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# The Agricultural and Industrial Demand for Corn

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## SUMMARY

The World War marked a turning point in the history of corn production in the United States. Previous to the World War the trend of corn production in this country was steadily rising. Since 1920, however, it has declined because of decreases both in yield and acreage.

From 1900 to 1920, the United States' corn crop averaged 68 percent of the world crop of corn, the annual percentages fluctuating about a horizontal trend. Since the World War, however, the United States' proportion of the world corn crop has been declining. The trend declined to 55 percent in 1933. Corn production has been increasing in other countries and decreasing in the United States.

Gross and net exports of corn from the United States have been declining. During the past 10 years they have only once (in 1928-29) exceeded 1 percent of the total crop. Foreign importers of corn are buying more corn from our competitors and less from us. This trend was clearly evident before the AAA reduction program was instituted.

### AGRICULTURAL DEMAND FOR CORN IN THE UNITED STATES

During 1924-29, 86.2 percent of the United States corn crop was fed to livestock on farms.

From 1920 to 1935, consumption of corn by horses and mules decreased about 180 million bushels. During the past 10 years, the horse and mule consumption of corn has been cut 40 percent; it now takes only 11 percent of the total corn crop. A further decline appears probable during the next few years.

The consumption of corn by hogs on farms increased 120 million bushels from 1910-14 to 1924-29. This increase was the result of two conflicting causes. A marked increase took place in total hog slaughter, but this was partially offset by changes in hog feeding and breeding methods that reduced the per capita hog demand for corn. It seems likely that, in the future, hog slaughter will increase only slowly, or not at all, over pre-1934 levels; while changes in breeding and feeding methods are likely to continue. The total hog demand for corn, therefore, is not likely to increase much in the future; it may decrease.

Consumption by cattle on farms increased 80 million bushels from 1910-14 to 1926-29, because of increases in cattle numbers

and perhaps also because of increased dairy production.

#### INDUSTRIAL DEMAND FOR CORN IN THE UNITED STATES

The consumption of corn by the milled products industry (makers of corn meal, corn flour and hominy grits) has been declining, from 200 million bushels before the war to 100 million soon after the war and to 40 million (2 percent of the corn crop) in 1932. This decline is probably permanent.

The consumption of corn by the corn products industry (makers of cornstarch, corn sirup, corn sugar and numerous by-products) has been slowly increasing, until now it accounts for 3 or 4 percent of the corn crop. Tapioca from Java is competing strongly with corn as a raw material in this industry, both at home and abroad. The working out of effective measures to meet this competition calls for further research.

Corn sugar has interesting possibilities for expansion. Present preliminary estimates place the probable outer limits of the consumption of corn as a raw material for corn sugar at about 75 million bushels (3 percent of the total production of corn) more than present consumption for this purpose. Extended research into this question is needed to determine how, and how closely, these limits may be approached.

The consumption of corn by the makers of distilled spirits and cereal beverages amounted, in the peak year (1917) to 34 million bushels. This is about 1.3 percent of the total crop. A considerable reduction has taken place since then. Expansion by this industry following repeal can probably increase the demand for corn only about 1 percent.

#### POSSIBLE NEW USES FOR CORN

An interesting possible new use for corn is opened up by the corn-alcohol fuel program. The outer limit of possible use for this purpose is about 600 million bushels of corn. Two major difficulties stand in the way of this program: (1) Corn alcohol at the plant costs several times as much per gallon as straight gasoline at the refinery, and it is doubtful whether consumers would pay the extra 2 or 3 cents a gallon needed for a 10 percent blend, unless they were coerced by some form of tax; (2) other products besides corn would probably be used in some measure unless their use were legally prohibited or made difficult. Further research is required here also.

## THE AGRICULTURAL AND INDUSTRIAL DEMAND FOR CORN<sup>1</sup>

By GEOFFREY SHEPHERD, JOHN J. DALTON and J. H. BUCHANAN

Corn is the most important crop in the United States; it leads all other crops in acreage, production and value.<sup>2</sup> In the central section of the Middlewest, particularly, corn holds a pre-eminent place, because it dominates the cropping system and is the chief feed for hogs and beef cattle and a major element in the ration of dairy cows.

It is not certain, however, that corn in the future will maintain as important a position in the United States as it has in the past. The trend of United States' corn production reached its peak 15 years ago, in 1920. The downward trend since then was clearly evident before the AAA corn-hog reduction program was instituted; it has, of course, been accentuated by that program. These changes in corn production are shown in fig. 1 and table 1.

The decrease in corn production since 1920 is the result of: (1) A decline in the trend of corn yield per acre, and (2) a decrease in corn acreage.

The decline in the trend of yield per acre is partly the result of a series of poor seasons in recent years, contrasted with the effect of a series of good seasons in the early 1920's.<sup>3</sup> This

<sup>1</sup> Project 369 of the Iowa Agricultural Experiment Station.

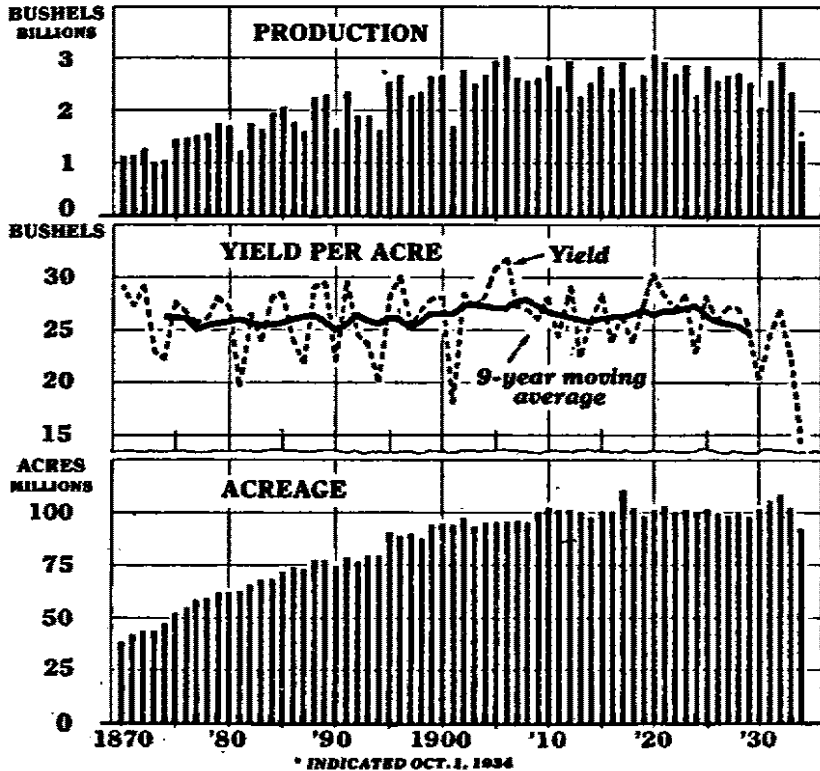
<sup>2</sup> The ranking of the major crops, for the period from 1931 to 1933, follows: (data for 1934 are not used because of the abnormal drouth in 1934.)

VALUE, ACREAGE AND PRODUCTION OF LEADING U. S. CROPS, 1931-33  
(in 1000's)

	Average farm Value, Dec. 1	Average Acreage	Average production. (bushels)
Corn.....	\$900,655	105,618	2,608,539
Cotton.....	504,034	34,929	(bales) 14,424
Wheat.....	343,765	63,933	734,470
Oats.....	221,656	39,350	1,032,018

Source: U. S. D. A. Yearbook.

<sup>3</sup> The decline in yield may have been partly because of the shift in corn acreage northwest, or because of a decline in soil fertility in the established Corn Belt.



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Fig. 1. United States corn production, yield and acreage, 1870 to 1934.

decline is shown in the central section of fig. 1. If weather conditions return to normal during the next few years, a part of the decline in corn production may prove to have been only temporary. But the lower section of fig. 1 shows that corn acreage has also changed. The figure shows that the trend of corn acreage, which rose steadily from 1870 to 1910, remained horizontal at about 100 million acres from 1910 to 1920. It shows further that in 1931 and 1932, farmers expanded their corn acreage in a desperate attempt to meet the depression. By 1933, however, corn acreage fell off sharply, and the AAA production control program instituted in 1934 caused a further drastic decline to 87 million acres in 1934, followed by a partial recovery to 96 million acres in 1935. The trend of corn acreage, after remaining horizontal for more than 20 years, has now "stepped down," temporarily at least, to a lower level.

TABLE 1—REVISED ESTIMATES OF CORN ACREAGE, PRODUCTION AND YIELD, U. S. D. A. MIM. REPORT, 1934

Year	Acresage	Yield	Production	Year	Acresage	Yield	Production
	1,000 acres	Bu. per acre	1,000 bushels		1,000 acres	Bu. per acre	1,000 bushels
1870...	38,408	29.3	1,124,775	1903..	93,655	26.9	2,515,093
1871...	42,029	27.3	1,141,715	1904..	95,228	28.2	2,686,624
1872...	43,818	29.3	1,279,369	1905..	95,746	30.9	2,954,148
1873...	44,124	22.9	1,009,326	1906..	95,624	31.7	3,032,910
1874...	47,668	22.2	1,058,778	1907..	96,094	27.2	2,613,797
1875...	52,504	27.6	1,450,276	1908..	95,285	26.9	2,566,742
1876...	55,347	26.7	1,478,173	1909..	100,200	28.1	2,811,157
1877...	58,892	26.7	1,515,862	1910..	102,267	27.9	2,852,794
1878...	59,768	26.3	1,564,537	1911..	101,393	24.4	2,474,635
1879...	62,354	28.1	1,751,984	1912..	101,451	29.1	2,947,842
1880...	62,699	27.2	1,706,673	1913..	100,206	22.7	2,272,540
1881...	63,191	19.7	1,244,726	1914..	97,796	25.8	2,523,766
1882...	66,157	26.5	1,755,272	1915..	100,623	28.1	2,829,044
1883...	68,168	24.2	1,650,748	1916..	100,561	24.1	2,425,206
1884...	68,834	28.3	1,947,838	1917..	110,893	26.2	2,908,242
1885...	71,854	23.0	1,637,807	1918..	102,195	23.9	2,441,249
1886...	73,911	24.1	1,782,748	1919..	98,145	27.3	2,678,561
1887...	73,296	21.9	1,604,549	1920..	101,359	30.3	3,070,604
1888...	77,474	29.1	2,250,632	1921..	103,155	28.4	2,928,442
1889...	77,656	29.5	2,294,389	1922..	100,345	27.0	2,707,306
1890...	78,783	22.1	1,650,446	1923..	101,123	28.4	2,875,292
1891...	79,855	29.6	2,335,714	1924..	100,420	22.9	2,298,071
1892...	76,914	34.7	1,897,412	1925..	101,331	28.2	2,853,083
1893...	79,832	23.8	1,800,401	1926..	99,452	25.9	2,574,511
1894...	80,069	20.2	1,615,010	1927..	98,357	27.2	2,677,871
1895...	80,479	28.0	2,234,762	1928..	100,336	27.1	2,714,535
1896...	89,074	30.0	2,671,048	1929..	97,806	25.0	2,435,546
1897...	89,065	25.4	2,286,628	1930..	101,083	20.4	2,065,273
1898...	87,784	26.9	2,351,323	1931..	105,948	24.4	2,589,599
1899...	94,691	23.0	2,145,796	1932..	108,668	26.8	2,905,873
1900...	94,853	23.1	2,161,978	1933..	103,260	22.8	2,351,658
1901...	94,422	18.2	1,715,752	1934..	87,486	16.2	1,380,719
1902...	97,177	23.5	2,273,954				

The decline in corn acreage, yield and production that has occurred during the past two decades may be only temporary. Corn production in the future may hold at about its present level. It is even conceivable that the upward trend from the Civil War to the World War will be resumed. On the other hand, it is possible that the downward trend since the war is the beginning of a long decline that will continue in the future, so that corn will gradually become less important in American agriculture. If we regard corn production as an industry, like the textile or the coal industry, we may ponder the words of the author of a recent study of production trends of industries in the United States since 1870. He points out that "There seems no warrant for the common notion that industries grow until they approximate some maximum size and then maintain a stationary position indefinitely . . . once an industry has ceased to advance, it soon begins to decline."<sup>4</sup>

<sup>4</sup>A. F. Burns, "Production Trends in the United States Since 1870," National Bureau of Economic Research, 1934, p. xix.

### THE FUTURE OF CORN PRODUCTION

It is a matter of vital concern to the Corn Belt, therefore, to ascertain as accurately as possible whether corn production in the future is likely to increase, to remain constant, or to decrease. This question calls for a study of two groups of forces, those that affect the demand for corn, and those that affect the supply of it. On the demand side, for example, corn production in the future may increase or decrease in response to an increase or decrease in the number of horses consuming corn, or because of a change in the demand for pork or lard, or a change in the efficiency of hogs or cattle as converters of grain into meat, or because of a change in the industrial demand for corn. On the supply side, corn production may increase because of a wide adoption of high-yielding hybrid corn, or the breeding up of early maturing drouth resisting varieties of corn adapted to northwest central states, and so on; or it may decrease because of soil erosion in some areas, which would necessitate a reduction in corn acreage.

The present bulletin deals mainly with the demand side of the question; a later bulletin will deal with the supply side. The first part of the present bulletin deals briefly with the corn situation as it stands today. The second part deals in detail with the present and prospective demand for corn, taking up first the agricultural demand, and then the industrial demand.

### WORLD PRODUCTION AND TRADE IN CORN

Let us first determine the position of the United States as a corn producer with respect to the rest of the world, and then investigate her position in world trade in corn.

#### RELATIVE IMPORTANCE OF THE UNITED STATES AS A PRODUCER OF CORN

For the period 1928-29 to 1932-33,<sup>5</sup> the average world production of corn was estimated at 4.3 billion bushels. The average production of corn in the United States during this period was nearly 2.6 billion bushels. This is 59 percent—roughly three-fifths—of the total world production. The United States, therefore, produced more corn than all the other countries of the world put together.

The corn production data by countries for the past few years are shown in table 2.<sup>6</sup> This table shows that corn pro-

<sup>5</sup> The year 1934 is omitted because of the drouth in that year.

<sup>6</sup> U.S.D.A. Yearbook, 1934, pp. 417-419.

TABLE 2—PRODUCTION OF CORN IN THE PRINCIPAL PRODUCING COUNTRIES—1928-29 TO 1932-33

Country	Production (million bu.)	Percent of world total
United States.....	2,557	59.3
Argentina.....	303	7.0
Rumania.....	204	4.7
Brasil*.....	188	4.4
Russia.....	134	3.1
Yugo-Slavia.....	137	3.2
Italy.....	98	2.2
South Africa.....	80	1.9
Java and Madam.....	73	1.7
British India.....	72	1.7
Mexico.....	70	1.6
Hungary.....	66	1.5
Bulgaria.....	33	0.8
Spain.....	26	0.6
France.....	19	0.4
Other countries (Excluding Russia).....	256	5.9
Total.....	4,314	100.0

\*8 year average 1928-31.

Source: U. S. D. A. Yearbook, 1934, pp. 417-419, with revisions from the U. S. D. A. Bureau of Agricultural Economics, 1934 Revised Estimates of Corn Acreage, Production and Yield, and Dec. 1934 U. S. D. A. Crop Report.

duction in the United States averages between 2.5 and 2.6 billion bushels, while in Argentina, the next largest producer, it averages about 300 million bushels. It is evident that as a corn producer the United States outranks Argentina, the next most important corn producing country, 8 or 9 times to one.<sup>7</sup>

Since the World War, the United States has been losing some of its world leadership as a corn producer. Table 3, reproduced graphically in fig. 2, shows that from 1900 to 1920, the United States-corn crop averaged 68 percent of the world crop, fluctuating from 59.9 to 73.4 percent. Over this period of years the trend of the percentage which the United States crop constituted of the world crop ran horizontal.

Since the war, however, the trend of the percentage has been declining. During the years 1928-29 to 1932-33, as shown in table 3, the percentage averaged 59.3. A low point of 52.8 percent was touched in 1930-31, largely because of the poor crop in the United States that year. The figure for the most recent year, 1933-34, was 58.0 percent. Looking at fig. 2, one can see that whereas before the war most of the data ranged

<sup>7</sup> The ratio between the corn acreages in the two countries is about 10 to 1, because yields per acre in the Argentine run about 10 percent higher than yields in the United States. Yields fluctuate very violently in Argentina from year to year, chiefly because of the extreme fluctuations in the rainfall. See Whitbeck, R. H., and Finch, V. C. Economic Geography, 1930, pp. 301-15.



TABLE 2—UNITED STATES AND WORLD CORN PRODUCTION  
(1,000,000 bus.)

	United States*	World †	Percent of world production
1900-01.....	2662	3750	71.0
1901-02.....	1716	2884	59.9
1902-03.....	2774	3841	72.2
1903-04.....	2515	3822	67.6
1904-05.....	2687	3663	73.4
1905-06.....	2954	4109	71.9
1906-07.....	3033	4230	71.7
1907-08.....	2614	3864	67.7
1908-09.....	2567	3811	67.4
1909-10.....	2611	3985	65.5
1910-11.....	2853	4119	69.3
1911-12.....	2475	3839	64.5
1912-13.....	2948	4271	69.0
1913-14.....	2273	3770	60.3
1914-15.....	2524	4041	62.5
1915-16.....	2829	4185	67.6
1916-17.....	2425	3635	66.7
1917-18.....	2908	4021	72.3
1918-19.....	2441	3517	69.4
1919-20.....	2679	4105	65.3
1920-21.....	3071	4552	67.5
1921-22.....	2928	4170	70.2
1922-23.....	2707	4043	67.0
1923-24.....	2875	4347	66.1
1924-25.....	2298	3867	59.4
1925-26.....	2853	4517	63.2
1926-27.....	2575	4375	58.9
1927-28.....	2678	4241	63.1
1928-29.....	2715	4224	64.3
1929-30.....	2536	4318	58.7
1930-31.....	2060	3904	52.8
1931-32.....	2567	4387	58.5
1932-33.....	2907	4739	61.3
1933-34.....	2330	4009	58.1

\*Revised Estimates of Corn Acreage, Production and Yield, U. S. D. A., Minn. report, 1934, and Dec. 1934 Crop Report.

†Computed by substituting Revised U. S. data in place of 1934 Yearbook Figures.

between 65 and 70 percent, during the past 5 years they range between 55 and 60 percent—a decline of a full 10 points.

Figure 2 shows that world production of corn has remained roughly constant during the past 20 years; the decline in the relative position of the United States has been the result of a decline in the production of corn in the United States and a compensating increase in other countries.

In which other countries has the recent increase in corn production taken place? Table 4 and fig. 3 show that the principal increases in recent years have occurred in the Argentine, Russia, Rumania and Yugoslavia.<sup>a</sup>

#### UNITED STATES EXPORTS AND IMPORTS OF CORN

Before discussing the bearing of these changes in corn production upon corn producers in the United States, we need to consider not only world corn production, but also international trade in corn.

<sup>a</sup> U.S.D.A. Yearbook, 1934, pp. 418-419.

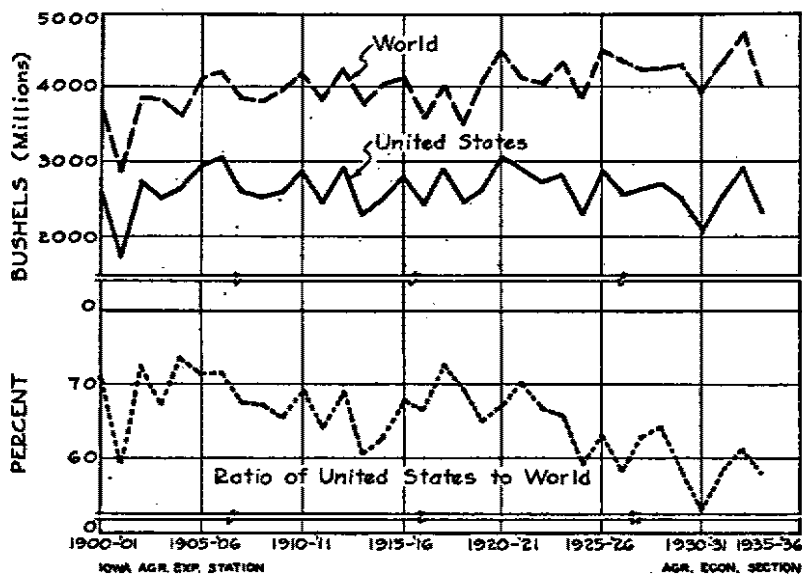


Fig. 2. United States and world production of corn, 1900-01 to 1933-34.

From 1928-29 to 1932-33, annual corn exports of the leading surplus producing countries, including corn meal in terms of grain, were estimated at 326 million bushels, 8 percent of total world corn production. Preliminary figures for 1932-33 place total exports at 349 million bushels, about half that of wheat.<sup>9</sup>

Corn exports from the United States, never very large, now constitute only an insignificant part of the total corn crop—a small fraction of 1 percent. The decline during recent years is shown in the tabulation of the United States' exports and imports in table 5.

In 1925-26 to 1929-30 the United States ranked third in the world as a corn exporting country; in 1931-32 it had dropped to eighth place and in 1932-33, to fifth place.<sup>10</sup>

#### COMPETITION BETWEEN THE UNITED STATES AND ARGENTINA

Comparative figures for the 5-year period 1929-30 to 1933-34 show that while the United States produced over eight times

<sup>9</sup> Average wheat exports, 1925-26 to 1929-30, were 800 million bushels. Preliminary estimates for 1932-33 were 828 million bushels. (Wheat, including flour, in terms of grain, for all exporting countries). U. S. D. A. Yearbook of Agriculture, 1934, pp. 409 and 422.

<sup>10</sup> Data in this and next few paragraphs from U. S. D. A. Yearbook, 1934, p. 422.

TABLE 4—CORN PRODUCTION IN SELECTED COUNTRIES  
(1000 bu.)

Country	1909-14	1921-26	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35
Argentina.....	191,698	227,393	280,617	419,661	299,329	263,765	246,000	433,000*
Rumania.....	101,000	140,515	251,410	177,940	247,638	235,930	185,000	189,000
Brazil.....		177,338	173,878	200,140				
Yugo-Slavia.....	30,000	109,399	163,285	136,393	126,000	189,000	144,000	303,000
Russia.....	86,000	91,344	118,838	105,015	181,092	135,000	189,000	
Italy.....	102,876	94,793	99,622	117,560	77,000	119,000	102,000	128,000
Hungary.....	60,813	68,353	70,631	55,395	60,000	96,000	71,000	83,000
Mexico.....	133,362	84,882	57,824	54,200	84,000	78,000	76,000	67,000

Source: 1909-14—1934 Yearbook, Page 417  
 1921-26—1934 Yearbook, Pages 418-419  
 1929-30—1933 Yearbook, Pages 435-436  
 1930-31—1934 Yearbook, Pages 418-419  
 1931-32—1934 Yearbook, Pages 418-419  
 1932-33—1934 Yearbook, Pages 418-419  
 1933-34—1934 Yearbook, Pages 418-419  
 1934-35—Foreign Crops and Markets, March 11, 1935, p. 249.

\*Preliminary.

as much corn as her closest rival, Argentina, the latter out-ranked the United States 40 to 1 as a corn-exporting country. During this period slightly over 70 percent of the world trade in corn originated in Argentina, and her exports of corn equalled 83 percent of her production.

While the corn exports of the United States have declined in recent years, those of Argentina, the leading exporting nation, have increased. They rose from an average of 220 million bushels during the period 1925-26 to 1929-30 to nearly 387 million bushels in 1931-32. In 1932-33, owing to a short crop, exports of corn from Argentina fell to only 207 million bushels.

TABLE 5—UNITED STATES EXPORTS AND IMPORTS OF CORN\*  
(Including corn meal in terms of grain)

Year (July 1 to June 30)	Exports		Imports
	(1000 bu.)	Percent of U. S. crop	(1000 bu.)
Average			
1899-00 to 1903-04.....	111,454	4.5	17
1904-05 to 1908-09.....	77,857	2.8	63
1909-10 to 1913-14.....	41,409	1.6	2,699
1914-15 to 1918-19.....	45,882	1.7	4,785
1919-20 to 1923-24.....	77,371	2.7	3,328
1925-26.....	24,783	0.9	637
1926-27.....	19,919	0.8	1,098
1927-28.....	19,499	0.7	5,463
1928-29.....	41,876	1.5	490
1929-30.....	10,270	0.4	497
1930-31.....	3,317	0.2	1,747
1931-32.....	3,969	0.2	386
1932-33.....	8,775	0.3	195
1933-34.....	4,965	0.2	244

\*U. S. D. A. Yearbook, 1934, p. 414. 1934 data from Foreign Crops and Markets, August 6, 1934 and November 19, 1934.

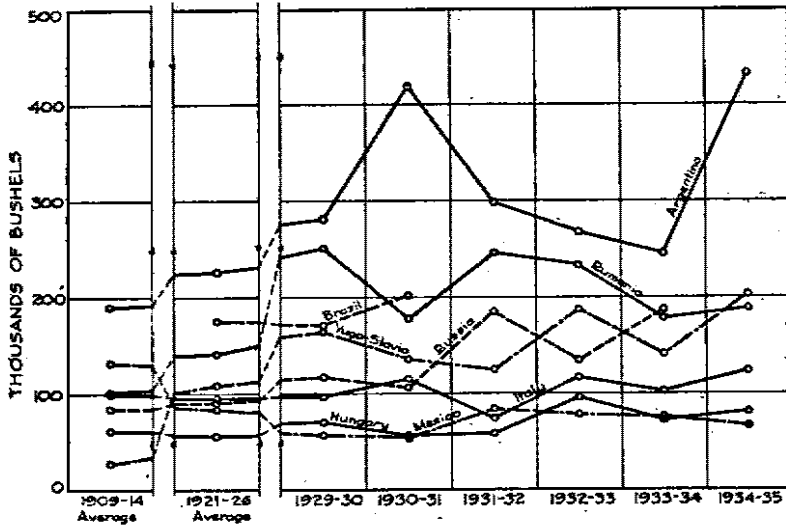


Fig. 3. Corn production in leading corn producing countries for pre-war and post-war periods, and annually since 1929-30.

In 1933-34, Argentina exports were 218 million bushels. In 1934-35, however, a record crop was harvested, and exports from it will undoubtedly be great. The trend of Argentina's exports appears to be upward.<sup>11</sup>

Shipments from Argentina, in the main, are consigned to the feed deficit countries of southern Europe, the non-corn produc-

<sup>11</sup> These comparisons are based upon the following data taken from U. S. D. A. Yearbooks 1934, pp. 418-422, and 1933, p. 435 with some revisions given in Foreign Crops and Markets March 11, 1935, pp. 248 and 257, and United States General Crop Report, December 1934, U. S. D. A. Bureau of Agricultural Economics.

#### CORN PRODUCTION (Thousand bushels)

	United States	Argentina
1929-30 .....	2,535,366	280,617
1930-31 .....	2,065,273	419,661
1931-32 .....	2,588,509	399,329
1932-33 .....	2,906,873	263,765
1933-34 .....	2,351,658	246,000

#### EXPORTS OF CORN (Thousand bushels)

	Total of principal exporting countries	United States	Argentina
1929-30 .....	274,465	10,281	168,585
1930-31 .....	375,356	3,317	274,044
1931-32 .....	482,231	3,969	388,262
1932-33 .....	352,615	8,775	306,840
1933-34 .....	272,307	4,065	218,242

ing countries of northern Europe, and England. Further, in spite of an existing 25 cents per bushel duty on corn imports into the United States, some Argentina shipments enter the United States along the Pacific coast and go to some of the New England states. The demand for this corn originates principally from the highly commercialized poultry industries, located in these areas because of closeness to market rather than to feed supply.<sup>12</sup>

#### OTHER CORN EXPORTING COUNTRIES

Argentina, we have seen, exports over 80 percent of her corn crop. Other countries rank considerably lower in the percentage exported. South Africa, from 1925-26 to 1931-32, shipped about 25 percent of her corn abroad, mainly to the United Kingdom. During the same period, Rumania, Bulgaria, Yugoslavia and Hungary shipped about 20, 16, 12 and 5 percent of their respective corn crops to the adjacent central and southern European deficit corn areas.

#### CORN IMPORTING COUNTRIES

Corn is a staple in the diet of the southern European countries, where it is called "polenta." A considerable part of our corn exports has been shipped to these countries in the past.

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<sup>12</sup> Fundamental differences in the economic structure of the United States and Argentina count for the wide disparity in the ultimate disposition of their respective corn crops. More than 85 percent of the corn crop of the United States is fed to livestock; corn is exported, in the main, in the form of pork products. Although Argentina possesses a considerable area which is naturally adapted to corn growing, there are several reasons why she is a corn exporting country, chief of which are: (1) The country is too sparsely populated to consume much of her production at home, (2) livestock there is fattened mostly on alfalfa, (3) the hog industry is relatively undeveloped, (4) small land holders producing and feeding their own livestock, so common in the United States, are comparatively few in Argentina, where most of the farming is done by short-term tenants on landed estates, whose insecure tenure discourages animal production.

The greater proportion of Argentina corn is flint corn, which is harder and has a lower moisture content than the common dent varieties grown in the United States. Because of these properties, Argentina corn is less affected by the changing conditions encountered on long ocean hauls than the American corn. It will stand ocean shipment across the equator, while dent corn would be likely to go out of condition because of the moisture and heat encountered on the trip. Another advantage is the fact that transportation costs in Argentina are less because of the shorter haul from the surplus producing areas to seaboard points. This is important, especially in times of low prices when transportation costs make up a very large part of the ultimate selling price. Lastly, the small, hard kernel of Argentina's flint corn is considered superior to the American corn for poultry feeding in some parts of Europe and on the Pacific coast of the United States. For these reasons, Argentina is in a more favorable competitive position than the United States to do a large corn export business.

For a fuller discussion, see Schultz, Theodore W., "The Tariffs on Barley, Oats and Corn," Tariff Research Committee, Madison, Wisconsin, 1933. See also Jefferson, Mark, "Peopling of the Argentine Pampa," Whitbeck, R. H., and Finch, V. C., "Economic Geography," pp. 301-315; and Smith, J. Russel, "Industrial and Commercial Geography," 1925, pp. 109-110, referred to by Schultz.

In the group of northern European countries, Denmark and the Irish Free State hold a conspicuous place as importers of corn. These countries are both serious competitors in our foreign pork and pork products trade. In this group are also Great Britain and Germany, which are important foreign consumers of our pork and pork products. Presumably, the larger proportion of the imports of corn by northern European countries is being fed to hogs.

Corn imports by the normally deficit corn producing countries, Italy, France, Czechoslovakia and Austria,<sup>13</sup> in 1931-32 were more than double those of 1925-26. Spain and Canada were the only countries that decreased their imports. In the non-corn producing countries, with the exception of Germany, the trend of imports is also upward.

This situation can be summarized by saying that foreign corn consuming countries are increasing their imports of corn, at the same time that our exports of corn are decreasing to the vanishing point. Our corn producing competitors are slowly displacing us in the international corn market.<sup>14</sup> This trend was clearly evident before the AAA. Foreign importers of corn are increasing their imports, but they are buying more from our competitors and less from us.

#### UTILIZATION OF THE UNITED STATES CORN CROP UTILIZATION OF THE CORN ACREAGE

Let us now consider in some detail the utilization of the corn crop in the United States.

Not all of the corn in the United States is harvested for grain. Of the average acreage for the two years 1932-33, 4.1 percent was cut for silage, 9.1 percent was "hogged down" or used for forage, and the remainder, 86.8 percent, was harvested for grain.<sup>15</sup>

A considerable variation in the amount of corn acreage used for the above purposes is found in the different sections of the country. In the Corn Belt states, where hog production is concentrated, about 11.9 percent of the crop is "hogged down,"

<sup>13</sup> These paragraphs are based upon a chart and statistics given in *Le Mals Dans Le Commerce Mondial*. Institute International D'Agriculture, Rome, 1932, pp. 41-2.

<sup>14</sup> This is not because we are finding it more advantageous to export our corn in the form of pork and pork products, for our exports of pork and pork products have also been decreasing.

<sup>15</sup> The calculations in this section are made from data given in U. S. D. A. Statistical Bulletin 28, *Corn Statistics*, January, 1930; *Yearbook of 1932*, Board of Trade, Chicago; U. S. D. A. *Yearbook of Agriculture*, 1934.

4.8 percent is cut for silage, and about 83.3 percent is harvested for grain. In the dairy states of New England and the Pacific northwest, and also Wisconsin, from 15 to 50 percent of the corn crop is cut for silage, about 10 to 50 percent is "hogged-down," and the balance is harvested for grain. In the southern states practically all of the crop is harvested for grain.

#### MOVEMENT OF CORN HARVESTED FOR GRAIN

The average amount of corn harvested for grain in the United States during the 5-year period, 1929 to 1933, was about 2.2 billion bushels. Eighty percent of this amount, or 1.75 billion bushels, was consumed directly on the farms in the counties where grown. The balance, equivalent to about 450 million bushels, was shipped out of the county where grown; this figure includes the shipments of corn (about 240 million bushels) which were consigned to the commercial grain markets.

Detailed figures as to the destination of the corn shipped out of the county where grown are difficult to obtain. One source of information quotes the Department of Agriculture as having reported that: "59.3 percent of this shipped corn moved east, 8.4 percent west, 9.5 percent north and 22 percent south."<sup>16</sup>

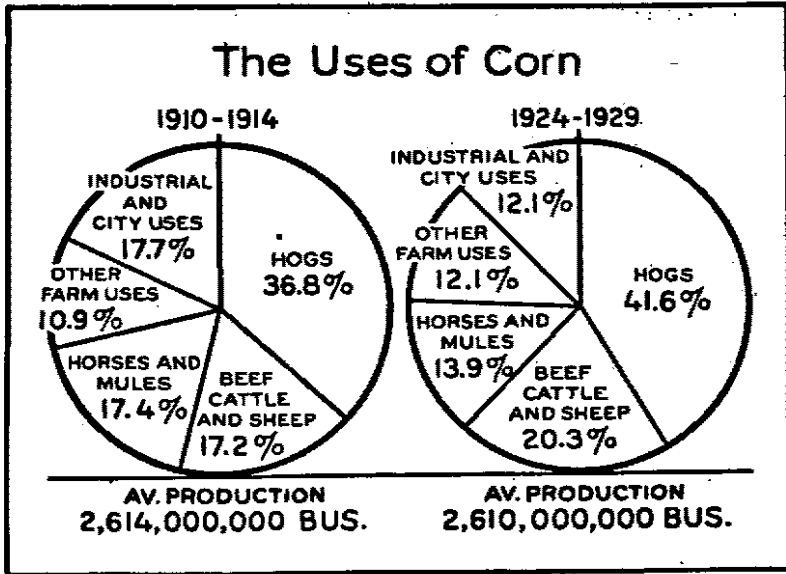
The amount of corn which leaves the farm depends upon several factors, chiefly: (1) The size of the crop and the price of corn, (2) the numbers of livestock being fed, and (3) the crop conditions of the cattle feeders and dairymen in the corn deficit areas. The latter, especially, is one of the determining influences governing corn receipts at the commercial grain markets. In a year of comparatively normal crops in the surplus corn areas and short crops in the deficit corn areas, receipts at the primary markets are likely to be small; shipments to the deficit corn areas, in such instances, are more commonly handled by the local grain dealers and elevators direct.<sup>17</sup>

#### CHANGES IN CONSUMPTION OF CORN, 1910-14 TO 1926-29

The average consumption of corn by the various outlets for this crop, for the periods, 1910 to 1914, and 1924 to 1929, is given in table 6. The data are shown graphically in fig. 4.

<sup>16</sup> What Becomes of Nation's Corn Crop? Ohio Farmer, IV-156, Feb 6, 1926.

<sup>17</sup> Bentley, R. C. "The Movement of Iowa's Commercial Corn and Oats," and "The Destination of Iowa's Commercial Corn." Iowa Agr. Exp. Sta. Buls. 252 and 318, respectively.



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Fig. 4. The uses of corn.

These estimates, prepared by the Bureau of Agricultural Economics, are the latest comprehensive estimates available. The authors urged the bureau to extend its estimates to include the period 1930 to 1934, without success, and were forced to abandon an attempt to do it themselves because of lack of time and data. The estimates for some sectors of the demand are brought up to date by the authors later in this bulletin, but data for some are lacking.

TABLE 6—CORN UTILIZATION: 1910-14 AND 1924-29

Uses	1910-1914			1924-1929		
	Thousand head	Million bushels	Percent of crop	Thousand head	Million bushels	Percent of crop
Livestock on farms:						
Horses and mules	24,733	455	17.4	21,514	362	13.9
Cattle	57,259	424	16.2	60,172	505	19.3
Hogs	53,300	963	36.8	58,410	1,085	41.6
Sheep	43,447	26	1.0	41,878	28	1.0
Poultry		235	9.0		270	10.4
Livestock NOT on farms		183	7.0		65	2.5
Industrial and commercial uses		235	9.0		230	8.8
Exports		44	1.7		22	.8
Famine on farms		31	1.2		28	1.0
For seed		16	.7		18	.7
<b>Total</b>		<b>2,614</b>	<b>100.0</b>		<b>2,610</b>	<b>100.0</b>

Allowance made for corn cut for silage, hogged down, or used for forage.  
Source: U. S. D. A. Bureau of Agricultural Economics.



According to the data in the preceding table, 86.2 percent of the total corn crop was fed to the various classes of livestock on farms during the period 1924-29.

Marked changes took place between the two periods in relative consumption of corn by the different groups of livestock. The average crop, it will be noted, was approximately the same for both periods, but consumption by horses and mules on farms declined from 17.4 percent in 1910-14 to 13.9 in 1924-29, while that of livestock not on farms declined from 7.0 percent in 1910-14 to 2.5 in 1924-29. On the other hand, cattle, hogs and poultry showed increases in consumption. In other words, horses and mules on farms consumed about 20 percent less corn in 1924-29 than in 1910-14; livestock not on farms consumed 67 percent less and cattle, hogs, and poultry showed increased consumption of 19, 13 and 15 percent, respectively.

### THE AGRICULTURAL DEMAND FOR CORN

One of the major reasons for the changes in corn consumption from 1910-14 to 1924-29 is changes in the numbers of the various kinds of livestock in the United States. These changes are shown in fig. 5. The situation for each kind of livestock is discussed in turn in the following sections. The discussion is somewhat brief, since it is given in some detail in an earlier publication<sup>18</sup> which is here brought up to date.

#### HORSES AND MULES

A drastic reduction has taken place in the numbers of horses and mules in the United States since the World War. The net reduction in the amount of corn formerly consumed by this class of stock, since 1920, (if the same per capita consumption of corn by horses and mules is assumed for 1935 as for the period 1924-29) amounts to slightly over 180 million bushels.<sup>19</sup>

<sup>18</sup> Shepherd, Geoffrey. The Secular Movement of Corn Prices, Iowa Agr. Exp. Sta., Rea. Bul. 140, 1931.

<sup>19</sup> This figure has been arrived at as follows: Average consumption of corn, 1924-29 (table 5), 302 million bu. Average number of horses and mules on farms, 1924-29, 21,514,000. Per capita consumption of corn.....16.8 bushels.

Estimated Decrease in Corn Consumption		
Horses and mules on farms 1920.....	25,748,000	
Horses and mules not on farms, 1920.....	2,064,000	
Total.....		27,812,000
Horses and mules on farms Jan. 1, 1935.....	16,622,000	
Horses and mules not on farms, 1930 (latest available).....	375,000	
Total.....		16,997,000
Total decrease in horses and mules.....		10,815,000
Decrease in corn consumption @ 16.8 bu. per head.....		182,628,000

The data in this footnote are taken from U. S. D. A. Yearbook of Agriculture, 1934, pp. 124 and 623, the 14th Census of Agriculture, Vol. V., p. 614, and U. S. Livestock Report, mimeographed, Feb. 15, 1935.

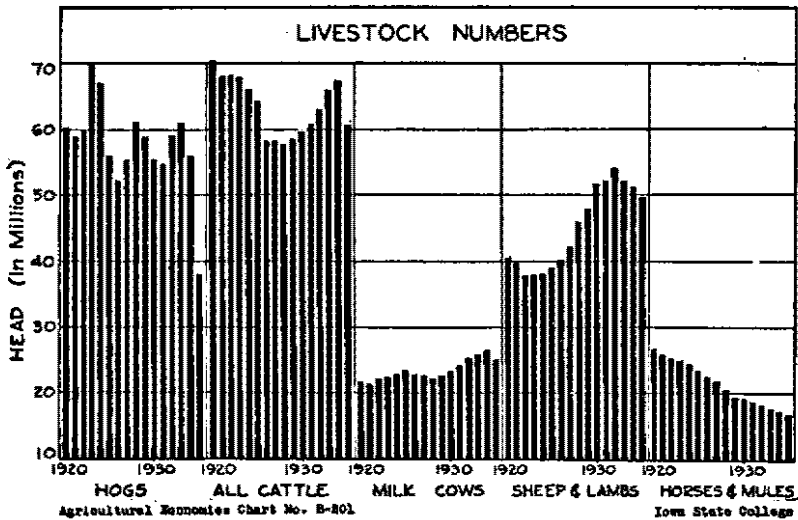


Fig. 5. Number of animals on farms as of Jan. 1, 1920 to 1934.

Horses and mules now consume only 11 percent of the corn crop, when formerly (just before the war) they took 17.4 percent. That is, the horse and mule demand for corn during the past 20 years has been cut 40 percent.

The decline in the number of horses and mules is the result, chiefly, of the substitution of motor power for animal power, which was given a great impetus by the World War. While farm purchases of mechanized equipment have declined during the past 2 or 3 years, this decline can be attributed to the ill-effects which the depression has had upon farm income, rather than to the lack of potential demand for this kind of equipment. The number of tractors on farms, according to census figures, increased 2.5 times from 1920 to 1930, to a total of 920,000 for the latter years; truck numbers increased about 5.5 times, to a total of 900,385 in 1930.

This substitution of mechanical power for animal power has not yet reached its limits, but it is beginning to approach them. The decline in the number of horses and mules appears now to be slowing down. "In the case of horses the decrease from Jan. 1, 1934, to Jan. 1, 1935, was only about 1 percent and was

the smallest decrease in any year since horse numbers began to decline about 20 years ago. The percentage decrease in the number of horses 2 years old and over was about the same as in other recent years, but there was a sharp increase in colt raising in 1933 and 1934. The number of colts under 1 year old Jan. 1, 1935 (colts raised in 1934), of 692,000 head, was 27 percent larger than a year earlier and 57 percent larger than on Jan. 1, 1931, and the largest number since 1922. The number of mules and mule colts decreased about 3 percent between Jan. 1, 1934, and Jan. 1, 1935. Although there was some increase in the number of mule colts raised in 1934 over 1933, this increase was less marked than with horse colts.<sup>20</sup>

## HOGS

### Increase in Domestic Slaughter

Figure 5 shows that corn consumption by hogs on farms increased from 963 million bushels during the pre-war period, 1910-14, to 1,085 million bushels in the period 1924-29. This is an increase of 13 percent.

The reasons for the increase are (1) the roughly 10 percent increase in numbers of hogs on farms from 1910-14 to 1924-29, (2) the increase of 33 percent in the number of hogs slaughtered, over the same period. Along with these increases in hog numbers, however, have gone changes in feed rations—the more extensive use of protein supplements, of barley and some other grains in place of corn, the development of more rapidly maturing breeds of hogs, and the increase in the number of pigs saved per litter. These changes have reduced the per capita demand of hogs for corn, so that the increase in total hog demand for corn is not as great as the increase in hog slaughter.

It is difficult to make accurate estimates of the precise effect of these changes on the total hog demand for corn, particularly since the beginning of the depression in 1929, which has greatly affected price relationships between hogs and hog feeds and between hog feeds themselves. Intensive research into this section of the demand for corn is required. Pending such research, we can only point out that if hog slaughter fails to increase above 1924-29 levels (and at present, owing to the AAA program and the 1934 drouth, hog slaughter is substantially below those levels) the decrease in per capita hog demand for

<sup>20</sup>The Agricultural Situation. March 1, 1935. Volume 19, No. 3. Washington, D. C.

corn which is likely to continue in the future will decrease the total hog demand for corn.

#### CATTLE

Consumption of corn by cattle was estimated in 1910-14 at 424 million bushels per year; in 1924-29 it was 505 million bushels, an increase of 81 million bushels, or 19 percent (see table 5). Numbers of cattle on farms for these periods were 57,259,000 and 60,172,000, respectively; reduced to a per capita basis, corn consumption was 7.4 and 8.4 bushels, respectively.

Part of the increased corn consumption for 1924-29 as compared with that of 1910-14 is therefore explained by the increase in cattle numbers. But since the per capita cattle consumption of corn increased also, there must have been other factors operating as well. One of these factors may well be the increased milk production per cow during the period 1924-29. Although there was relatively little change in the milk cow numbers during these years, milk production per cow increased from 2,903 pounds in 1924 to 4,426 pounds in 1929.<sup>21</sup>

This increase in milk production per cow resulted from improvements in care and management, and from more intensive feeding.

#### POULTRY

The consumption of corn by poultry increased from 9 percent of the total crop in 1910-14 to 10.4 percent of the crop in 1924-29. Apparently, there has been little increase since 1926; the number of chickens on farms since 1926 has fluctuated closely about 450 million.

#### SHEEP

The consumption of corn by sheep for the periods 1910-14 and 1924-29 shows no change, although the number of sheep on farms in the latter period was slightly below that of 1910-14. The amount of corn for both periods was estimated at 26 million bushels, or about 1 percent of the total corn crop.

Sheep production, following a period of 9 years of expansion in numbers, (from 1924 to 1932 inclusive), is now declining. The data in the preceding paragraph indicate, however, that changes in sheep numbers cause very little change in the total

<sup>21</sup> Number of dairy cows in 1924, 22,268,000; in 1929, 22,330,000. The highest number for the period was in 1923, 22,503,000; the lowest number was in 1928, 22,129,000. U. S. D. A. Yearbook of Agriculture, 1933, p. 634. Figures on milk production obtained from the pamphlet, "The Agricultural Situation," Bureau of Agricultural Economics, U. S. D. A. Vol. 18, No. 5, May, 1934, p. 10-11.

consumption of corn, since sheep consume a very small percentage of the total crop.

#### OTHER CHANGES IN THE AGRICULTURAL DEMAND FOR CORN

Two small agricultural outlets for corn remain to be discussed: The amount of corn consumed by families on farms and that used for seed purposes. The combined corn consumption by these outlets amounts to about 1.5 percent of the crop.

In 1910-14 families on farms consumed 31 million bushels of corn; for the period 1924-29 this figure dropped to 26 million bushels, a decline of about 16 percent. In keeping with the changing dietary habits of the American people, the corn consumed by families on the farm will, undoubtedly, show a further decline in the coming years.<sup>22</sup>

The amounts of corn used for seed purposes during the two periods under consideration were identical—about 18 million bushels. Future requirements will depend, of course, upon the trend of corn production. Present indications point to some decline in acreage; changes in the amount of seed employed, however, will be negligible.

#### THE INDUSTRIAL DEMAND FOR CORN

About 7 percent of the total United States corn crop is used for industrial purposes; it is ground or otherwise processed in corn products factories and made into cornstarch, corn sirup, corn sugar, corn meal, hominy, breakfast foods, industrial alcohol, and a number of by-products.

An idea of the relative importance of the industrial demand for corn may be gained by comparing it with some of the sections of the agricultural demand. Since the industrial demand takes about 7 percent of the corn crop, it is two-thirds as important as the demand for feeding to horses and mules, which now takes about 11 percent of the crop. It is roughly equal to one-third of the demand for feeding to cattle. And it is nearly equal to the lard section of the hog demand for corn, since the total hog demand takes between 40 and 45 percent of the corn crop, and lard represents about one-fifth of the value of hogs.

<sup>22</sup> U. S. D. A., Economic bases for the Agricultural Adjustment Act, December, 1933, p. 36.

## EFFECT OF CHANGES IN INDUSTRIAL CONSUMPTION OF CORN

The statement is often made that the corn which flows through the channels of trade, even though it is less than 10 percent of the total production of corn, sets the price for the entire crop. The further opinion is sometimes added that if a new industrial use for corn were discovered, which would use up say 5 percent of the total crop, that would increase the industrial demand 50 percent, and that in turn would raise the price of corn 50 percent.<sup>23</sup>

This view is not borne out by the facts. Statistical studies have shown that the chief factors determining the price of corn are: (1) The demand for meat, which is reflected in the numbers of livestock (which consume over 85 percent of the corn crop) and the prices of livestock, and (2) the size of the total United States corn crop.<sup>24</sup> There is no statistical indication that the amount of corn which passes through the markets is an important price determining factor.

An increase in industrial demand which opened up a new outlet for 5 percent of the total production of corn would have the same effect on prices as an equal increase in demand coming from any other source—increased number of hogs, or cattle, or horses and mules, on the farm or off. The statistics indicate that an increase in consumption equal to 5 percent of the total crop, from whatever source, would raise the farm price of corn about 8 percent. This is well worth going after, of course. But we should not delude ourselves into thinking that if the 5 percent increase came from some new industrial outlet, it would raise prices 50 percent. It would raise them only 8 percent. Our energies will be better directed if we focus our attention on this more modest gain.

### THE MILLED PRODUCTS OR "DRY-PROCESS" INDUSTRY

The industrial demand for corn originates from three chief sources: (1) The milled products industry, (2) the corn products refining industry, and (3) the manufacturers of industrial alcohol, distilled spirits and cereal beverages. We shall discuss these sources of industrial demand in the order given.

<sup>23</sup> Des Moines Register, Aug. 25, 1932. Editorial Page.

<sup>24</sup> Shepherd, Geoffrey, Annual fluctuations in the price of corn. Iowa Agr. Exp. Sta., Bul. 100, 1930.

The milled products or "dry-process" industry embraces the manufacturers of the various cereal foods. The industry gets its name from the fact that it grinds or mills corn in a dry condition. The chief products manufactured from corn in this industry are four in number—flaked hominy and hominy grits, corn meal, corn flour and corn breakfast foods.<sup>25</sup>

In the manufacture of these products, the hull and germ of the corn<sup>26</sup> are first removed. The rest of the corn, the starchy body of the seed, is then coarsely crushed and screened. The very coarse particles are sold as flaked hominy; when more finely ground they are sold as hominy grits. When the grinding process is carried still further, the product becomes corn meal, and finally, corn flour.

#### Decrease in Consumption of Corn by Milled Products Industry

The number of bushels of corn consumed by this industry, at periodic intervals from 1899 to 1931, is shown in table 7 and fig. 6.

TABLE 7—AMOUNT OF CORN GROUND BY THE MILLED-PRODUCTS INDUSTRY

Year	Thousands of bushels
1899.....	180,573 <sup>1</sup>
1909.....	209,281 <sup>2</sup>
1914.....	180,116 <sup>3</sup>
1919.....	113,761 <sup>2</sup>
1921.....	122,168 <sup>3</sup>
1923.....	125,194 <sup>4</sup>
1925.....	105,355 <sup>4</sup>
1927.....	82,693 <sup>5</sup>
1929.....	87,453 <sup>5</sup>
1931.....	53,902 <sup>5</sup>
1933.....	40,112 <sup>6</sup>

<sup>1</sup>1910 Census of Manufactures, Vol. X, p. 415.

<sup>2</sup>1920 Census of Manufactures, Vol. X, pp. 111-112.

<sup>3</sup>Statistical Abstract of United States, 1925.

<sup>4</sup>Statistical Abstract of United States, 1931, p. 747.

<sup>5</sup>Statistical Abstract of United States, 1933, p. 631.

<sup>6</sup>Letter from Norman F. Kennedy, Director of Research, Corn Industries Research Foundation, New York City.

Figure 6 shows that before the war, the milled products industry used about 200 million bushels of corn annually. This was about 8 percent of an average United States corn crop. After the war, the annual consumption of corn by the milled

<sup>25</sup>Corn breakfast foods—corn flakes, for example—are considered as being separate from the milled products industry in the Census of Manufactures. For present purposes, however, this corn food product can be discussed under milled products, since corn milling establishments also produce corn breakfast foods as secondary products.

<sup>26</sup>The corn kernel consists of three parts, (a) the outer covering, or hull; (b) the endosperm, or starchy body of the seed; (c) the embryo, or germ.

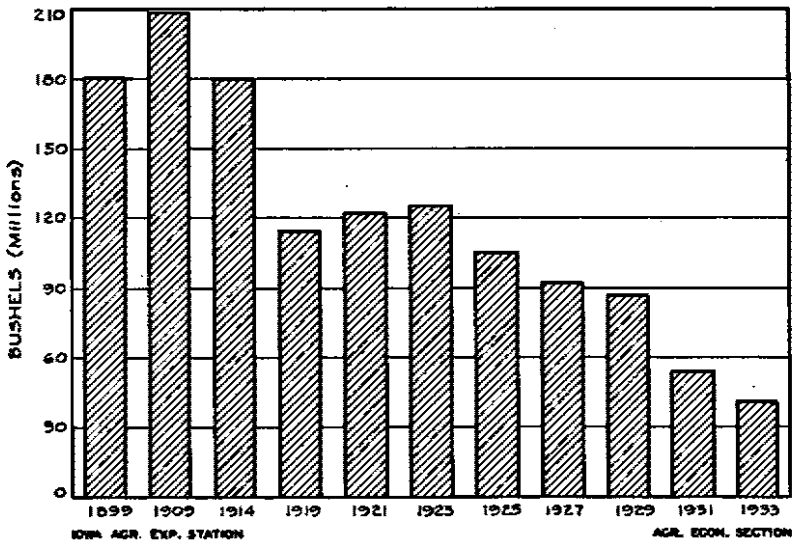


Fig. 6. Amount of corn grown by milled products industry.

products industry declined to about 100 million bushels. During the recent depression, consumption declined further, to 40 million bushels. This is about 2 percent of an average United States corn crop.

The downward trend in corn consumption by this industry has been very pronounced, especially since the close of the World War. It is, in the main, the result of a shift in human dietary habits from the starchy type of foods to those richer in protein. This shift in turn has resulted chiefly from the declining proportion of our population that is engaged in muscular work, and from the rise in the standard of living of certain groups, particularly of negroes who have come north since the World War. In addition, the exports of milled corn products have substantially declined.<sup>27</sup>

The dietary changes which have reduced the consumption of milled corn products in the past are likely to persist and in fact to carry on further in the future. There will probably be some recovery from the low levels of consumption of milled corn products during the recent depression, but it seems likely that the general trend of the consumption of corn by the milled products industry in the future will be downward.

<sup>27</sup> Statistical Abstract, 1933, p. 433.



### Increase in Consumption of Corn Breakfast Foods

The consumption of one somewhat minor milled corn product, corn breakfast foods—corn flakes, etc.—has been increasing in recent years, in contrast with the general downward trend. Census figures for the production of corn breakfast foods were taken separately for the first time in 1925; production has increased from 250 million pounds then to 385 million pounds in 1931. No estimate is given in the census reports as to the corn equivalents of these figures. The Bureau of Agricultural Economics, however, estimates that one bushel of corn is converted, on the average, into 21 pounds of corn breakfast foods. This means that 12 million bushels of corn were made into corn breakfast foods in 1925, and 18 million bushels in 1931. The percentage increase is great, and further increases are likely to take place; but the amounts involved are comparatively small.

### Net Effect of Dietary Changes on Corn Consumption

It has sometimes been suggested that a campaign should be started to increase the consumption of the milled corn products in the average American diet, with the object of increasing the demand for corn. Such a campaign, however, would be working against the trend, and even if successful would result only in the displacement of some other food product from the average menu. This is clearly brought out by the Department of Agriculture in a study of changes in the consumption of food products per person, from 1909 to 1931. This study shows that while there has been a decline in the per capita consumption of all cereal products, at the same time, increases in the consumption of other food products, principally fruits, vegetables, sugar, meat and dairy products, have offset these declines, so that little or no change has occurred in the total per capita food consumption.<sup>28</sup>

On the whole, as one authority states,<sup>29</sup> the shift from the direct consumption of corn in the form of corn meal, corn flour, etc., should not be looked upon by the Corn Belt farmer with regret. The increase in the consumption of meat and dairy

<sup>28</sup> U.S.D.A., Economic Bases for the Agricultural Adjustment Act, December, 1933, p. 36.

<sup>29</sup> O. E. Baker, Bureau of Agricultural Economics, Washington, D. C. *The Trend of Agricultural Production in North America and Its Relation to Europe and Asia*, p. 211.

products has provided an outlet for considerably more corn than would have been the case if the population had continued to consume this grain in its various direct preparations.

### THE CORN PRODUCTS REFINING OR "WET-PROCESS" INDUSTRY

The second important industrial outlet for corn listed above is the corn products refining or "wet-process" industry, so called because it steeps corn in water before grinding it.

The chief products of this industry are cornstarch, corn sirup and corn sugar. There are numerous by-products. The industry offers a fertile field for expansion of the present commercial and industrial uses for corn. It is the research chemist and engineer who have been largely responsible for the development here, and there are good prospects for further discoveries by the men in these two fields.

A brief historical sketch of the development of the corn products industry will provide a background for a study of the industry today and its prospects for the future.

#### Historical Development of the Corn Products Refining Industry

Cornstarch was the first product manufactured from corn. About 75 years ago one Thomas Kingsford established a plant at Oswego, N. Y. The enterprise proved profitable, and within a comparatively short time others were attracted to this field. Increasing competition drove the cornstarch manufacturers to convert the waste products remaining after the extraction of the starch into useful by-products. The recovery of gluten was an example of this. Originally, the gluten was collected in a wet condition and sold to local farmers for feeding purposes. Eventually, as the output of cornstarch increased, the local outlets for the wet gluten feed became unable to absorb the increasing quantities of this by-product. This led to drying the gluten feed, to permit shipping it to distant points. In a similar manner, the hull of the corn was transformed from a waste product to a valuable by-product and sold as corn bran. Later, through the application of chemical research, the manufacture of corn sirup was started. In time, the next important step in the industrial utilization of corn, the recovery of the germ which yields corn oil, was undertaken.



TABLE 8—ANNUAL CORN GRINDINGS OF CORN PRODUCTS INDUSTRY  
1921 TO 1934

Year	Total corn grindings in thousands of bushels <sup>1</sup>	Total corn crop U. S. in thousands of bushels <sup>2</sup>	Corn grindings in percent of U. S. crop	Primary market receipts of corn in thousands of bushels <sup>3</sup>	Corn grindings percent of primary market receipts
1921.....	58,518	2,929,442	2.0	349,378	16.7
1922.....	66,854	2,707,306	2.4	380,032	17.6
1923.....	68,160	2,878,292	2.3	273,130	24.3
1924.....	75,344	2,298,071	3.3	278,522	27.1
1925.....	70,263	2,853,083	2.5	226,381	31.0
1926.....	12,221	2,574,511	3.2	236,478	34.8
1927.....	85,554	2,477,671	3.2	245,184	34.9
1928.....	86,924	2,714,535	3.2	336,838	25.8
1929.....	86,619	2,535,546	3.4	266,944	32.4
1930.....	76,659	2,065,273	3.7	260,556	30.2
1931.....	66,857	2,588,509	2.6	174,000	38.4
1932.....	61,880	2,906,873	2.1	160,230	41.0
1933.....	76,118	2,351,658	3.2	254,529	29.5
1934.....	65,854 <sup>4</sup>	1,360,718 <sup>5</sup>	4.8	.....	.....

<sup>1</sup>Figures supplied by the Corn Industries Research Foundation, New York.

<sup>2</sup>United States General Crop Report, Dec. 1934—U. S. D. A. Bureau of Agr. Ec.

<sup>3</sup>Chicago Board of Trade Yearbook, 1934, p. 162; 1924, p. 122; 1923, p. 91.

<sup>4</sup>Survey of Current Business, Mar. 1935, p. 40.

<sup>5</sup>Crops and Markets, U. S. D. A., Dec. 1934, p. 467.

income for this period, showing a relatively close positive relationship, except for the year 1933. It is not easy to account for the residuals (that is, for the deviations of the dots from the curved line) in fig. 8; neither the price of corn nor the size of the corn crop serves to explain them.

The annual distribution of the products of the corn refining industry for the period 1924 to 1934 is shown in table 10 and fig. 9. The different products are discussed separately below.

TABLE 9—CORN GRINDINGS AND NATIONAL INCOME, 1921-1934

Year	Corn grindings <sup>1</sup>		National Income <sup>2</sup>	
	Thousand bushels	Percent of '21-'33 average	Million dollars	Percent of '21-'33 average
1921.....	58,509	78.6	56,430	84.1
1922.....	66,854	90.0	67,626	87.9
1923.....	68,160	89.1	65,949	100.1
1924.....	75,344	105.2	68,461	103.9
1925.....	70,263	100.5	73,067	110.2
1926.....	12,221	110.7	74,954	113.3
1927.....	85,554	115.2	76,007	115.4
1928.....	86,924	117.0	77,291	117.3
1929.....	86,619	116.6	79,702	120.9
1930.....	76,659	101.8	72,690	110.6
1931.....	66,857	90.0	60,790	92.3
1932.....	61,880	83.1	47,900	72.7
1933.....	76,118	101.1	46,030	69.9
1934.....	65,854 <sup>3</sup>	84.5	61,690	76.8

<sup>1</sup>Figures supplied by Corn Industries Research Foundation, New York.

<sup>2</sup>U. S. D. A. Bureau of Agr. Ec., The Agricultural Situation, Feb. 1935, p. 5. Their 1934 figure is estimated.

<sup>3</sup>Survey of Current Business, Mar. 1935, p. 40.

## Cornstarch

It will be observed from fig. 9 that the trend in cornstarch production from 1927 to 1932 was downward. An increase of about 200 million pounds was recorded for 1933, but this level is still below that of earlier years. Production for 1934 amounted to 667 million pounds, distributed by trades as shown in table 10.

The decline in the production of cornstarch appears to be caused by (a) reduced industrial demand resulting from reduced industrial activity, as shown in fig. 8, (b) a reduction in exports of cornstarch, as shown in table 12 later in this section, and (c) increasing competition from imported starches, also shown in table 12.

Exports of cornstarch during the past year (1934) amounted to less than one-fourth of the 1921-30 average. From present indications, this decline may continue in the future. In the April, 1933, issue of "Food Industries," a trade magazine, it

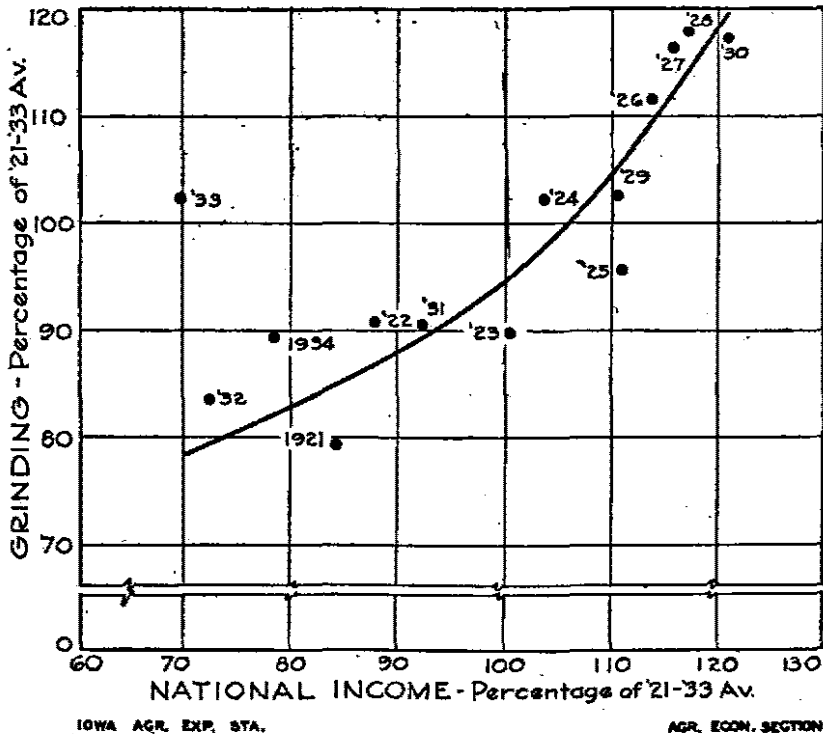


Fig. 8. Relation between corn grindings and national income.

TABLE 10—PRODUCTS OF THE CORN REFINING INDUSTRY

Year	Corn sirup unmixed (millions of pounds)	Cornstarch (millions of pounds)	Corn sugar (millions of pounds)	Dextrin (millions of pounds)
1924	1,106	877	557	42
1925	1,060	799	535	59
1926	1,109	836	697	68
1927	1,065	906	897	109
1928	1,107	859	959	110
1929	1,111	880	895	114
1930	1,023	711	849	89
1931	929	635	802	79
1932	795	529	777	62
1933	1,001	742	842	85
1934	996	807	634	70

Year	Crude corn oil (millions of pounds)	Refined corn oil (millions of pounds)	Stock feed (tons)	Corn oil, cake (tons)
1924	37	68	497,042	37,041
1925	31	59	509,887	29,775
1926	38	66	575,890	23,032
1927	40	58	647,347	37,527
1928	44	74	658,767	39,536
1929	54	79	634,068	27,883
1930	40	78	576,121	24,832
1931	42	72	479,123	20,828
1932	35	76	542,228	18,634
1933	34	81	507,593	22,807
1934	42	87	509,033	21,351

Note: Corn sirup used for mixing is included in corn sirup unmixed.

Data in tables 9 and 10 from Corn Industries Research Foundation, New York.

is stated that some American mills had transferred to foreign countries that production which had previously been conducted in the United States for shipment abroad, because of the lower price of corn abroad. The Corn Industries Research Foundation states that entry into foreign manufacture was a result of foreign tariff restrictions and an effort to hold business, and was not due solely to cheaper foreign corn. Whatever the reason for the decline in exports, the fact is that some of the foreign outlet for cornstarch has disappeared and domestic production of cornstarch has declined.

#### Competition Between Cornstarch and Imported Tropical Starches

During the past few years cornstarch has encountered strong competition, both at home and abroad, from starch made from "cassava," commonly known as tapioca. Imports of cassava starch, in the main, come from Java. They enter this country duty free, as this commodity is considered a food item rather than a raw material for the industrial market.<sup>30</sup>

<sup>30</sup> The duty on other starches and materials for starch making at present are: potato dextrin, 3c per pound; potato starch, 2½c per pound; all other starches not especially provided for, 1½c per pound.

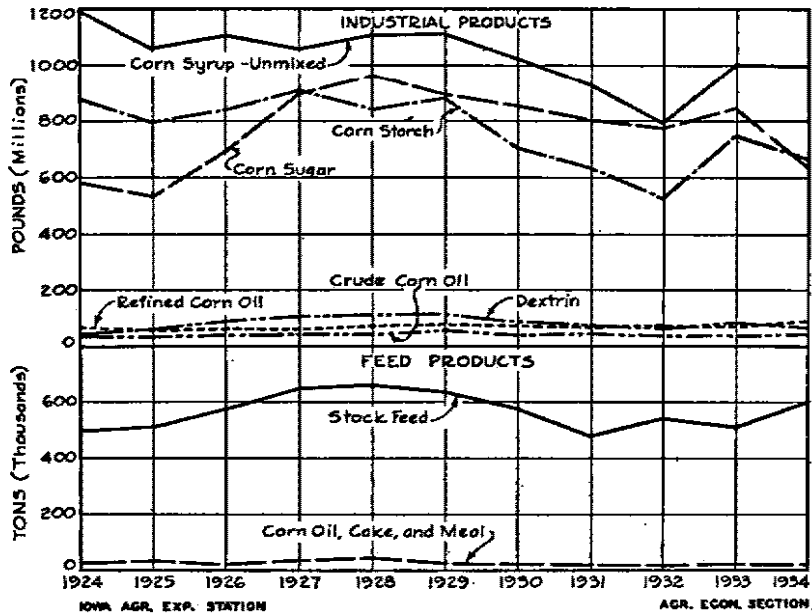


Fig. 9. Products of the corn refining industry.

Tapioca starch, until recent years, was used almost exclusively as a "vegetable glue," largely displacing animal glue from the packing industry. These vegetable glues are used in large quantities for wood veneering in the manufacture of furniture, wood panels and other types of wood working. Aside from this outlet, tapioca starch was also used in fairly large quantities in the manufacture of dextrin for postage stamps and envelope flaps. In recent years, the uses of tapioca starch have been expanded to include explosives, textiles, paper and paper boxes, shade cloth, and confectionery. It is in these newer uses that

TABLE 11—DISTRIBUTION OF CORNSTARCH, IN POUNDS, 1934

Packages (grocers).....	168,586,050
Cotton mills and textiles.....	101,483,030
Paper, paper boxes.....	62,224,197
Baking powder mfg.....	53,871,934
Dealers, repackers.....	50,331,995
Miscellaneous.....	48,326,075
Confectioners.....	38,995,509
Chemists.....	16,517,687
Bakers.....	24,381,387
Brewers.....	39,207,363
Laundry.....	11,990,754
Total domestic.....	605,987,995
Export.....	60,861,207
Total domestic and export.....	666,849,202

TABLE 12—COMPARISON OF IMPORTS OF TROPICAL STARCHES AND EXPORTS OF U. S. CORNSTARCH

Year	Imports of tropical starches (1,000,000 lbs.)*	Domestic production of cornstarch (1,000,000 lbs.)	Exports of corn starch	
			(1,000,000 lbs.)	In percentage of domestic production of starch
1921-25.....	83		250	
1926-30.....	140	835	214	26
1928.....	176	835	231	28
1929.....	181	875	235	27
1930.....	114	710	154	22
1931.....	151	635	88	14
1932.....	141	530	53	10
1933.....	205	740	60	8
1934.....	172	667	65	

\*Source: Statistical Abstract, 1933, p. 444; Bureau of Foreign and Domestic Commerce, U. S. Dept. of Commerce.

tapioca starch competes directly with cornstarch and cornstarch derivatives.

Tapioca can be produced cheaply abroad, and outyields corn in the relative amount of starch produced per acre of raw material. It can ordinarily be laid down in the United States at a lower price than corn. It is, therefore, in a favorable competitive position with corn where there is no discrimination against either product as a raw material.

Imports of tropical starches for recent years are given in table 12. For comparative purposes, exports of cornstarch, in percentages of domestic production, are also shown.

Not all of the decline in the domestic production of cornstarch shown in table 12 is to be attributed to the competition of imported tapioca. Figure 8, page 278 shows that the decline in the production of cornstarch and other corn products is explained by the decline in industrial activity that has taken place since 1929. Yet imports have increased and exports have decreased; domestic consumption of starch, then, has increased relative to domestic production and to the usual relation of domestic consumption to domestic industrial activity. (The reasons for this increase are given below.) What has happened, apparently, is that domestic production has not received the full benefit of increased domestic consumption. That is, the competition of tapioca at home and abroad has reduced the domestic production of cornstarch, not absolutely, but relatively to the expansion in domestic demand.

It is because of this situation that pressure is being exerted by the corn products industry for a revision of the tariff on



starches with the object of having tapioca included under the heading of starch. The corn products industry is asking that a duty of  $2\frac{1}{2}$  cents per pound be levied against all imports of tapioca, the same as for potato starch. This would offer one solution to the problem, and it is possible, since a 5 cents per bushel processing tax has been levied on corn as part of the AAA program, that the government will take some action toward levying a special tax on products competing with corn.

The question as to the effect of a tariff on tapioca upon the utilization of corn and the price of corn in this country involves some complex issues. Some of these issues are: What would be the effect on our exports of other agricultural products? Would the benefits be greater than the costs, both to agriculture and to society as a whole? These questions constitute a research project in themselves, and can only be indicated here.

A second way to meet the competition from tapioca is to engage in research directed towards (a) a reduction in the cost of manufacturing cornstarch, and (b) a greater utilization of the by-products of the corn products industry or in the development of new products, the returns from which might conceivably permit certain reductions in the price of starch to meet foreign competition. The Corn Industries Research Foundation has recently obtained the cooperation of a number of the leading American universities and colleges, as well as the approval of officials of the U. S. Department of Agriculture, in opening up a research program aimed at the conversion of greater quantities of corn into industrial uses.

#### Cornstarch Derivatives

When pure cornstarch is heated in a closed container in the presence of an acid, such as dilute hydrochloric, the resulting product, after neutralization of the acid, is found to be sweet in taste. If the chemical action is halted at the proper stage, a sirup (corn sirup) consisting of dextrose, maltose and dextrans in varying proportions is obtained. If the chemical action is followed through to completion, corn sugar (dextrose) may be crystallized out. This process is called the hydrolysis of cornstarch, and is employed by the corn refining industry to obtain a series of products known as cornstarch derivatives.

Since corn sirup and corn sugar are products of different stages of the same process of hydrolysis, the two products may be discussed jointly.

#### Corn Sirup and Corn Sugar

Corn sirup is used principally in the manufacture of candy, for preserving canned fruit, in making jellies and jams, and as a table sirup. Corn sugar is used by the baking, canning, condensed milk, ice cream, beverage and confectionery trades. For the trend of production in these two products during recent years, the reader is referred to fig. 9. For the past year, 1934, the production of corn sirup, mixed and unmixed together, amounted to 1 billion pounds; the production of corn sugar was 634 million pounds.

The extent to which the demand for these two products may expand in the future depends upon their ability to replace cane and beet sugar; and this, in turn, depends mainly upon the physical, chemical and nutritional qualities of the two sugars. Corn sugar is less sweet than cane or beet sugar, having a relative sweetness of 70 (relative to cane and beet sugar regarded as 100). It will require, therefore, 1.43 pounds of corn sugar to equal 1 pound of cane or beet sugar. On the other hand, corn sugar is the most readily assimilated of all the sugars and, having a higher osmotic pressure than cane or beet sugar, has better preserving action.<sup>21</sup>

The lower sweetening value of corn sugar is not in all cases a detriment. For some purposes, indeed, it is an asset. The use of corn sugar in combination with cane or beet sugar makes it possible to reduce sweetness in a product and still maintain the same nutritive advantages as before. Candy manufacturers, for example, find that candy made with corn sugar does not cloy the taste as quickly as candy made from ordinary cane sugar. Consumers, therefore, can eat more corn sugar candy than cane sugar candy.

In nearly all cases (except for the baking and wine industries) a mixture of corn and other sugars gives best results. The correct proportion of corn to other sugar varies for different products. Recent experimental work with corn sugar in the manufacture of preserves, for example, shows that for

<sup>21</sup> Research conducted by United States Bureau of Standards, Washington, D. C., on establishment of dextrose and levulose industries.

each of the types of preserves studied there is a certain proportion between cane and corn sugar that will produce the best quality product—a product superior to any obtained by the use of either cane sugar or corn sugar alone.<sup>32</sup>

The use of corn sugar has been retarded, in the past, by the fact that if corn sugar is used alone in preserving fruit, it crystallizes more easily than cane sugar. The correct mixture of corn and cane sugar, however, crystallizes less easily than either corn or cane sugar alone. If the product is sold, already mixed in its proper proportions, as preserving sugar, crystallization will be no more troublesome (in fact, it will be less troublesome) than with ordinary cane sugar.

A tentative estimate of the additional amount of corn which might be consumed by the corn refining industry through an increase in the industrial demand for corn sugar in the future may be calculated on the basis of the figures for 1932 sugar production and consumption<sup>33</sup> shown in table 13.

TABLE 13—UNITED STATES CANE AND BEET SUGAR PRODUCTION, IMPORTS AND EXPORTS, AND CONSUMPTION, 1932  
(Millions of pounds)

Output of domestic beet producers.....	2,136
Output of domestic cane producers.....	76
Imports.....	10,220
	12,443
Less exports.....	205
Total for domestic consumption.....	12,238

It is estimated that of the total 12,238 million pounds of sugar consumed in the United States, 8,738 million pounds were used by homes, restaurants, retail stores, institutions, etc., leaving about 3,500 million pounds for consumption by the food industries.

The potential consumption of bushels of corn can be computed by applying to the approximate amounts of sugar used by the individual food manufacturers the percentages of corn sugar content which may be efficiently employed in each industry.<sup>34</sup> This has been done in table 14.

<sup>32</sup> "The Value of Types of Dextrose in the Preservation of Fruits and Vegetables," Bureau of Publications, Teachers College, Columbia University, New York City, 1933. This agrees with the conclusions reached at Iowa State College.

<sup>33</sup> Estimates of "Food Industries," a trade magazine. Domestic consumption figures checked for accuracy by J. H. Buchanan.

<sup>34</sup> These estimates of the percentage of cane or beet sugar replaceable by corn sugar, for the various industries, are supplied by the Corn Industries Research Foundation, and have been checked for accuracy by J. H. Buchanan.

TABLE 14—PRACTICAL ATTAINABLE REPLACEMENT OF CANE AND BEET SUGAR BY CORN SUGAR IN SPECIFIED FOOD INDUSTRIES

Industry	Estimated sugar consumption (million pounds)	Percent replaceable by corn sugar	Total replacement (million pounds)
Beverages	272	75	204
Bakery products	1,073	20	214.4
Chocolate, confectionery and chewing gum	1,006	40	402
Jams, jellies, fruits	521	20	104
Ice cream	262	25	65.5
Condensed milk	175	50	87.5
Total			1,652.3

Using 1.43 lbs. corn sugar for each lb. cane-beet sugar..... 1,504.8 million pounds  
 Potential consumption of corn<sup>1</sup>..... 60,188,000 bushels

<sup>1</sup> Conversion basis, 25 lbs. of corn sugar per bushel of corn.

These estimates appear to err on the side of conservatism rather than of extravagance. Our estimates, based upon research work here, run higher than these. We estimate 40 percent attainable replacement, instead of 20 percent, for bakery products, and 25 percent each for jams, jellies, fruits and ice cream, instead of 20 percent. Furthermore, two new outlets for corn sugar have recently opened up, in the wine industry and the meat packing industry. The amounts taken by these two industries are not accurately determinable at present, but the total is near 100 million pounds; a considerable expansion in these two items is expected in the future. The upper limits of our estimates are therefore not clearly definable until data from these two industries become available; but the lower limits are in the neighborhood of 75 million bushels of corn. This is somewhat higher than the Corn Industries Research Foundation estimate, 61 million bushels, given in table 14.

It is possible that corn sugar may also replace a small part of the 8.7 billion pounds of cane and beet sugar at present consumed in homes, restaurants, etc. If 10 percent were thus replaced, that would require 874 million times 1.43 pounds of corn sugar, equal to 50 million bushels of corn. The likelihood of corn sugar being thus used in homes and restaurants, however, is somewhat problematical at present, except for home canning; so the possible home use of corn sugar is not included in the estimates here. Attention is drawn to the matter, however, because of the large possibilities in the home consumption field if ways can be found for opening it up.

The practically attainable replacement of cane or beet sugar by corn sugar, exclusive of the home demand, is therefore be-

tween 60 and 75 million bushels of corn. This is 3 percent of an average corn crop.

What are the barriers which prevent the attainable consumption of corn sugar in the food industries from being reached? Apparently, corn sugar has qualities which commend it to industrial food purposes; the chief obstacle to its use is that its qualities have only recently been given specific legislative recognition. Previously, manufacturers were compelled to state on the labels of their products if corn sugar or glucose was a constituent. The implication of this was disparaging. In 1930, however, in recognition of the good qualities of corn sugar, this regulation was repealed by the secretary of agriculture, and corn sugar was put legally on an equality with cane and beet sugar. Educational work is now required to bring to the attention of manufacturers the specific uses in which corn sugar is advantageous.

#### Problems Resulting from Replacement

The partial replacement of cane and beet sugar by corn sugar, however, is likely to create at least two problems. First, there is the danger of causing serious economic disturbances in the domestic cane and sugar beet industries. This problem is usually dismissed by advocates of the corn sugar program by assuming that the entire substitution of sugar will take place in the imports of cane sugar. There is no basis to support this contention, unless imports were restricted by legislative action; and it is not clear that this action, with all its ramifying effects, would be desirable. The more reasonable belief, therefore, is that both the domestic sugar producer and the sugar importers would be affected. The question needs extended study.

The second question is, would there be a ready market for the disposal of the resultant by-products, corn oil and stock feeds, obtained in the processing of the additional amount of corn required to obtain the necessary corn sugar?

#### Corn Oil

Approximately 1.5 pounds of corn oil and 15 pounds of stock feeds are obtained from each bushel of corn processed. An increase of about 75 million bushels in the corn grindings of the corn refining industry would be roughly equal to the present total corn consumption of this industry. The result of such an increase would be that the current outlets for corn oil and

stock feed would have to expand in like proportion, or new outlets would have to be found for these by-products.

Figure 9, showing the annual distribution of corn products, gives the production record for corn oil, both crude and refined, for the period 1924 to 1933. The average annual production of crude and refined corn oil is about 115 million pounds; about 70 percent of the total production is refined, and the remainder is sold in the crude form. The refined product is used in the manufacture of salad oils, dressings, compounds and vegetable shortenings. The crude is disposed of in the manufacture of soap and miscellaneous products, (dyes, paints, varnishes, greases, oilcloth, etc.)

Doubling the present production of corn oil would, undoubtedly, have some effect upon cottonseed oil, since the uses of these two products are practically identical. It would appear, however, from a recent study conducted at Iowa State College with reference to animal and vegetable fats and oils<sup>25</sup> that the use of corn oil could be doubled without creating any serious economic disturbances in the vegetable oil market. Cottonseed oil easily dominates in this field, contributing over 90 percent of the total; corn oil ranks second, with 7 percent.

#### Stock Feed

An increase in consumption of corn by the corn refining industry of about 75 million bushels would not actually relieve the market of that amount, since about 15 pounds, or nearly 30 percent, of each bushel of corn finds its way back to the farm in the form of various commercial feeds. The extent of the problem of disposal of this feed depends chiefly upon the price asked for it. A large potential market in the eastern dairy states obviously exists and, if the price were right, might naturally be expected to absorb large quantities; this, however, would be at the expense of the present consumption by this territory of corn and other feeds shipped from the Corn Belt.

#### Dextrin

One important derivative of cornstarch has not yet been mentioned, and that is dextrin. Heating starch changes its physical characteristics and produces a series of products called dextrins, which possess certain adhesive properties. They are

<sup>25</sup> Schickele, R. and Schultz, T. W., *Competitive Position of Lard in the Market of Animal and Vegetable Fats and Oils*, Iowa Agr. Exp. Sta., Res. Bul. 171, p. 175-7, 1934.

used chiefly as a substitute for gums and for stiffening fabrics. Production of dextrin in 1924 amounted to about 42 million pounds, and increased steadily thereafter to reach 115 million pounds in 1929. Since 1929, the manufacture of dextrin has fluctuated in response to fluctuations in business activity. Improved economic conditions during 1934 brought the total up from the low point, 62 million pounds in 1932, to 70 million pounds in 1934. (See fig. 9.) The prospects for an expansion of the present demand for dextrin are favorable, in view of the many industries using this product. The corn refining industry faces the competition of the tropical starches, however, which are better adapted than cornstarch for the manufacture of some (though not all) types of dextrin.

## INDUSTRIAL ALCOHOL, DISTILLED SPIRITS, AND CEREAL BEVERAGES

### INDUSTRIAL ALCOHOL

The possibility of converting corn into alcohol for industrial and beverage purposes has attracted a good deal of attention in recent years. Industrial alcohol is one of the most important chemicals (quantitatively speaking) used in industry. The peak of production of industrial alcohol was reached in 1926 and touched again in 1929, when 200 million gallons were produced in the United States. Since that time, production has declined, under the influence of the recent depression, to 116 million gallons in the year ended June 30, 1933.<sup>36</sup>

Most of the industrial alcohol is made from molasses, a waste product of the sugar industry. In 1932-33, 83 percent of the industrial alcohol in the United States was manufactured from molasses. In the same year, 9.70 percent was made synthetically, and 4.13 percent was made from grains. The remaining 3.17 percent was made from grain—molasses—chemical mixtures and other raw materials.

### The Competition Between Molasses and Corn As a Raw Material for Industrial Alcohol<sup>37</sup>

Before 1918, a number of alcohol plants in this country, located in Illinois, Indiana and Ohio, were producing alcohol

<sup>36</sup> Statistics Concerning Intoxicating Liquors, Bureau of Industrial Alcohol, United States Treasury Dept., Dec. 1933, p. 24.

<sup>37</sup> This section is adapted from "The Use of Alcohol in Motor Fuels," Progress Reports Nos. 3 and 5, Iowa State College, Divisions of Industrial Science, Engineering and Agricultural Economics, 1933, Mimeographed.

from cereals, principally corn, barley and rye. The output of these plants was of great importance during the World War. During this time there was considerable expansion in the whole industry, the greatest expansion taking place in the plants along the Atlantic seaboard which used blackstrap molasses rather than cereals. At the close of the war, the potential production was in excess of the demand for industrial alcohol, which was now the only outlet for this material. The competition forced the grain alcohol producers out of business, because the molasses plants could produce alcohol at a lower cost than could these grain alcohol plants. Until prohibition was repealed, only one or two of these grain alcohol plants were still in operation, and these for only a part of the time. There is still a small demand for grain alcohol, although this may now contain 49% alcohol made from molasses and only 51 made from grain. A few users of alcohol prefer grain alcohol to molasses alcohol. The perfume industry is an example. Perfumers prefer to use grain alcohol because it leaves less objectionable odor after evaporation.

The plants for the production of alcohol from molasses are located along the seaboard in Baltimore, Philadelphia, New York and Boston, New Orleans and San Francisco. These locations were chosen because the molasses, produced mainly in Cuba, Louisiana and Porto Rico, could be brought to the plants in tank steamers with a minimum transportation charge.

Since molasses is a waste by-product, it will be sold at any price which will pay a little more than the cost of handling and transportation. The price of molasses on the Atlantic seaboard during the past 10 years has varied from as low as 3 cents to as high as 12 cents per gallon. In general, this cost has been very nearly the price of corn on the Chicago market, calculated on an equivalent carbohydrate basis. The production of alcohol from molasses is relatively inexpensive, since little processing of the molasses is required prior to fermentation.

Table 15 shows that corn at 25 cents a bushel is about equivalent (in the manufacture of alcohol) to molasses at 5 cents a gallon; corn at 20 cents is equivalent to molasses at 4 cents per gallon.



TABLE 15—PRODUCTION COSTS PER GALLON OF ALCOHOL MADE FROM CORN AND MOLASSES<sup>22</sup>

	Corn		Molasses		
	20c per bu.	25c per bu.	4c per gal.	5c per gal.	6c per gal.
Raw material cost.....	.08	.10	.108	.135	.163
Barley and chemicals for fermentation.....	.0501	.0501	.0050	.0050	.0050
Conversion cost <sup>1</sup> .....	.1201	.1501	.1130	.1400	.1670
	.1054	.1054	.0700	.0700	.0700
Credit by-products.....	.2355	.2555	.1830	.2100	.2370
	.0471	.0511			
Cost per gallon.....	.1884	.2044	.1830	.2100	.2370

<sup>1</sup>The "Conversion Cost" includes total factory expense, insurance, depreciation and overhead, but DOES NOT include selling expense and cost of denaturization, which amounts to about 2½c per gallon for completely denatured formula.

<sup>22</sup>Watson, Warren N., "Facts About Industrial Alcohol." Chemical and Metallurgical Engineering, March, 1930, Vol. 27, p. 160.

In the past, molasses has had a competitive advantage over corn. The average Dec. 1 farm price of corn in Iowa from 1922 to 1929 was 66 cents. On the basis of the method of calculation given above, the cost of producing corn alcohol would have been approximately 33½ cents per gallon. For the same period the price of molasses averaged about 8 cents per gallon, c. i. f. North Atlantic port. The cost of alcohol from molasses on the same basis as the calculation of corn would have been 27½ cents per gallon. The differential in favor of making alcohol from molasses rather than corn was, therefore, 5 cents a gallon.

One other competitive raw material for industrial alcohol remains to be considered. A small amount of the alcohol produced in this country is now being made synthetically from ethylene at a plant in West Virginia. This industry was started in 1930 and during the first year produced about 4 million gallons of alcohol, about 5 percent of the ethyl alcohol sold during that year. Although this is a new industry in this country, alcohol was produced by this method in Germany and in England as early as 1921. It is stated that the capacity of the West Virginia plant will be about 6 million gallons of alcohol annually. The cost of production in the English process was estimated at 30 cents per gallon. It is estimated that the cost in this country is about 27 cents per gallon at the present time and that future improvements may lower this to 24 cents.

TABLE 16—GRAIN USED IN BREWING AND DISTILLING  
(In 1000's of bu.)

Year	Brewing	Distilling
1913.....	79,173	33,554
1914.....	80,221	30,356
1915.....	71,760	18,654
1916.....	67,374	39,272
1917.....	91,846	40,212
1918.....	43,044	16,426
1919.....	26,694	4,574

Corn, of course, was only one of the grains used. In 1917 the brewing and distilling industry consumed 34 million bushels of corn.<sup>39</sup>  
<sup>39</sup>The figures in this paragraph are taken from "Statistics Concerning Intoxicating Liquors," Bureau of Industrial Alcohol, U. S. Treasury Dept., Dec. 1938, p. 62.

### Distilled Spirits and Cereal Beverages

During the years just before and after the advent of prohibition in 1918, the amounts of grain of all kinds used annually in the United States in brewing and distilling liquor were as shown in table 16. This is about 1.3 percent of an average crop. After prohibition, the amount legally consumed dropped off sharply to 4 million bushels in 1919, 7 million bushels in 1925, and 6 million bushels in 1933.

There was some feeling, in 1933, that the repeal of prohibition would open up a large outlet for grain and help agricultural recovery. The statistics given above show how vain was this hope. The production of grain in the United States runs well over 5 billion bushels annually. The legal consumption of grain by the brewing and distilling industries in the peak year, 1917, was 132 million bushels. This is about 2.5 percent of the total production of grain. Prohibition cut the legal consumption of grain sharply, but how much it affected illegal consumption is not known. A return to full pre-prohibition consumption would probably increase the demand for grain only 1 or 2 percent.<sup>40</sup>

<sup>40</sup> The smallness of the extent to which the brewing and distilling industries can expand the demand for grain has been emphasized by the brewers themselves. Their testimony, given just before the passage of the 18th amendment, follows:

"Headed by Gustave Pabst, a delegation representing the brewers of the United States, was heard today by the senate agriculture committee on Senator Gronna's bill to forbid the manufacture of grain into alcoholic liquors during the war. The actual amount of grain used in brewing, principally barley, they told the committee, represents less than three-quarters of 1 percent of all the grain produced in the United States, and in addition to that the barley used, they said, is not a staple human food, here or abroad. The amount of land required to raise all the grain used in brewing in the United States, the committee was told, is less than seven-one-hundredths of 1 percent of the total of all the agricultural land in the country. From these figures, the brewers argued that the brewing industry was too small a factor to be considered in the food conservation program." (Des Moines Register, 1931.)

## POSSIBLE NEW USES FOR CORN

### A NATIONAL CORN-ALCOHOL MOTOR FUEL PROGRAM

The suitability of alcohol for use in internal combustion engines, especially those of the high compression type, has been demonstrated by many tests conducted here and abroad. As a natural consequence, the utilization of agricultural wastes and surplus products in the manufacture of alcohol to blend with motor fuel has frequently been advanced as a means to increase the income of the American farmer.

Advocates of corn alcohol for fuel purposes have recommended that a mixture of 10 percent alcohol and 90 percent gasoline be used in place of straight gasoline. The universal use of a 10 percent corn-alcohol blend in the United States would conceivably provide an outlet for 600 million bushels of corn<sup>41</sup>, or 23 percent of the average corn crop for the 10-year period, 1924-33. The magnitude of such a plan warrants careful attention to its possibilities.

The Department of Agriculture estimates that with corn at 50 cents per bushel and gasoline at 13 cents per gallon, the use of a 2 percent blend would add about  $\frac{1}{2}$  cent, while the use of a 10 percent blend would add about 2 3-5 cents, per gallon, to the cost of motor fuel.<sup>42</sup>

The proposed fuel possesses certain advantages over straight gasoline. These advantages are: (a) Reduction of "knocking," (b) good top-gear performance, especially in hill-climbing, (c) improved acceleration at low speeds, (d) increased mileage on short runs because of better volatility characteristics of the fuel, (e) cooler operating engine, particularly noticeable in air-cooled engines, and (f) less formation of carbon and gummy deposits.<sup>43</sup>

The excellent engineering, physical and chemical properties of the blended fuel have led some to believe that it affords a solution to the problem of low agricultural prices. Such ob-

<sup>41</sup> In 1932 consumption of gasoline in the United States by motor vehicles amounted to 14,250 million gallons. (U. S. D. A. Yearbook of Agriculture, 1934, p. 750.) In a more normal year consumption would run higher. If a billion gallons were used, and 10 percent of this amount were corn alcohol, that would call for 1.5 billion gallons of corn alcohol. The production of 1.5 billion gallons of corn alcohol would require 600 million bushels of corn.

<sup>42</sup> U. S. D. A., Senate Document 57, Use of Alcohol from Farm Products in Motor Fuel, May 1, 1933.

<sup>43</sup> Statement of Prof. L. T. Brown, Mechanical Engineering Department, Iowa State College, based upon research work conducted at Iowa State College and abroad.

servers, however, have not squarely faced some economic difficulties that require solution before a corn-alcohol program can be successful.

### Economic Difficulties

The program faces two major economic difficulties. In the first place, there is not sufficient evidence that the public will pay a premium of 2 to 3 cents a gallon for this new fuel. The fuel may not be able to sell on its own merits, if it costs between 2 and 3 cents more than straight gasoline. Even if it does sell on its own merits, it may not be used very extensively; premium fuels constitute only a relatively small element in our total fuel consumption.

In the second place, it is not certain that all the "corn alcohol" would be made from corn. The assumption is usually made that corn would be the sole raw material employed. This assumption may well be questioned. Under present competitive conditions, molasses would be a more suitable raw material; even synthetic alcohols might prove to be cheaper to produce than corn alcohol. About 85 percent of the present output of alcohol is obtained from molasses; about 10 percent is produced by the synthetic process and only 3.75 percent is produced from grain.<sup>4</sup> Most of the molasses is obtained from Cuba, which is one of our best foreign customers for lard. Tariffs reducing imports from Cuba would reduce our exports to Cuba, lard among them. Even if molasses imports could be effectively controlled by legislative action, the domestic cane sugar industry, of which molasses is a by-product, would be spurred to convert this by-product into alcohol. At the present time, not only molasses but cassava is offering serious competition to corn in the starch industry; they would do the same in a "corn alcohol" industry.

Part of the initial benefits to be obtained by corn producers from such a program would be offset, apparently, by the effects of the disposal of the by-products produced in the manufacture of alcohol. About 1½ pounds of corn oil and 15 pounds of stock feed are obtained per bushel of corn converted into alcohol. If 600 million bushels of this grain were to be utilized eventually in the production of alcohol, about 900 million pounds of corn oil would have to be disposed of in the vegetable

<sup>4</sup> Oil, Paint and Drug Reporter, 122:52, Dec. 26, 1932.

oils and fats market, while about 4.5 million tons of stock feed would be returned to the farm.

Since corn oil is used for the same purposes as cottonseed oil, the latter might be expected to decline proportionately more in price than other less competitive oils. A large part of both cottonseed and corn oil production would probably flow to the channels now served by lard, with a consequent unfavorable effect upon lard prices also. Packers, in that case, would pay less for hogs than formerly; the extreme lard type hog, especially, would be penalized heavily.

Disposal of the large quantity of stock feed which would be available might not be a very serious problem. A large potential market exists in the eastern dairy states and in the normally deficit corn areas bordering on the Corn Belt. The presence of large quantities of this commercial feed, however, would have a depressing effect upon grain prices.

Corn alcohol, therefore, is in a rather weak economic position. The sellers of the alcohol would have to meet the competition of the cheaper and only slightly inferior product, straight gasoline. And some buyers of raw material to make the alcohol would probably prefer to use other materials—molasses, minerals, or cassava—rather than corn.

### Taxes and Tariffs

Some advocates of the corn-alcohol program meet these two major difficulties by a simple proposal. They propose to (1) enforce the sale of the blended fuel by putting a 3-cent tax on straight gasoline; and (2) enforce the use of corn as a raw material for the alcohol by tariffs on imports of other raw materials, and/or legal compulsion on the alcohol manufacturers to use only corn.

These proposals do not settle the difficulties; they simply raise new ones. Consumers of gasoline, including farmers, would object to legislation which would compel them to pay 2 or 3 cents more per gallon for fuel; and being numerous, they would probably resist such a proposal effectively. Producers of other raw materials would also object, asking why producers of corn should be favored over them. And finally, alcohol manufacturers would be hesitant to erect the new plants needed to manufacture the alcohol from corn, if the product

produced in such plants depended upon taxes, tariffs and other political devices for its use and sale.<sup>45</sup> It is a question whether a corn alcohol program that could not run on its own merits, but had to be supported at both ends, and would be crippled if either support were removed, would attract the necessary capital into the business.

The fundamental difficulty in the corn-alcohol program is that corn-alcohol at the plant costs several times as much as gasoline<sup>46</sup> at the refinery. This difficulty may be solved, eventually by (a) reductions in the costs of corn-alcohol production, or by (b) a rise in the price of gasoline<sup>47</sup> owing to approaching exhaustion of petroleum supplies. There is need for research into the costs of corn alcohol production, so that if the supply of petroleum should begin to diminish in the near future, the corn alcohol industry would be in the best position to be launched.

The economic difficulties confronting the corn alcohol program are not insuperable. They do necessitate, however, an extensive program of further chemical, engineering, and economic research before they can be solved. This program would be strengthened by the building of an experimental corn-alcohol plant in the heart of the Corn Belt, subsidized by federal funds, and operated in close conjunction with established facilities for chemical, engineering and economic research. The operation of such a plant would throw many of the problems and the benefits of a corn-alcohol program into sharp focus; and this would expedite the solution of the problems.

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<sup>45</sup> The existing alcohol manufacturing plant capacity above past maximum commercial requirements would not be sufficient to meet more than 1 percent of the total additional new demand. Aside from the difficulty of attracting capital, 2 or 3 years would probably be required before the additional plant capacity could be developed to provide sufficient alcohol for a 10 percent motor fuel blend.

<sup>46</sup> The cost of corn alcohol at the plant is shown in table 14 to be 20 cents per gallon, with corn at 25 cents per bushel. The price of gasoline at the refinery in Texas and Oklahoma in January, 1935, averaged 4.4 cents per gallon. (U. S. D. L. Bureau of Labor Statistics monthly bulletin, Wholesale Prices, January 1935, p. 22.)

<sup>47</sup> In European countries the price of gasoline is much higher than it is in this country. This (along with the desire to be self-sufficient in case of war) is one of the basic factors contributing to the wide use of alcohol blends in some European countries.