculture Yearbook, 1926*, pp. 819, 820, 834) by 9.91 in the case of wheat, 10.53 in the case of rye, the number of bushels represented by 1,000,000 calories.

PRE-WAR PRICES

In the five years before the war, the terminal price of a million calories of wheat varied from $8.32 to $10.90, the average for the three types of wheat ranging from $9.39 to $9.83. The terminal price of a million calories of rye varied from $6.74 to $9.58, the average being $8.00. The year of lowest wheat prices was 1913–14, also the year of the lowest prices of rye. The year of the second lowest prices of rye, 1912–13, was also a year of low wheat prices, in spite of the relatively high price of red winter wheat. The annual variations of both wheat and rye prices are to be explained mostly from the side of supply. The rye crop of 1913 (41.4 million bushels) was the largest of the period and the price the lowest; the rye crop of 1911 (33.1 million bushels) was the smallest of the period, and of poor quality, and the price the highest.[1] The wheat crop of 1913 was the largest crop of the period, leading to the lowest price of the period and also presumably of influence in lowering the price of rye. The wheat crop of 1911, like the rye crop, was the smallest of the five pre-war years. The short crop of rye was accompanied by a higher price for rye, but the short crop of wheat was not accompanied by a relatively high price of wheat. The low price for the wheat crop of 1911 was due to a low world price, the result of conditions outside of the United States, which did not directly affect rye because we were practically on the domestic basis for rye.

It may be found suggestive to convert these figures into index numbers, using wheat as equaling 100; the index numbers appear in the last three columns of Table 4

[1] Though the amounts were trifling, it is significant to note that during the crop year 1911–12, imports of rye exceeded exports.

With the average unit price for each type of wheat taken as 100, the average pre-war index for rye was 81 per cent of hard spring wheat, 85 per cent of hard winter wheat, and 82 per cent of red winter wheat.

Table 5 contains a recomputation of farm prices of wheat and rye to the basis of one million calories of each grain.

TABLE 5.—PRODUCERS' PRICES OF ONE MILLION CALORIES OF WHEAT AND RYE, AND RELATION OF RYE PRICES TO WHEAT PRICES, PRE-WAR AND POST-WAR*

Crop year July-June	Wheat *(dollars)*	Rye *(dollars)*	Relation of rye price to wheat price *(per cent)*
1909-10	9.98	7.86	79
1910-11	9.09	7.73	85
1911-12	8.75	8.53	97
1912-13	8.26	7.23	88
1913-14	7.86	6.62	84
Average	8.79	7.59	86
1921-22	10.35	9.15	88
1922-23	9.71	7.17	74
1923-24	9.16	6.25	68
1924-25	12.66	10.14	80
1925-26	14.46	8.75	61
1926-27	12.17	8.87	73
Average	11.42	8.39	74

* These prices are obtained by multiplying the producers' prices (as given in the *Agriculture Yearbook, 1926*, pp. 818, 833), by 9.91 in the case of wheat and 10.53 in the case of rye, the number of bushels represented by 1,000,000 calories.

Comparing the two tables, one observes a general concordance. The year of highest terminal wheat price, 1909–10, was the year of highest farm price, and the year of lowest terminal wheat price, 1913–14, was the year of lowest farm price. But there was considerable fluctuation in the different years in the margins between terminal prices and farm prices. For rye, the year of highest terminal price, 1911–12, was the year of highest farm price; and the year of lowest terminal price, 1913–14, was the year of lowest farm price. Also with rye, the margins between terminal prices and farm prices varied from year to year. For the period, the terminal rye price was 82.8 per cent of the average of the three terminal wheat prices; the producers' price of rye was 86.3 per cent of the producers' price of all wheat.

For the purpose of the present study it suffices to note that the price of rye, judged by energy values, in averages of the five pre-war years, was somewhere between 81 and 86 per cent of the price of wheat, with rather wide variations in individual years. Even allowing for the fact that we were then heavy exporters of wheat, but not of rye, this difference expressed the superiority of wheat over rye (in gluten, color, odor, and taste) as a bread grain in the estimation of the American public; but the price differences were not the effect of consumers' preferences solely, since other factors certainly existed.

It would be interesting to compare representative European price indexes with the American, but it is difficult to secure comparable figures. The prices to be compared ought to be representative for representative products in representative countries. Prices in terminal markets in importing countries must be cautiously compared with those in exporting countries. The collection of price data here and abroad have not been done with identical methods. The grading of products has been different. The best method would be to use the prices of domestic products in the importing European country. In any event, such a comparison must remain somewhat arbitrary; but the results ought still to be suggestive.

A tentative computation[1] carried out with the prices of domestic wheat and rye on the Berlin market during the five years before the war has indicated that on the calorie basis rye was priced 79 to wheat 100. The rye on the Berlin market was probably above the average for the country, since the poorer rye was ground in smaller rural mills; the wheat, on the other hand, was probably no better than the average of the country.[2] If this inference be correct, the

[1] Data from M. Sering, *International Price Movements and the Condition of Agriculture in Non-Tropical Countries* (Berlin, 1927). The prices of the grains were in Berlin, in marks per thousand kilograms, for the calendar years 1909–13, requiring no correction for value of exchange since during this period the German mark fluctuated very little.

[2] Comparisons of rye and wheat prices in seven other German cities show that during the pre-war period rye prices were in no instance more than 81.9 per cent of wheat prices; the average relation for these cities was 80 per cent.

price of rye should have been high relative to wheat, rather than low. Possibly the explanation is to be found in the tariff. The tariff duty was the same for wheat and rye; but since Germany was a heavy net importer of wheat but a net exporter of rye, it seems reasonable to infer that the tariff was effective for wheat and not effective for rye, which would tend to make rye priced low relative to wheat. It may appear rather odd to find rye in Germany standing lower than rye in the United States in relation to wheat, since rye was a favorite bread grain in Germany. The explanation may possibly be found in the relative marginal costs of production.

Post-War Prices

From 1921 to date the prices of the several cereal grains have been rather topsy-turvy. This has been exaggerated by the fact that all five grains have been on the export basis more or less continuously, and the annual volumes of exports have in most years been heavier than during the years just preceding the war. The price of wheat was highest for the crop year 1925–26, next highest in 1924–25. The price of rye was highest for the crop year 1924–25, but only fourth highest in 1925–26.

The high price of wheat in 1924–25 was due to international rather than to domestic circumstances; but domestic influences were largely responsible for the high prices of 1925–26. In that year the United States was practically on a domestic basis for wheat but not for rye; the tariff on wheat was largely effective. The crop of 1923, the second shortest crop since the war, gave a low price. The largest crop of rye in our history, that of 1922, sold for a price considerably higher than that of the crop of 1923, which was only two-thirds as large. The crop of 1924, which sold for the highest prices since the war, was the second largest crop of the period; the crop of 1925, which was a small crop, sold for considerably less. While it is not possible to distribute the influences, it is reasonable to infer that the rather unusual behavior of the domestic rye price over the period was influenced not only by domestic supplies of rye, but also by domestic and world supplies of wheat. One gets the impression that, on account of the heavy volume of export of rye in proportion to the crop, the foreign price of rye has more influence than the domestic prices of wheat and coarse grains.

Of the record rye crop, 103 million bushels in 1922, over 52 million bushels were exported. The rye crops of 1923 and 1924 were 63 and 65 million bushels respectively. Of the 63 million bushel crop in 1923, 20 million bushels were exported; against the 65 million bushel crop in 1924, stood an export during the crop year of no less than 50 million bushels.[1] The large export during 1924–25 was at the highest price of the period, the small export during 1923–24 was at the lowest price of the period.

Turning now to the price indexes, one observes that the indexes of rye, relative to wheat, have tended to be lower since the war than before the war. The average relation of the price of rye to the price of hard spring wheat before the war was 81 per cent, the highest was 90, and the lowest was 74; the average relation since the war was 72 per cent, the highest 85, and the lowest 63. The average relation of the rye price to the price of hard winter wheat before the war was 85, the highest 100, and the lowest 75; the average relation since the war was 79, the highest 98, and the lowest 63. The average relation of the price of rye to the price of soft red winter wheat before the war was 82, the highest 107, and the lowest 67; the average relation since the war was 76, the highest 84, and the lowest 62. The average for the five years before the war was made rather high for rye by the exceptional year 1911–12; also, the average for the period since the war has been made somewhat low for rye by exceptional wheat prices during 1925–26. On the entire record, rye since the war has been worth less, relative to wheat, than before the war. Over most of the period since the war the trading forces have pulled together for wheat and rye, though occasionally they have pulled apart, usually to the advantage of wheat but sometimes to the advantage of rye, if one were to judge directly.

Despite the unsatisfactory nature of price quotations in Germany since the war, we have attempted a comparison of prices of

[1] Obviously, some of the rye exported had been carried over from the previous crop.

wheat and rye, using Berlin quotations. The lowest position of rye was in 1923–24, when the price of rye was 77 per cent of the price of wheat. The highest position was in 1924–25, when the price of rye was 87 per cent of the price of wheat. The average for the six years was 84 per cent. If the post-war comparisons are comparable with the pre-war comparisons, rye has been relatively higher since the war than before. In the United States, the average price of rye was some 83 per cent of the average price of wheat before the war and 74 per cent since the war. In Germany, the average price of rye was 79 per cent of the price of wheat before the war and 84 per cent since the war. While rye has depreciated in the United States, it has appreciated in Germany, relative to wheat. We have no entirely satisfactory explanation of the trend in the German figures. It may be mentioned, however, that Germany before the war was a net importer of wheat but not rye, while since the war she has been a net importer of both commodities, with tariff protection in both periods. Furthermore, the situation may have been influenced by the fact that, while production both of wheat and rye has declined in western Europe, the lesser decline in wheat has apparently been more than offset by increases in wheat production elsewhere in the world, whereas the greater decline in rye perhaps has not, or at least not so completely. In any event, it is obvious that the closer the price of rye approaches the price of wheat in Germany, the more incentive to import wheat rather than rye.

The Prices of Wheat and Rye Flour

It is easy to make arbitrary comparisons of wheat and rye flour prices; it is less easy to make interpretations. In so far as there may be a relationship between the mill-door prices of wheat and rye, if the returns on millfeed, the expenses of operations, the overhead, and the costs of selling were identical or comparable, the wholesale prices of wheat and rye flours ought to stand a certain distance apart, but show the same trends. But the stipulations do not hold. Purchase of rye and sale of rye flour are not so routinely protected by hedging as those of wheat. The miller of rye is not confronted with premiums for protein as is the miller of wheat. Since rye is ground in smaller mills than wheat, the relations to capacity output are different. Rye flour is little advertised and the cost of selling is less. The fraction of flour secured from the unit of rye is lower than from the unit of wheat; therefore, the price of millfeed is more important. These several circumstances impair the usefulness of direct price comparisons.

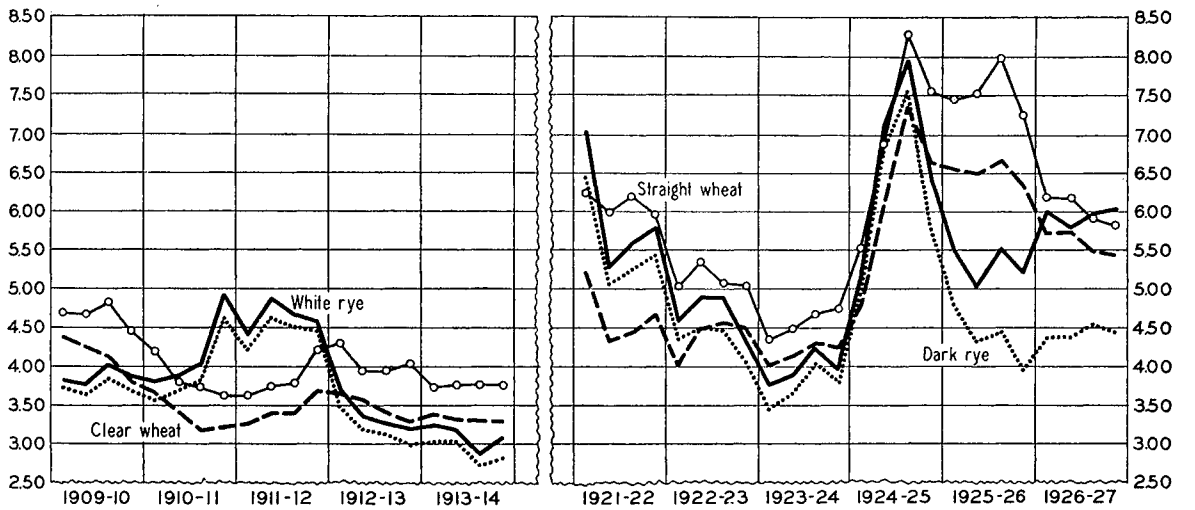
There is little purpose in comparing rye and wheat flours according to names, for example, patent wheat flour with patent rye flour, since the flours have different uses and are not interchangeable. The wheat flours whose prices ought to be compared with those of rye are the flours that are, to some extent at least, interchangeable with rye flour, with which the rye flours are substitutive, with which they are commonly mixed. The proportions of wheat and rye flours in a so-called rye blend depend upon the prices and the qualities in a particular season. In the rye blends one finds mostly clear and straight wheat flour, but little patent, even of the cheapest. For the most part, the question of price is in the mind of the baker, not of the bread buyer. Therefore, the most useful price comparisons would apply to the wheat and rye flours that compete, are mixed together, are substitutive in making rye bread.

In this country rye flour is not used to stretch or dilute wheat flour; rather, wheat flour is used to strengthen and improve rye flour. A comparison of prices of wheat and rye flours must be based upon this consideration. There may be circumstances under which a rye blend would be prepared with the cheapest wheat flour and the cheapest rye flour; possibly also occasions when a high-priced patent wheat flour would be used with the highest-priced rye flour. But a blend of high-grade rye flour with a lower-grade wheat flour will usually give a better blend for the American public than one of higher-grade wheat flour with low-grade rye flour. Under these circumstances, the baker of rye bread, in choosing a wheat flour for his rye blend, would naturally choose the cheapest wheat flour. He would compare it with the dearest rye flour. The highest-priced rye flours are the most representative rye flours. These we compare not with the highest-priced wheat flours, with

which rye flours do not come into contact, but with the low-priced wheat flours with which rye does come into contact. The price series that follow, therefore, contain the top prices for white rye and dark rye respectively and the bottom prices for the straight and first clear wheat flours. The four Chicago flour prices compared over the intervals under consideration are (1) the cheapest straight wheat flour (hard spring, hard winter, or red winter); (2) the cheapest first clear wheat flour (hard spring, hard winter, or red winter); (3) the dearest white rye flour (a short patent); and (4) the dearest dark rye flour (a straight or a long patent). Chart 2, based upon quarterly averages of weekly quotations, shows these comparisons.

CHART 2.—QUARTERLY PRICES OF RYE FLOUR AND WHEAT FLOUR AT CHICAGO, 1909–14 AND 1921–27*

(Dollars per barrel)



* For data see Appendix Table XII.

The price of white rye flour, a patent, is of course always higher than the price of dark rye, a straight flour; but the margin varies from year to year and even from month to month, and tends to be wider when the price level is high. Straight wheat flour is a higher-priced product than first clear wheat flour; but the margin varies from year to year and even from month to month. What seems to be the most frequent relationship between rye flour and wheat flour is for white rye flour to be priced in the neighborhood of first clear wheat flour. At times, white rye flour may be definitely cheaper than the first clear wheat flour; on the other hand, white rye flour is often priced above first clear wheat flour. Beyond that, white rye flour may be priced with straight wheat flour, rather than with clear wheat flour, sometimes even above it. Finally, under exceptional circumstances, white rye flour may be priced with high-grade patent wheat flours.

Whatever the price relation of white rye flour to wheat flours, dark rye flour lags a varying distance behind white rye flour, depending somewhat on the rate of extraction. Also, rye millfeed is priced lower than wheat millfeed, on account of lower protein and higher fiber content.

During the crop year 1909–10, white rye flour was quoted almost consistently below the price of the cheapest first clear wheat flour, and did not approach the level of the cheapest straight wheat flour. Occasionally, the difference was nearly a dollar a barrel; in many weeks it was 50 cents; sometimes it was only 10 cents; but in several weeks, toward the close of the crop year, the top price of white rye flour exceeded the price of the cheapest first clear wheat flour. At the closest, the price of white rye flour stood 35 cents below the price of the cheapest straight wheat flour.

During the crop year 1910–11, the prices of rye flours tended to be relatively higher. For the most part, the top price of white rye flour was definitely above the price of

the cheapest first clear wheat flour; indeed, the top price of dark rye flour was usually above the price of the cheapest first clear wheat flour. During over half of the year, the top price of white rye flour exceeded the price of the cheapest straight wheat flour; toward the close of the year, the top price of dark rye flour also exceeded the price of the cheapest straight wheat flour. Finally, toward the close of the crop year, the top prices of both white and dark rye flours stood considerably above the price of the cheapest patent wheat flour.

During the crop year 1911–12, the prices of rye flours were consistently high, relative to wheat flours. Dark rye flour stood above first clear wheat flour, usually above straight wheat flour, and often above the cheapest standard patent wheat flour. White rye flour stood almost consistently above the cheapest standard patent wheat flour.

During the crop year 1912–13, the price relations reverted to the earlier position. The top price of white rye flour stood near the price of the cheapest first clear wheat flour a little above or below, with dark rye lagging behind. Not once during the year did the top price of white rye flour approach that of the cheapest straight wheat flour, and the difference was frequently almost a dollar a barrel.

During the crop year 1913–14, the same relations were again in effect. The top price of white rye flour stood a little below that of the cheapest first clear wheat flour, with dark rye lagging behind. The price of the cheapest straight wheat flour ranged from 35 cents to 95 cents per barrel over that of white rye flour.

Over the five-year period the average prices for the four flours ranged as follows:

Straight wheat flour	$4.02
White rye flour	3.82
Dark rye flour	3.62
First clear wheat flour	3.55

If one regards the prices during 1910–12 as unusual, averages for the other three years, regarded as the more usual, would be as follows:

Straight wheat flour	$4.15
First clear wheat flour	3.64
White rye flour	3.44
Dark rye flour	3.25

If the step-like relationship between the prices of straight wheat, first clear wheat, white rye, and dark rye flours is to be regarded as the more usual, what explanation is to be offered for the crop years 1910–12, when the prices of rye flour stood relatively much higher? The explanation lies directly at hand. The wheat crops of 1910 and 1911 were rather small, but were normal for the country on the export basis. The rye crops of 1910 and 1911 were somewhat short. Also, the quality of the rye was below normal in these two years. The prices of the wheat and rye flours reflected the prices of wheat and rye. The average cash Chicago price for No. 2 rye for the 1911 crop, 91 cents, was by far the highest of the five-year period; the price of the 1910 crop was 84 cents; but the prices during the other three years were 76, 65, and 64 cents. It was not that wheat prices were down out of line, but that rye prices were up out of line, and substantially so. A somewhat short crop of rye, of unsatisfactory quality, a short crop of corn, relatively more rye fed on farms and less sent to market, low primary receipts, small visible supplies, with millers seeking 12 million bushels and distillers seeking 5 million bushels — naturally the price of rye rose in 1911–12 relative to that of wheat.

The figures illustrate again the familiar experience that shortage of a naturally low-price crop may drive its price above that of a naturally high-price crop. Considering the aversion of Americans to dark rye bread, it is surprising enough to witness dark rye flour selling for more not only than straight and first clear wheat flour, but also than standard patent flour made of soft red winter wheat. It is little less than astonishing to learn that dark rye flour has occasionally been quoted in Chicago up to standard patent flour made of hard wheat. All of which merely proves that despite the general low esteem in which rye bread is held, with those who prefer it, the demand must be relatively inelastic.

During 1921–22 the top price of white rye flour was always above that of first clear wheat flour and often far above it. The top price of dark rye flour was always above the price of the cheapest first clear wheat flour, sometimes over a dollar above it. The top price of white rye flour was above the

price of the cheapest straight wheat flour early in the season, and was a few times as high as that of standard patent wheat flour. The top price of dark rye flour was sometimes above that of straight wheat flour.

During 1922–23 the top price of white rye flour was usually above the price of the cheapest first clear wheat flour, also sometimes equaling and even exceeding the price of the cheapest straight wheat flour. The top price of dark rye flour was often as high as that of first clear wheat flour, but never as high as that of straight wheat flour.

During 1923–26 there were three successive years of closely corresponding price relations. The top price of white rye flour was near that of first clear wheat flour, usually a little below it, sometimes below it by more than a dollar a barrel, but quite often above it. The top price of white rye flour equaled the price of the cheapest straight wheat flour in only a few weeks during the three years, was usually definitely below it, and sometimes stood by more than $2.00 below it. The top price of dark rye flour was only occasionally as high as the price of the cheapest clear wheat flour, rarely above it except in 1924–25, and was often below it by more than $2.00 a barrel.

During 1926–27, the price of white rye flour exhibited a somewhat unusual behavior. In the first week of the season the order of prices was in the usual sequence—straight wheat flour, clear wheat flour, white rye flour, and dark rye flour. Then the price of white rye flour rose relative to the others, and throughout the year, with the exception of a few weeks, the top price stood above the price of the cheapest first clear wheat flour, and indeed in several weeks in the last half of the year stood above the price of straight wheat flour, once by as much as 60 cents a barrel. The price of dark rye flour, however, did not advance in the same way and remained low. On the average, over the season, the top price of white rye flour was but little behind that of straight wheat flour, considerably above that of first clear wheat flour, and around $1.50 a barrel above that of dark rye flour.

What ought to be regarded as the usual relationship between the prices of straight wheat, first clear wheat, white rye, and dark rye flours is as much a question of judgment as of statistics. Certainly, a classification should not rest merely upon a bare average covering a number of years. It is necessary to contrast years within the period. We have surveyed the prices for five years before the war and six years since the war. On the basis of the averages for the several years, the positions may be summarized as follows:

	Highest price	Second price	Third price	Lowest price
Wheat, straight..	9	0	2	0
Wheat, clear....	0	5	2	4
Rye, white	2	4	5	0
Rye, dark.....	0	2	2	7

In considering just what is to be regarded as usual, several considerations must be held in mind: first, the prices used for straight and clear wheat flours were always the lowest of the three (hard spring, hard winter, and red winter) while the top prices were used for the rye flours; secondly, several times the price of rye has been high enough relative to wheat to make the calorie price for rye flour equal to or above that of wheat flour, which may reasonably be regarded as abnormal, in view of the gluten superiority of wheat flour. Also, Chicago is the market in which rye flour reaches its relatively highest price, since it is in the midst of the heavy rye-consuming region. With these qualifications in mind, it seems reasonable to regard the following order of prices as usual:

Straight wheat flour
First clear wheat flour
Patent rye flour
Straight rye flour

An exchange of positions between clear wheat flour and patent rye flour occurs so frequently that one cannot term it abnormal, since clear wheat flour was second or better five times while white rye flour was second or better six times. From present indications, the price of white rye flour will be above that of clear wheat flour during the crop year 1927–28.

Using the prices over the eleven years (five pre-war and six post-war), with the average price of straight wheat flour taken as 100, the average price of first clear wheat flour was 87.2, that of white rye flour 91.2, and that of dark rye flour 82.7. On this rating, white rye flour would rank ahead of first clear wheat flour. Rating the two by weeks of leadership, it would appear that

during the eleven years the price of first clear wheat flour stood above that of white rye flour in 44 per cent of the weeks. While we are inclined to regard it as the more usual relation to have first clear wheat flour stand above white rye flour, the point is not important enough to warrant involved discussion. It is enough to have it made clear that patent rye flour and first clear wheat flour have roughly the same price relations and are the usual components of blended flour in the United States.

Judged on the calorie basis, the price of white rye flour usually approximates that of first clear wheat flour. But if one were purchasing these flours on protein analysis, as concentrates are purchased for feeding, the rye flour would be substantially overpriced. White rye flour has the lowest protein content of any rye flour; first clear wheat flour has a high protein content for wheat flour, more than patent or straight. Not only does the first clear wheat flour contain substantially more protein than white rye flour, but this protein stands higher in gluten behavior than the protein of the rye flour. While white rye flour cannot be regarded as overpriced on the basis of calories, the price cannot be explained by the protein content. The only attribute of rye flour to which this price can be attributed lies in the flavor.

Further Comparisons of Flour Prices

It may be of some interest to contrast the prices of wheat and rye flours that are comparable from the milling standpoint. Pertinent figures for pre-war and post-war years are as follows:[1]

Year July–June	Wheat patent flour *(dollars)*	Rye patent flour *(dollars)*	Relation of rye to wheat *(per cent)*
1909-10	5.15	3.86	75
1910-11	4.42	4.15	94
1911-12	4.49	4.63	103
1912-13	4.44	3.37	76
1913-14	4.26	3.09	73
1921-22	6.74	5.94	88
1922-23	6.15	4.67	76
1923-24	5.51	3.96	72
1924-25	8.03	6.67	83
1925-26	8.56	5.32	62
1926-27	7.01	5.94	85

The patent wheat flours selected for price comparison with patent rye flours corresponded to first patent. These patent flours before the war were not strictly comparable with those after the war; also, the patent rye flours are not strictly comparable. The rye price was the highest quotation for "rye flour, white, jute." "First patent, Kansas, jute" and "spring wheat patent, jute" represented the hard wheats; "patent, southern, jute" represented soft winter wheat.

For the period since the war, the quotation for rye is for "rye flour, white." "Spring first patent" and "hard winter short patent" represented the hard wheats and "soft winter short patent" represented soft winter wheat. In both periods, the highest quotation of patent rye is contrasted with the highest quotation of the cheapest first patent wheat flour on the Chicago market.

In looking over the flour prices from week to week and the averages from quarter to quarter, one observes rather notable fluctuations, whereby the margin between wheat and rye patent flours is widened or narrowed. Usually patent spring wheat flour stands above the others in Chicago; the lowest-priced variety is either hard or soft winter wheat.

In three of the five pre-war years the average price of patent rye flour stood close to three-fourths of the average price of patent wheat flour. During 1911–12 the average top price of patent rye flour stood above the average top price of patent wheat flour of the cheapest variety of wheat.

When the prices for the year 1911–12 are scrutinized in more detail, one obtains the following relation. The highest price of the year was spring patent, with an average price of $5.05, of which the rye flour price of $4.63 was 92 per cent. The average price of first patent hard winter wheat flour was $4.99, of which the rye flour price of $4.63 was 93 per cent. The average price of patent soft red winter wheat flour was $4.51 of which the rye price of $4.63 was 103 per cent. The price of patent rye flour was high relative to the prices of patent flours of all varieties of wheat, but particularly high compared with soft winter patent flour, because soft red winter wheat during this season stood relatively low compared with the hard wheats.

[1] Chicago quotations, compiled from the *Northwestern Miller*.

Since the war, the relations between the prices of patent rye and wheat flours have fluctuated much after the same fashion as before the war; but the comparisons are more trustworthy since the war because the flour grades have been more uniform. The highest position occupied by rye since the war was during the year 1921–22, when the price of rye flour was 88 per cent of the price of wheat flour. The lowest position was during 1925–26, when the top price of patent rye flour was only 62 per cent of the top price of first patent wheat flour of the cheapest variety. This was the crop year of short wheat crop and poor quality, when the country was on a domestic basis (practically speaking) and millers had to search about for wheats with which to mill flours up to their accustomed standards. The rye crop was normal and mills had no difficulty in finding rye to grind to patent rye flour up to their accustomed standards. Of course, no one can say what the price of rye flour would have been if the wheat crop had been normal, but it seems clear that the high price of patent wheat flour exerted little influence in drawing up the price of patent rye flour, this confirming the general experience that rye flour is not used as a substitute for wheat flour in bakery or kitchen in this country.

Averages over short periods mean little, but for whatever meaning they have it may be observed that the average price relationship, during the five pre-war years, of the top patent rye flour to the top first patent wheat flour of the cheapest wheat variety was 84 per cent, a figure somewhat too high to represent customary relations on account of the year 1911–12. The average price relationship during the past six crop years of the top patent rye flour to the top first patent wheat flour of the cheapest wheat variety was 77 per cent, a figure somewhat too low on account of the crop year 1925–26. The only significant inference to be drawn is that patent rye flour tends to stand at a somewhat heavier discount below patent wheat flour since the war. This may reasonably be attributed in part to improvement in first patent wheat flour, associated with shorter extraction.

It is tempting to contrast the margins between rye and the wheats with those between patent rye flour and the patent wheat flours. If we had comparable material over a long term of years, something positive might come out of such a comparison. But over a short period bias is introduced into such a comparison because of the influence of protein premiums on the prices of patent wheat flours. To secure wheat prices comparable with flour prices, one would need to know not the average prices of wheats by grades, but the average mill prices of wheats as actually purchased, representing in different years various increases over the grade prices to correspond to premiums on protein. Out of official figures there is no way of weighting the influence of premium on protein from year to year. Where premiums on protein are low, then the margin between rye and wheat flour prices ought to correspond roughly to the margin between rye and wheat, other things being equal. Where the premiums on protein are high, the margin between rye patent and wheat patent flour would necessarily be much wider.

Prices of Wheat and Rye Breads

Comparisons between prices of wheat and rye breads would be interesting and instructive, but they are impracticable. We have nowhere been able to find a series of trustworthy rye bread prices that could be compared with those of wheat bread. The Department of Labor reports prices of neither rye flour nor rye bread. Local figures are available since the war, but these would not serve the purpose desired. Rye bread is made of cheaper flour, contains few ingredients outside of flour, the processes of manufacture are simpler, the costs of delivery are lower, there is less stale bread loss, and the cost of selling is lower. Rye bread is not wrapped as a rule; it is advertised little; the separate expense of delivery is lower than for wheat bread. It seems natural to make the inference that rye bread is made and merchandised on a narrower margin than holds in the case of wheat bread. The accounts of bakeries making both kinds of bread would doubtless reveal interesting comparisons, but these are not available to us. For the most part, rye bread does not appeal to poorer classes on the basis of price. It does not hold to wheat bread a relation comparable

to that which shoulder holds to ham. For most people in all income classes, rye bread is different from wheat bread and appeals to its own clientele for reasons that lie largely outside of price under most conditions. Even under these circumstances, one has the right to infer not merely that rye bread is cheaper than wheat bread pound for pound, but that the margin between rye grain and rye bread is narrower than between wheat grain and wheat bread. How much narrower we are unable to show.

Before the war it was common custom in Europe to sell the pound of bread for the price of the pound of flour. This of course held only for the common types of bread, but applied to both wheat and rye. The baker, using only water, salt, and yeast in addition to flour, was supposed to have labor costs and profits covered by the increased outturn of bread in terms of pounds. Since the war, whenever public bodies undertake to control the retail price of bread in Europe, they incline to apply the pre-war rule with stipulation for standard price of flour. But the bakers who were able to conduct their business according to this rule before the war are apparently unable to do so since the war, labor costs having increased. The continued social importance of the retail price of bread in Europe is illustrated by the attention being given to the price of flour and bread, ten years after the close of the war, by the Food Council of Great Britain. Of all the hangovers of the war, controls of price of bread and of rent remain the longest and will be the most difficult of disposition.

V. PROSPECTS FOR USE AND PRODUCTION OF RYE

Substitutions for Rye and by Rye in Europe

The substitution of rye for and by wheat and the coarse grains and potatoes is important in Europe, but adequate statistical data are wanting. Certain general observations, however, may be ventured. Four sets of circumstances are involved: (1) customary crop relations in Europe; (2) the customary disposition of the crop; (3) relative prices of the several grains and potato; (4) state of business, income, and purchasing power.

With respect to the customary relations between the crops of cereals, conditions before the war in Europe were relatively immovable and are tending to become so again. For most European countries, favorable systems of crop rotation had been worked out and these rotations were not lightly disrupted either by large landlord or peasant. These rotations were in large part the expression of limiting factors in disposition. Fluctuations in domestic supplies were largely the result of variations in yields, not in acreages. A higher or lower price for a particular cereal had little effect upon the acreage of the following year. In short, for the most part, adaptation on the side of supply was hardly practicable in Europe, so far as the supply represented domestic production.

Fluctuations in the prices of substitutive products, if not notable in causing variations of domestic supplies, were significant with respect to utilization. As a continent, Europe endeavored to judge cereals and potatoes on the basis of price per calorie. This was particularly true of the coarse grains. Rye stood in between, with wheat above, the coarse grains below. From the most select use of wheat to the lowest use of potato, was a series of overlapping uses.

Just as crop rotations were highly developed and fairly fixed in most countries, so the dispositions between human beings, animals, and industries were well established in each country, partly on the basis of price directly, but partly on the basis of established animal husbandry. These relations were necessarily subjected to control during the late war, since the warring countries, under blockade, could not afford to use high-cost cereals for low-value purposes. Germany may be cited in illustration. According to the Eltzbacher Commission, the customary pre-war disposition of the domestic crops, after subtraction of seed, was about as follows, in percentages:

	Food use	Animals and industry
Wheat	90	10
Rye	75	25
Potato	30	70
Barley	15	85
Oats	5	95

The scope for adaptation is clearly revealed in the figures, which, with variations from year to year and from country to country, may be regarded as illustrative for the northern and central portions of Europe. As between use by animals and by industries, very little of the wheat went to industries; possibly a third of the 25 per cent of rye went to industries; a large part of the barley went to industries (depending on the prominence of brewing in the particular country); practically none of the oats went to industries; while industries used from a fourth to a half of the 70 per cent of potatoes.

Economic conditions in Europe presumably determine to some extent the effective demand for foodstuffs. With high employment, the per capita intake tends to be increased; with low employment, some reduction would be observed. The income of the urban working classes is so close to the level of minimum needs that retrenchment and expansion in subsistence occur with changes in income. The proportion of income expended for food in Europe is relatively high; but the amount in absolute terms of gold is relatively low, especially by comparison with the United States and Canada. With prosperity, the proportion of the income so expended is likely to be increased, and the absolute amount is certain to be increased. During hard times, the absolute outlay may be reduced, but the proportion of the family income expended for foodstuffs may be increased. The most important items in the cost of living of the urban working classes of Europe are bread and rent. Bread is the staff of life everywhere in Europe, even in England where the per capita consumption of animal products is high. Upon the bread staff everyone leans more or less, but most of all during hard times. Nevertheless, fluctuations in income presumably affect per capita consumption of cereals but slightly. Fluctuations in income probably affect not so much the absolute intake of cereals and potatoes as the relative amounts of each. It is impossible to prove these inferences, but they are well supported by observation.

Other things being equal, certain amounts of wheat, rye, barley, oats, corn, and potato are regarded as appropriate in the diets of different classes in different countries. With increase of income, with prosperity, the use of wheat tends to be expanded, replacing rye, in some classes; in others, the use of rye tends to be expanded, replacing coarse grains and potatoes. During hard times, the use of wheat tends to be curtailed in some classes, to be replaced by rye; in other classes, the use of rye tends to be curtailed, to be replaced by coarse grains and especially potatoes. The net result may be nil for rye, but a gain or loss for wheat and a gain or loss for potato. Or the net result may also be a gain or loss for rye. The adaptations and substitutions vary from country to country, in accordance with the crops of wheat, rye, coarse grains, and potatoes respectively. In human consumption, wheat tends to impinge on rye; in animal consumption, coarse grains and oil seed concentrates tend to impinge on rye. It is at present practically impossible to measure the extent of these substitutions, either in Europe as a whole or in particular countries. But the facts are a commonplace to the trade.

At no time during the past seven years has Europe imported all the wheat and rye available throughout the world. In every year there has been some short shifting in Europe, varying from country to country and from season to season. If the average supply of wheat, rye, and potatoes has been higher since the war (adjusted for population), that means little because animal husbandry has been upon a lower level. Year after year, back-and-forth substitutions and adaptations occur, and appreciation of these movements is of great importance to the trade in judging European requirements for imported wheat and rye in any season. Also, from this standpoint does the trade try to judge of the demand for rye in place of wheat or of wheat in place of rye.

Potatoes in Europe and the United States

It may not be out of place here to draw a contrast between the relations of the potato to bread grains in the United States and in Europe. Despite the preponderance of North European stock in our population, we lack the predilection of our forebears for potato. In Germany, rye, wheat, and potato form the bulk of the national ration,

contributing over 50 per cent of the total calories of the national dietary; in the United States, wheat, rye, and potatoes contribute less than 30 per cent of the calories of the national dietary. In northern Europe the potato is pre-eminently a calorie-carrying food; in the United States the potato is one of the fresh vegetables. The larger average gold income in the United States, the smaller proportion of the average income expended for foodstuffs, the trend toward diversification of the diet and latitude in the selection of the diet, all make for greater adaptability of food supply in the United States than in Europe. In Europe, north of the latitude of the Alps, the potato goes into three uses—foodstuffs, feeding stuffs, and industrial raw materials. In each direction it may act as substitute and may also be substituted on the basis of price. When potatoes are cheap, less wheat and rye are consumed; when potatoes are dear, more wheat and rye are consumed. Demand is elastic in both directions.

The relations of the potato are best known for Germany, though generally applicable to other countries in northern Europe. Potato crops in Germany vary from 25 to 45 million tons; in each decade they count on one crop failure (below 30 million tons) and on two bumper crops (over 40 million tons). The customary use for seed, food, and industries, including the usual waste, is around 20 million tons. If less than 10 million tons are available for feeding stuffs, substitutes must be procured. With large crops, the excess must be used for human food (largely replacing rye) or for animal feed (replacing rye and other grains that can be carried over), dried and carried over into the next crop year, or wasted. The problem of finding a use for too many potatoes comes oftener than the problem of finding substitutes when there are too few. As better-yielding varieties are developed, the problem of the potato surplus is accentuated in Germany.

In the United States the potato is raised almost entirely as human foodstuff. The feeding uses of potato are scarcely more than incidental to the salvage of an excessive crop. We have practically no distillation of potato, and little fabrication into starch or other industrial use. Under these circumstances, variations in yield have a heavier influence on price than is the case in Europe. People tend to consume a certain amount of potato in connection with other vegetables. When potatoes are cheap, consumption is not notably stimulated, and but few people eat more potatoes and less bread. When the crop is short and price is high, consumption is not seriously curtailed. For the small amount of potato the average American uses, consumption is maintained, with that of other vegetables, in about the same proportion. Indeed, one of the striking facts in potato consumption in this country is the insistence on continued use in the customary, though limited, place in the diet, despite high prices. There have been times when raw potatoes cost more per pound than flour, under which circumstances, considering the waste of potatoes, the price per calorie has been not far below ten times as much as the price per calorie in flour.[1] Such prices were procurable only because consumers insisted that potatoes, as a vegetable, be served with certain other foodstuffs, especially meat, quite irrespective of cost.

In summary, the potato in Europe occupies a broad position in the diet, supplementing bread grains; in the United States the potato occupies a narrow position in the diet, and is one of the fresh vegetables. In Europe, consumption expands with lower prices and contracts with higher prices; in the United States, consumption expands little with lower prices and contracts little with higher prices. In particular, the average American does not regard the potato as a substitute for wheat or rye.

Prospect for Rye

The prospect for rye in the near future in the United States would seem to depend on expansion of use as feeding stuff. There is little reason to expect the human per capita consumption of rye bread to increase

[1] It is astonishing enough, from the standpoint of calories, to observe that, according to the United States Department of Agriculture, in three of the past six years, the farm price of potatoes per pound has been higher than the farm prices of wheat and rye—with potatoes containing 80 per cent of water and the bread grains less than 15 per cent! Considered nutritionally, some of these prices touch absurdity. Thus, in 1925, the producers' price of rye was reported as 83 cents and of potatoes 186 cents, making potatoes practically ten times as expensive as rye at the farm door, in terms of nutrient value.

unless use of rye bread for sake of variety expands notably. On the contrary, with continuation of restriction on immigration and the acquisition of the wheat-bread habit by the second generation of immigrants, the per capita consumption of rye bread may decline. Notable expansion in the use of rye "health bread" is hardly to be expected.[1] There is no prospect for revival of use of rye in distillation, and no other industrial uses of moment are in sight.

As pointed out, the agricultural advantages of raising rye are several. It fits well into diversified agriculture, alike in the relations to soil, climate, farm labor, crop rotation, and fodder use. These advantages are, in one way or another, quite as prominent in southern and western states as in the states adjacent to the Great Lakes. The position of rye depends on the cash price of rye as an income crop or the product price of rye as a feeding stuff, in competition with the coarse grains. In terms of calories, oats are over-priced in comparison with rye. In connection with the declining numbers of work animals (to which oats are regarded as peculiarly adaptable, since the bulk of the hulls protects against gorging), it is possible that rye might fall heir to some of the embarrassed oat acreage if farmers generally would learn to employ rye effectively in mixed-grain rations. The rye acreages harvested in 1913 and 1914 were practically identical, at 2.5 million acres. The acreage of 1926 was nearly 3.6 million acres, while the acreage of 1927 was nearly 3.7 million acres. Rye acreage has declined from the peak of 1922, 6.7 million, to a point scarcely more than a million acres above the pre-war level. Whether this acreage will be maintained remains to be seen; but the trend is hardly a matter of immediate importance. One million acres of rye is a third of the total in rye and therefore a large percentage; but it is practically negligible in the gross cereal acreage of the United States.

It would hardly seem that European demand for American rye holds out worthwhile prospect to American farmers. If we were able to offer Europe a bread rye of high type, a limited market might continue available in Europe, pending recovery of Russian exports. European purchases of American rye since the war have represented little else than a phase of post-war recovery. In each year since the war additional rye could have been purchased in the United States at prices below the equivalent prices of wheat; but it was not wanted. Even more than before the war, despite the poverty of Europe, wheat is preferred to rye; when rye is preferred, American rye is the least sought. The export of the crop year 1926–27 was over 21 million bushels, corresponding roughly to the outturn of nearly two million acres. It is not known whether or not this export has been remunerative to growers. It is difficult to expect this level of exports to be maintained during the next few years. The rye exports of the present season are heavy, but it cannot be lightly assumed that this level of exports will be maintained in coming years. The current exports of rye, and of barley, are in part related to a short crop of corn and mediocre crops of rye, barley, and oats, and to the high count of livestock in western Europe. Except in years of crop failure abroad, therefore, European demand for American rye cannot be counted on. This situation creates a problem for the Dakotas in their rye and durum wheat acreage; if not planted to rye and durum wheat, to what use shall this acreage be put? American farmers, however, can hardly maintain a rye acreage in expectation of crop failure abroad.

The international position of rye would seem to be readily appraisable. In Europe and Russia, established ideas on rotations will tend to keep rye and wheat acreages in the same relative position they occupied before the war. Let us assume for the near future the recovery of Russian agriculture, in so far as it involves wheat and rye. European cereal agriculture may be regarded as already restored. The war expansions of rye acreage tend everywhere to recede; the war expansions of wheat acreage tend, outside of the United States, to be maintained. Per capita consumption of wheat in the world is increasing, and the wheat-consuming population is growing. So long as good new wheat land is available in Canada, Ar-

[1] To the extent that effective demand for graham bread represents a craving for roughage, rye bread ought to be preferred to wheat bread, since rye bran is less digestible than wheat bran.

gentina, Australia, and elsewhere, the expanding world demand for bread grain will be satisfied without invoking the tillage of new rye land. In Canada, in Argentina and other South American states, in Australia, in South Africa, and in Manchuria and Mongolia are extensive regions better adapted to rye than to wheat. But so long as new wheat lands are still available there, these will have first call. Possibly for many decades, wheat culture in the world will keep abreast of world demand for bread grain. Later it is reasonable to expect that the potential rye lands of the world—what might be called the second line of bread-grain defenses—will be brought into operation. How long one expects this to be deferred, depends upon one's notion of population growth of the world. But it will not be soon.

This study has been written by Alonzo E. Taylor, with the aid of Elizabeth M. Brand and the assistance of the Institute staff

APPENDIX

TABLE I.—RYE ACREAGE, PRODUCTION, AND YIELD PER ACRE IN PRINCIPAL EUROPEAN PRODUCING AREAS, AVERAGE, 1909–13, AND ANNUALLY, 1920–27*

A.—ACREAGE

(Thousand acres)

Year	Hungary	Other Balkans[a]	Russia[b]	France	Germany	Belgium and Netherlands[c]	Scandinavia[d]	Spain and Portugal	Czecho-Slovakia	Poland	Austria	Baltic States[e]	Others[f]
Average 1909-13	1,608	2,560	61,055	3,095	12,713	1,255	1,650	2,259	2,605	12,127	1,110	3,712	482
1920	1,475	1,733	.....	2,148	10,589	1,034	1,510	2,331	2,238	7,236	714	2,640	405[g]
1921	1,341	1,722	.....	2,227	10,539	1,079	1,508	2,359	2,181	8,866	758	2,745	384[g,h]
1922	1,663	1,588	.....	2,195	10,236	1,051	1,449	2,347	2,174	11,225	834	2,931	368[h]
1923	1,620	1,555	.....	2,215	10,790	1,112	1,470	2,351	2,123	11,477	922	3,086	433
1924	1,643	1,568	65,837	2,196	10,525	1,065	1,145	2,294	2,005	10,860	928	2,943	358[h]
1925	1,700	1,613	69,024	2,147	11,635	1,077	1,422	1,846[i]	2,091	12,044	949	2,959	358[h]
1926	1,711	1,689	68,127	2,122	11,694	1,070	1,376	1,865[i]	2,068	11,916	956	2,630	347[h]
1927	.....	1,543	69,588	1,977	11,723	1,070	.....	1,860[i]	2,043	12,064	...	2,470	334[j]

B.—PRODUCTION

(Million bushels)

Year	Hungary	Other Balkans[a]	Russia[b]	France	Germany	Belgium and Netherlands[c]	Scandinavia[d]	Spain and Portugal	Czecho-Slovakia	Poland	Austria	Baltic States[e]	Others[f]
Average 1909-13	31.4	38.0	735.5	25.5	368.3	40.7	44.2	29.9	63.5	218.9	23.8	56.0	9.2
1920	20.6	21.7	.....	34.5	194.2	33.3	36.4	33.0	32.9	73.7	10.1	34.6	7.2[g]
1921	23.2	21.3	.....	44.4	267.6	36.7	39.8	32.7	53.7	167.6	13.2	48.5	9.2
1922	25.1	20.1	.....	38.4	206.0	35.8	37.3	31.7	51.1	197.4	13.6	48.6	8.4
1923	31.3	20.7	.....	36.5	263.0	35.8	39.3	33.3	53.3	234.7	15.8	50.5	8.7
1924	22.1	15.9	679.1	40.2	225.6	36.5	21.9	32.3	44.7	143.9	16.2	42.9	8.0
1925	32.5	24.8	815.5	43.7	317.4	38.5	41.0	34.5	58.1	257.4	21.7	59.4	9.3
1926	31.4	26.7	897.3	30.1	252.2	34.1	36.5	27.1	45.9	197.3	18.7	36.3	9.5
1927	22.6	23.7	968.4	36.8	269.0	33.9	29.8	30.9	48.9	223.9	18.2	49.4	8.8

C.—YIELD PER ACRE

(Bushels)

Year	Hungary	Other Balkans[a]	Russia[b]	France	Germany	Belgium and Netherlands[c]	Scandinavia[d]	Spain and Portugal	Czecho-Slovakia	Poland	Austria	Baltic States[e]	Others[f]
Average 1909-13	19.5	14.8	12.0	17.0	29.0	32.4	26.8	13.3	24.4	18.1	21.4	15.1	19.1
1920	13.9	12.5	....	16.1	18.3	32.2	24.1	14.2	14.7	10.2	14.1	13.1	17.8[g]
1921	17.3	12.4	....	19.9	25.4	34.0	26.4	13.9	24.6	18.9	17.4	17.7	21.0[g,h]
1922	15.1	12.7	....	17.5	20.1	34.0	25.7	13.5	23.5	17.6	16.3	16.6	19.7[h]
1923	19.3	13.3	....	16.5	24.4	32.1	26.7	14.2	25.1	20.5	17.2	16.4	20.2
1924	13.5	10.2	10.3	18.3	21.4	34.3	19.2	14.1	22.3	13.2	17.4	14.6	21.1[h]
1925	19.1	15.3	11.8	20.3	27.3	35.7	28.8	16.2[i]	27.8	21.4	22.8	20.1	23.3[h]
1926	18.4	15.8	13.2	14.2	21.6	31.8	26.5	12.6[i]	22.2	16.6	19.6	13.8	23.3[h]
1927	....	15.4	13.9	18.6	22.9	31.7	....	14.3[i]	23.9	18.6	....	20.0	17.8[j]

* Data of U.S. Department of Agriculture. For 1909–13, including U.S. Department of Agriculture estimates for areas within post-war boundaries. In a few cases pre-war averages are for three or four years. Dots (....) indicate that data are not available.

[a] Bulgaria, Jugo-Slavia, and Roumania.
[b] Asiatic and European territory. The pre-war estimate is regarded as too low by Soviet officials.
[c] Including Luxemburg.
[d] Denmark, Norway, and Sweden.
[e] Finland, Latvia, Esthonia, and Lithuania.
[f] Italy, Switzerland, Greece.
[g] Old boundaries for Italy.
[h] Excluding Greece.
[i] Spain only.
[j] Italy only.

TABLE II.—UNITED STATES ACREAGE, PRODUCTION, AND YIELD PER ACRE OF RYE, AND IMPORTS AND EXPORTS OF RYE AND RYE FLOUR, 1890–1928*

Crop year July–June	Acreage (thousand acres)	Production (thousand bushels)	Yield per acre (bushels)	Trade (thousand bushels)		
				Exports	Imports	Net exports
1890-91	2,184	26,414	12.1	358	59	299
1891-92	2,234	32,761	14.7	12,069	0	12,069
1892-93	2,251	29,253	13.0	1,494	0	1,494
1893-94	2,178	28,592	13.1	249	0	249
1894-95	2,164	29,613	13.7	32	0	32
1895-96	2,153	31,139	14.5	1,011	0	1,011
1896-97	2,126	28,913	13.6	8,576	1	8,575
1897-98	2,077	33,433	16.1	15,562	1	15,561
1898-99	2,071	32,888	15.9	10,170	1	10,169
1899-00	2,054	30,334	14.8	2,382	0	2,382
1900-01	2,042	30,791	15.1	2,346	0	2,346
1901-02	2,033	31,103	15.3	2,712	1	2,711
1902-03	2,051	35,255	17.2	5,445	1	5,444
1903-04	2,074	31,990	15.4	784	4	780
1904-05	2,085	31,805	15.3	30	21	9
1905-06	2,141	35,168	16.4	1,388	1	1,387
1906-07	2,186	36,559	16.7	770	1	769
1907-08	2,167	35,455	16.4	2,446	2	2,444
1908-09	2,175	35,768	16.4	1,296	1	1,295
1909-10	2,196	35,406	16.1	242	30	212
1910-11	2,185	34,897	16.0	40	227	(187)[a]
1911-12	2,127	33,119	15.6	31	134	(103)[a]
1912-13	2,117	35,664	16.8	1,855	1	1,854
1913-14	2,557	41,381	16.2	2,272	37	2,235
1914-15	2,541	42,779	16.8	13,027	147	12,880
1915-16	3,129	54,050	17.3	15,250	566	14,684
1916-17	3,213	48,862	15.2	13,703	428	13,275
1917-18	4,317	62,933	14.6	17,186	834	16,352
1918-19	6,391	91,041	14.2	36,467	...	.....
1919-20	6,307	75,483	12.0	41,531	...	.....
1920-21	4,409	60,490	13.7	47,337	...	.....
1921-22	4,528	61,675	13.6	29,944	...	.....
1922-23	6,672	103,362	15.5	51,663	...	.....
1923-24	5,171	63,077	12.2	19,902	...	.....
1924-25	4,150	65,466	15.8	50,242	...	.....
1925-26	3,974	46,456	11.7	12,647	...	.....
1926-27	3,578	40,795	11.4	21,698	...	.....
1927-28	3,670	58,572	16.0	.....	...	.....

* Data from official sources. Import data on a crop-year basis are not available after June 1918, but since 1922, imports of rye and rye flour have been practically negligible; hence net exports would differ little from gross exports in the years 1918–19 and following. Acreage figures are for acreage harvested.

[a] Net import.

TABLE III.—CANADIAN ACREAGE, PRODUCTION, AND YIELD PER ACRE OF RYE, AND NET EXPORTS OF RYE AND RYE FLOUR, 1890–1928*

Crop year	Acreage (thousand acres)	Production (thousand bushels)	Yield per acre (bushels)	Net exports (thousand bushels)
1890-91	122	1,341	11.0	338
1891-92	68	1,135	16.7	219
1892-93	73	1,133	15.5	56
1893-94	71	1,024	14.4	61
1894-95	93	1,447	15.6	60
1895-96	123	1,981	16.1	(5)[a]
1896-97	152	2,283	15.0	212
1897-98	191	3,430	18.0	1,132
1898-99	168	2,737	16.3	317
1899-00	141	2,349	16.7	468
1900-01	177	2,317	13.1	678
1901-02	161	2,610	16.2	411
1902-03	192	3,559	18.5	462
1903-04	184	3,059	16.6	86
1904-05	137	2,128	15.5	6
1905-06	109	1,879	17.1	(35)[a]
1906-07	94	1,651	17.6	(39)[a]
1907-08	74	1,133	15.3	(49)[a]
1908-09	100	1,711	17.0	246
1909-10	91	1,715	18.8	30
1910-11	114	1,537	13.4	52
1911-12	131	2,492	19.0	(37)[a]
1912-13	127	2,428	19.1	(99)[a]
1913-14	119	2,300	19.3	5
1914-15	111	2,017	18.1	179
1915-16	122	2,486	20.4	782
1916-17	148	2,876	19.4	.....
1917-18	212	3,857	18.2	.....
1918-19	555	8,504	15.3	.....
1919-20	753	10,207	13.5	2,523
1920-21	650	11,306	17.5	3,205
1921-22	1,842	21,455	11.8	4,279
1922-23	2,105	32,373	15.5	9,789
1923-24	1,448	23,232	16.0	7,982
1924-25	891	13,751	15.4	6,311
1925-26	643	9,158	14.2	6,200
1926-27	754	12,179	16.2	8,257
1927-28	743	14,951	20.1	.....

* Data from official Canadian sources and International Institute of Agriculture. Acreage, production, and yield figures, 1891–92 and 1892–93, are for Ontario alone; 1893–94 to 1899–1900 and 1901–2 to 1904–5 for Ontario and Manitoba; 1905–6 to 1907–8 for Ontario and Prairie Provinces; 1890–91 and 1900–1901 are census figures for all Canada. Trade figures 1890–91 to 1905–6 are for years ending June 30, thereafter for years ending July 31. Dots (....) indicate that comparable data are not available. Canadian imports of rye and rye flour exceeded 100,000 bushels in only three years, 1912–15, when they ranged from 101,000 to 125,000 bushels.

[a] Net import.

TABLE IV.—ARGENTINE ACREAGE, PRODUCTION, YIELD PER ACRE, AND NET EXPORTS OF RYE, 1909–28*

Calendar year	Acreage (thousand acres)	Production (thousand bushels)	Yield per acre (bushels)	Net exports (thousand bushels)
1909	23	.....	....	3
1910	27	.....	....	36
1911	32	408	12.8	22
1912	38	427	11.2	445
1913	99	1,413	14.3	861
1914	228	3,346	14.7	451
1915	229	1,811	7.9	194
1916	212	2,008	9.5	129
1917	180	858	4.8	(2)[a]
1918	253	843	3.3	2
1919	274	393	1.4	201
1920	205	868	4.2	500
1921	218	821	3.8	726
1922	242	1,692	7.0	1,102
1923	366	3,526	9.6	2,750
1924	404	4,000	9.9	3,185
1925	387	1,457	3.8	213
1926	501	4,733	9.4	2,914
1927	544	3,268	6.0	5,196
1928	895	6,693	7.5	.....

* Data from official sources and International Institute of Agriculture. Dots (....) indicate that data are not available. Acreage figures are for acreage sown for the crop harvested in the year indicated.

[a] Net import.

TABLE V.—RYE RECEIPTS AT PRIMARY MARKETS IN THE UNITED STATES, MONTHLY FROM JULY 1909*

(Thousand bushels)

Crop year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1909-10	156	557	966	1,032	840	510	524	559	510	355	304	308	6,621
1910-11	166	444	523	493	534	614	435	324	468	255	271	117	4,644
1911-12	193	983	1,359	1,438	1,087	721	647	617	532	336	285	282	8,480
1912-13	159	1,462	2,690	2,935	2,576	1,366	1,125	1,012	961	844	633	623	16,386
1913-14	784	1,741	2,675	2,153	1,435	1,204	960	750	878	672	594	769	14,615
1914-15	529	1,598	3,262	3,210	3,302	2,717	1,479	984	615	446	386	423	18,951
1915-16	255	1,302	3,642	3,725	4,895	2,997	1,594	1,323	1,162	1,110	835	917	23,757
1916-17	656	1,221	3,981	3,906	3,451	2,537	1,425	676	1,124	948	715	494	21,134
1917-18	317	1,613	4,025	4,624	3,106	2,410	1,596	1,890	2,392	1,273	664	473	24,383
1918-19	465	2,158	4,337	5,234	6,210	5,971	5,549	2,390	4,923	5,425	4,246	2,757	49,665
1919-20	3,045	3,580	5,195	4,275	2,412	2,738	4,236	3,180	3,439	2,857	3,696	3,135	41,788
1920-21	3,068	3,118	5,390	4,331	3,647	3,429	1,997	1,341	1,268	1,501	1,315	1,445	31,850
1921-22	2,501	6,066	5,416	2,915	1,885	1,680	1,172	1,523	3,191	1,368	3,514	1,783	33,014
1922-23	1,801	13,934	11,883	7,734	7,704	6,963	7,045	4,647	3,604	3,966	2,141	2,522	73,944
1923-24	1,430	3,812	5,212	3,324	3,442	3,052	6,495	1,829	1,537	929	2,142	3,978	37,182
1924-25	4,890	4,678	14,208	17,608	8,827	3,766	2,072	1,397	784	1,457	4,584	862	65,133
1925-26	384	1,895	6,460	3,343	2,579	2,100	1,499	1,054	1,033	1,248	1,350	1,190	24,135
1926-27	786	1,927	3,873	2,661	2,228	1,237	1,277	2,130	1,462	1,413	3,241	1,360	23,595

* Data for 1909–10 to 1923–24 from *Wheat and Rye Statistics* (U.S. Department of Agriculture Statistical Bulletin 12), January 1926; for 1924–25 to 1926–27 obtained directly from Bureau of Agricultural Economics of U.S. Department of Agriculture. Markets included are Chicago, Milwaukee, Minneapolis, Duluth, St. Louis, Toledo, Kansas City, Peoria, Omaha, and Indianapolis. No record for Indianapolis until 1914–15.

TABLE VI.—RYE SHIPMENTS FROM PRIMARY MARKETS IN THE UNITED STATES, MONTHLY FROM JULY 1909*

(Thousand bushels)

Crop year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1909-10	174	145	400	568	581	366	325	357	296	287	260	268	4,027
1910-11	174	190	177	233	402	375	383	357	417	185	143	61	3,097
1911-12	61	274	722	619	541	565	437	492	306	388	224	134	4,763
1912-13	93	479	1,428	1,827	1,804	1,004	973	807	1,126	894	557	392	11,384
1913-14	494	835	1,480	1,079	965	958	726	627	823	649	957	606	10,199
1914-15	439	779	2,229	2,552	2,710	2,580	1,593	976	621	357	401	416	15,723
1915-16	180	1,183	1,4 2	3,531	3,894	2,662	1,621	982	1,210	1,319	897	958	19,909
1916-17	671	613	2,733	2,763	2,962	1,917	1,049	687	938	1,294	1,141	640	17,408
1917-18	222	644	3,494	2,253	2,545	1,179	1,360	1,128	1,370	1,090	478	417	16,180
1918-19	288	818	1,072	4,817	4,872	1,551	760	408	3,232	8,103	7,524	2,728	36,173
1919-20	1,595	1,517	2,347	1,380	3,079	2,301	3,700	2,099	3,069	8,811	7,011	5,448	42,357
1920-21	4,483	2,931	4,288	4,719	2,958	3,149	2,192	1,014	1,052	1,515	1,273	1,426	31,000
1921-22	1,057	4,605	5,526	2,226	1,586	1,783	314	685	838	1,530	7,865	2,976	30,991
1922-23	1,126	12,069	10,038	4,358	7,414	6,769	4,464	2,430	918	967	4,453	3,729	58,735
1923-24	4,049	2,612	3,323	1,148	2,658	1,158	3,239	391	823	960	4,228	5,374	29,963
1924-25	8,129	2,279	16,229	16,365	5,657	7,452	2,819	396	350	1,834	6,571	1,471	69,552
1925-26	3,382	653	2,493	1,308	1,071	331	323	530	741	693	3,338	1,032	15,895
1926-27	2,711	831	1,902	723	1,646	1,454	697	657	516	8,715	7,033	2,026	28,911

* Data for 1909–10 to 1923–24 from *Wheat and Rye Statistics* (U.S. Department of Agriculture Statistical Bulletin 12), January 1926; for 1924–25 to 1926–27 obtained directly from Bureau of Agricultural Economics of U.S. Department of Agriculture. Markets included are Chicago, Milwaukee, Minneapolis, Duluth, St. Louis, Toledo, Kansas City, Peoria, Omaha, and Indianapolis. No record for Indianapolis until 1915–16.

TABLE VII.—VISIBLE RYE SUPPLY IN THE UNITED STATES, MONTHLY FROM JULY 1909*

(Thousand bushels)

Crop year	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1
1909-10.....	157	93	240	458	642	932	814	784	771	686	630	496
1910-11.....	378	243	172	353	433	507	491	361	251	114	60	32
1911-12.....	15	16	316	511	1,165	1,351	1,432	1,099	1,003	828	651	544
1912-13.....	427	243	441	1,062	1,256	1,888	1,719	1,469	1,202	1,063	684	503
1913-14.....	449	382	674	1,549	2,032	2,299	2,226	2,085	1,822	1,447	1,165	613
1914-15.....	369	168	290	1,245	1,897	1,941	1,448	1,445	1,363	779	945	286
1915-16.....	210	95	536	1,239	1,304	2,686	3,003	3,150	2,377	1,844	1,687	951
1916-17.....	452	350	418	1,007	2,009	1,962	2,577	2,230	2,014	1,693	1,538	708
1917-18.....	515	480	727	2,029	3,550	3,818	2,480	1,676	1,225	1,086	1,000	852
1918-19.....	707	580	1,325	3,829	6,694	11,511	15,687	20,764	17,896	15,193	17,246	11,384
1919-20.....	8,981	9,866	12,327	15,395	17,248	17,198	17,477	19,195	20,389	18,467	15,560	11,570
1920-21.....	4,423	2,555	2,210	4,407	2,778	4,320	3,236	2,083	1,978	1,790	1,441	1,131
1921-22.....	587	1,346	4,371	5,131	6,005	6,846	6,770	7,097	7,227	9,236	8,163	4,358
1922-23.....	1,635	1,154	4,707	8,180	10,115	10,284	10,193	11,710	14,954	18,268	19,459	16,545
1923-24.....	15,101	12,726	13,374	15,188	16,960	16,904	19,052	19,874	21,205	21,716	20,374	18,749
1924-25.....	17,229	14,437	15,279	12,440	17,231	20,543	20,932	23,479	23,381	21,954	12,126	10,226
1925-26.....	8,706	4,729	4,542	8,726	9,976	11,214	12,702	13,564	13,981	13,443	13,754	11,318
1926-27.....	10,981	8,666	9,706	11,313	12,824	12,890	12,880	12,929	13,912	14,040	8,212	4,191

* Data for 1909-10 to 1923-24 from *Wheat and Rye Statistics* (U.S. Department of Agriculture Statistical Bulletin 12), January 1926; for 1925-27 from *Daily Market Record*, February 6, 1928. Data are for the Saturday nearest the first of the month, and include grain in regularly authorized warehouses at prominent grain centers of the United States east of the Rocky Mountains, and in transit by canals and lakes. Stocks at Omaha and private elevator stocks at Chicago, St. Louis and Buffalo included after July 1911. Canadian rye in bond included from May 1917 to July 1921.

TABLE VIII.—AVERAGE DAILY VOLUME OF TRADING IN RYE FUTURES IN UNITED STATES MARKETS, MONTHLY FROM JANUARY 1921*

(Million bushels)

Crop year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
1920-21.....	...	...	...	...	...	...	.8	.6	.6	.9	.7	.7	.7[a]
1921-22.....	.8	.8	.9	.8	.9	.6	.3	1.3	.9	1.1	1.1	1.2	.9
1922-23.....	1.5	2.2	2.3	2.3	3.4	2.3	1.5	.9	1.0	2.4	1.8	2.3	1.9
1923-24.....	1.0	1.7	1.8	1.3	1.7	1.1	.6	.6	1.1	2.0	1.0	3.0	1.4
1924-25.....	4.3	4.0	5.9	6.1	5.1	3.8	4.4	4.1	4.5	3.0	1.9	2.0	4.1
1925-26.....	1.4	2.0	2.3	1.1	2.1	3.6	1.6	2.2	1.7	2.3	1.5	2.6	2.0
1926-27.....	3.5	2.0	1.4	1.1	2.4	1.3	2.0	1.7	1.9	2.4	2.6	1.9	2.0

* Data supplied by Grain Futures Administration of U.S. Department of Agriculture. Not compiled prior to January 1921.

[a] Six-month average.

TABLE IX.—INTERNATIONAL TRADE IN RYE (INCLUDING FLOUR) OF PRINCIPAL EUROPEAN COUNTRIES, AVERAGE, 1909–14, AND ANNUALLY, 1920–27*

(Thousand bushels)

Crop year August–July	HUNGARY			OTHER BALKANS[a]			RUSSIA			FRANCE		
	Imports	Exports	Net exports	Imports	Exports	Net exports	Imports	Exports	Net exports	Imports	Exports	Net imports
Average 1909–14.....	120	13,624	13,504	26	4,917	4,891	5,381	32,734	27,353	3,148	19	3,129
1920–21.....	0	0	0	2	5,437	5,435	.....	.....	.....	9,640	26	9,614
1921–22.....	7	34	27	1	1,565	1,564	.....	.....	.....	28	1,295	(1,267)[b]
1922–23.....	2	21	19	0	550	550	.....	8,571[c]	.....	632	570	62
1923–24.....	0	3,804	3,804	0	1,357	1,357	.....	53,143[c]	.....	2,911	906	2,005
1924–25.....	4	5,289[d]	5,285[d]	15	708	693	.....	2,571[c]	.....	1,134	384	750
1925–26.....	1[d]	6,806[d]	6,805[d]	51	505	454	.....	7,094	.....	873	128	745
1926–27[e].....	1	10,040	10,039	0	2,441	2,441	.....	16,251	.....	4,906	1	4,905

Crop year August–July	GERMANY			BELGIUM AND NETHERLANDS			SCANDINAVIA			CZECHO-SLOVAKIA		
	Imports	Exports	Net imports	Imports	Exports	Net imports	Imports	Exports	Net imports	Imports	Exports	Net imports
Average 1909–14.....	16,405	42,090	(25,685)[b]	33,883	17,938	15,945	22,496	334	22,162	.....	...	...
1920–21.....	24,256[f]	615[f]	23,641[f]	2,335	1,489	846	6,734	2,444	4,290	3,117	2	3,115
1921–22.....	7,078	947	6,131	1,850	1,398	452	10,203	2,491	7,712	782	113	669
1922–23.....	43,471	495	42,976	4,047	2,427	1,620	14,063	721	13,342	40	364	(324)[b]
1923–24.....	22,315	86	22,223	11,242	2,832	8,410	23,287	615	22,672	5,924	957	4,967
1924–25.....	22,683	5,676	17,007	6,656	3,199	3,457	17,841	513	17,328	5,475	23	5,452
1925–26.....	8,796	14,739	(5,943)[b]	8,257	398	7,859	17,913	489	17,424	6,807	21	6,786
1926–27[e].....	25,311	7,342	17,969	7,462	688	6,774	14,237	1,925	12,312	4,492	54	4,438

Crop year August–July	POLAND			AUSTRIA			BALTIC STATES[g]			OTHER[h]		
	Imports	Exports	Net imports	Imports	Exports	Net imports	Imports	Exports	Net imports	Imports	Exports	Net imports
Average 1909–14.....	...	...	...	1,469	2	1,467	.....	...	.....	1,325[i,j]	34[i]	1,291[i]
1920–21.....	...	...	...	1,645	1	1,644	2,626	0	2,626	4,157[j]	3	4,154
1921–22.....	482	386	96	2,139	3	2,136	3,992	98	3,894	54[j]	2	52
1922–23.....	8	1	7	1,708	8	1,700	7,243	133	7,110	926[j]	3	923
1923–24.....	2	2,482	(2,480)[b]	3,888	38	3,850	14,515	14	14,501	190[j]	235	(45)[b]
1924–25.....	2,582	1,721	861	3,138[k]	15	3,123	8,890	164	8,726	64	339	(275)[b]
1925–26.....	59	12,677	(12,618)[b]	3,706[d]	162	3,544	11,364	78	11,286	614[i]	10[i]	604[i]
1926–27[e].....	3,186	3,212	(26)[b]	3,464[i]	167	3,297	9,013	18	8,995	521[i]	2[i]	519[i]

* Data from International Institute of Agriculture. Dots (....) indicate that data are unavailable. Pre-war averages are for territory within pre-war boundaries and in many cases are not comparable with post-war figures. In a few cases pre-war averages are for three-year periods only.

[a] Bulgaria, Jugo-Slavia, and Roumania.
[b] Net export.
[c] Data from Broomhall's *Corn Trade Year Book*, 1927.
[d] Fiscal year ending June 30.
[e] Data incomplete. Figures for rye and rye flour imports of exporting countries, and for rye exports of importing countries are for ten months in most cases.
[f] Eight months figure for rye flour imports and rye and rye flour exports.
[g] Finland, Latvia, Esthonia, Lithuania.
[h] Italy, Greece, Switzerland, Spain.
[i] Excluding Greece.
[j] Excluding Spain.
[k] Eleven months.

TABLE X.—WEIGHTED AVERAGE CASH SALES PRICES OF RYE AND WHEAT IN THE UNITED STATES, ANNUALLY, 1909–27*

(Cents per bushel)

Crop year July–June	No. 2 Rye (Chicago)		Wheat *(60-lb. bushel)*		
	(56-lb. bushel)	*(60-lb. bushel)*	No. 1 Northern Spring (Minneapolis)	No. 2 Hard Winter (Kansas City)	No. 2 Red Winter (Chicago)
1909–10	76	81	109	107	110
1910–11	84	90	105	98	102
1911–12	91	97	107	97	90
1912–13	65	70	87	88	103
1913–14	64	69	88	84	88
Average 1909–14	76	81	99	95	99
1914–15	105	113	120	105	108
1915–16	99	106	109	119	113
1916–17	154	165	176	171	168
1917–18	211	226	220	252	225
1918–19	161	172	225	219	222
1919–20	170	182	272	242	224
1920–21	162	174	207	183	223
Average 1914–21	152	163	190	184	183
1921–22	97	104	143	120	125
1922–23	81	87	120	113	114
1923–24	70	75	117	105	102
1924–25	125	134	156	135	158
1925–26	96	103	161	163	164
1926–27	101	108	146	135	138
Average 1921–27	95	102	141	129	134

* Data from *Agriculture Yearbook, 1926;* 1926–27 figures supplied directly by Bureau of Agricultural Economics of U.S. Department of Agriculture. Figures for rye on 60-lb. bushel basis computed by Food Research Institute.

TABLE XI.—ESTIMATED WEIGHTED AVERAGE RYE AND WHEAT PRICES RECEIVED BY PRODUCERS IN THE UNITED STATES, ANNUALLY, 1909–27*

(Cents per bushel)

Crop year July–June	Rye		Wheat
	(56-lb. bushel)	*(60-lb. bushel)*	*(60-lb. bushel)*
1909–10	74.6	79.9	100.7
1910–11	73.4	78.6	91.7
1911–12	81.0	86.8	88.3
1912–13	68.7	73.6	83.3
1913–14	62.9	67.4	79.3
Average 1909–14	72.1	77.3	88.7
1914–15	83.3	89.3	99.4
1915–16	85.0	91.1	98.2
1916–17	113.0	121.1	144.4
1917–18	176.4	189.0	205.8
1918–19	152.1	163.0	206.3
1919–20	146.9	157.4	218.6
1920–21	148.2	158.8	182.9
Average 1914–21	129.3	138.5	165.1
1921–22	86.9	93.1	104.4
1922–23	68.1	73.0	98.0
1923–24	59.4	63.6	92.4
1924–25	96.3	103.2	127.8
1925–26	83.1	89.0	145.9
1926–27	84.2	90.2	122.8
Average 1921–27	79.7	85.4	115.2

* Data from *Agriculture Yearbook, 1926;* 1926–27 figures supplied directly by Bureau of Agricultural Economics of U.S. Department of Agriculture. Figures for rye on 60-lb. bushel basis computed by Food Research Institute.

TABLE XII.—PRICES OF WHEAT FLOUR AND RYE FLOUR AT CHICAGO, QUARTERLY, 1909–14 AND 1921–27*

(Dollars per barrel)

Period	Wheat flour		Rye flour		Period	Wheat flour		Rye flour	
	Straight	First clear	White	Dark		Straight	First clear	White	Dark
1909–10					1922–23				
July–Sept.	4.69	4.38	3.82	3.72	July–Sept.	5.02	4.03	4.59	4.33
Oct.–Dec.	4.67	4.25	3.75	3.64	Oct.–Dec.	5.33	4.49	4.88	4.50
Jan.–Mar.	4.83	4.13	4.02	3.83	Jan.–Mar.	5.06	4.56	4.87	4.45
Apr.–June	4.45	3.80	3.86	3.68	Apr.–June	5.03	4.50	4.35	4.07
July–June	4.66	4.14	3.86	3.72	July–June	5.11	4.40	4.67	4.34
1910–11					1923–24				
July–Sept.	4.18	3.66	3.79	3.55	July–Sept.	4.34	4.02	3.76	3.45
Oct.–Dec.	3.80	3.42	3.87	3.68	Oct.–Dec.	4.49	4.13	3.88	3.64
Jan.–Mar.	3.74	3.17	4.02	3.81	Jan.–Mar.	4.67	4.29	4.24	4.02
Apr.–June	3.62	3.22	4.92	4.60	Apr.–June	4.74	4.24	3.96	3.78
July–June	3.84	3.37	4.15	3.90	July–June	4.56	4.17	3.96	3.72
1911–12					1924–25				
July–Sept.	3.62	3.25	4.41	4.21	July–Sept.	5.52	4.79	5.17	4.94
Oct.–Dec.	3.73	3.40	4.86	4.60	Oct.–Dec.	6.88	6.14	7.13	6.81
Jan.–Mar.	3.78	3.40	4.66	4.50	Jan.–Mar.	8.27	7.34	7.93	7.54
Apr.–June	4.20	3.68	4.58	4.45	Apr.–June	7.55	6.63	6.44	5.75
July–June	3.83	3.43	4.63	4.44	July–June	7.06	6.23	6.67	6.26
1912–13					1925–26				
July–Sept.	4.28	3.65	3.70	3.48	July–Sept.	7.45	6.54	5.51	4.76
Oct.–Dec.	3.94	3.56	3.35	3.18	Oct.–Dec.	7.51	6.49	5.03	4.31
Jan.–Mar.	3.94	3.41	3.26	3.12	Jan.–Mar.	7.97	6.66	5.51	4.43
Apr.–June	4.03	3.29	3.19	2.97	Apr.–June	7.25	6.35	5.21	3.94
July–June	4.05	3.47	3.37	3.12	July–June	7.55	6.51	5.32	4.36
1913–14					1926–27				
July–Sept.	3.72	3.39	3.24	3.02	July–Sept.	6.20	5.72	5.98	4.36
Oct.–Dec.	3.75	3.32	3.17	3.02	Oct.–Dec.	6.18	5.73	5.80	4.37
Jan.–Mar.	3.75	3.30	2.87	2.72	Jan.–Mar.	5.91	5.48	5.96	4.52
Apr.–June	3.75	3.29	3.08	2.82	Apr.–June	5.82	5.43	6.03	4.43
July–June	3.74	3.32	3.09	2.90	July–June	6.03	5.59	5.94	4.42
1921–22									
July–Sept.	6.24	5.21	7.02	6.45					
Oct.–Dec.	5.97	4.33	5.37	5.07					
Jan.–Mar.	6.20	4.42	5.58	5.24					
Apr.–June	5.95	4.65	5.78	5.42					
July–June	6.09	4.66	5.94	5.53					

* Averages computed from weekly quotations compiled from the *Northwestern Miller*. In each case the cheapest wheat flour and the dearest rye flour quotations available for the specified grades were selected.

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