WHEAT STUDIES

OF THE

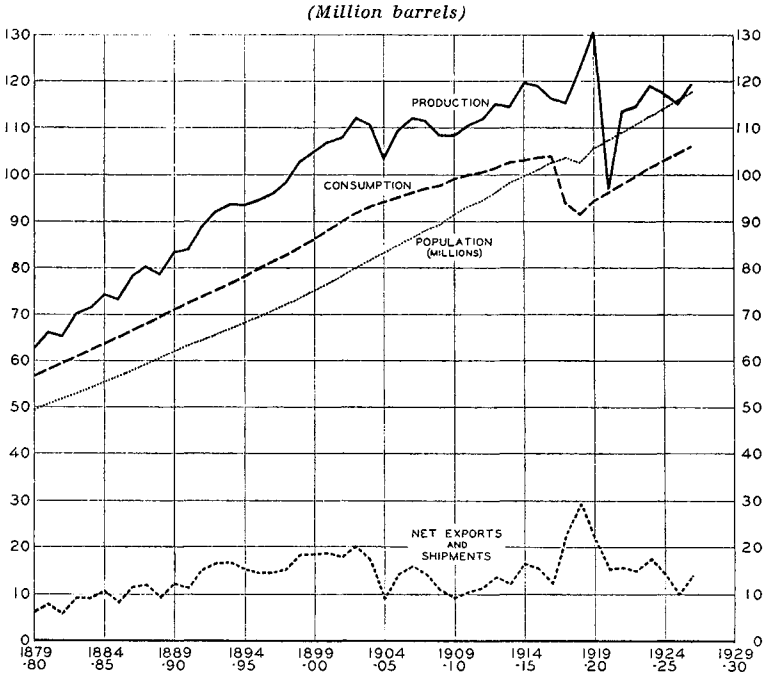
FOOD RESEARCH INSTITUTE

VOL. IV, NO. 2 DECEMBER 1927

STATISTICS OF AMERICAN WHEAT MILLING AND FLOUR DISPOSITION SINCE 1879

FLOUR PRODUCTION AND DISPOSITION, 1879–80 TO 1926–27

(Million barrels)



Flour consumption in the United States increased in direct proportion to the increase in population up to about 1903, but somewhat more slowly between 1903 and 1917. After the entry of the United States into the war, annual flour consumption was reduced over 10 per cent. Since 1918 per capita consumption has remained practically constant at about nine-tenths of a barrel. Total annual output has followed the same general trend as domestic consumption, but has varied considerably from year to year, influenced by export demand and changes in flour stocks.

STANFORD UNIVERSITY, CALIFORNIA

December 1927

WHEAT STUDIES

OF THE

FOOD RESEARCH INSTITUTE

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

Each volume also includes six special studies bearing on the interpretation of the wheat situation and outlook or upon important problems of national policy. Subjects of issues already published are listed inside the back cover.

The series is designed to serve the needs of all serious students of the wheat market, in business, government, and academic circles, by summarizing and interpreting basic facts and presenting current developments in due perspective. The special studies are written not merely for students of the wheat market, but as well for various groups of readers who are especially concerned with the fields discussed.

Volumes I–III are now available, bound in red buckram, at $10.00 each. The ten issues of Volume IV will be published monthly from November 1927 to September 1928, except in April 1928. Ordinarily each issue will reach subscribers in North America early in the month designated. The subscription price for the volume, including a temporary binder, is $10.00. Individual issues may also be purchased separately. Orders, subscriptions, and other communications should be addressed to FOOD RESEARCH INSTITUTE, STANFORD UNIVERSITY, CALIF.

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

STATISTICS OF AMERICAN WHEAT MILLING AND FLOUR DISPOSITION SINCE 1879

I. SUMMARY

The publication of greatly improved statistics of American flour output and wheat grindings in recent years has emphasized the need for similar statistics covering earlier years. On investigating the possibility of preparing estimates to supply this need, we have found that such estimates may be derived with practically the same accuracy as is shown by most of the more recent statistics. In addition, we find that the current estimates of monthly flour output, based on incomplete reports, contain appreciable errors, and we have accordingly prepared revised estimates in which the major errors are removed.

The principal results of the present study are embodied in tables and charts showing: (1) for each crop year since 1879–80 the approximate flour output of the mills of the United States, the quantities of wheat ground and millfeed produced, and the domestic consumption of flour; (2) revised estimates of the monthly flour output of the mills of the United States since May 1923; and (3) estimates showing, in terms of deviations from a 4-year average, the approximate total stocks of flour in all positions (including retail and household stocks) in the United States on the first of each month since May 1, 1923. These are all brought together, with related data, in Appendix Tables I and II, and are shown graphically in a series of charts running through the text.

Several incidental conclusions seem to be worthy of special mention. It appears that the severe decline in consumption of flour per capita in the United States, amounting to over 20 per cent since 1904, took place in two stages: a steady decline of about 11 per cent between 1904 and 1917, and a further decline of about 10 per cent during the last six months of 1917. Since 1918 the rate of consumption has been practically constant at about nine-tenths of a barrel per capita. The war-time curtailment of flour consumption was apparently facilitated by the fact that it involved dietary changes in line with previous tendencies. A continuation of the pre-war trend without any interruption would have brought the rate of consumption down to its present level at about the end of 1927.

The total quantity of wheat milled is found to vary from year to year considerably more than the total flour output, owing to variations in the amount of wheat required per barrel of flour. The latter is found to depend very closely on the average weight per bushel of the wheat crop of the country. It is important to take account of these variations in wheat requirements per barrel of flour in calculating the disposition of wheat in the United States from year to year.

In connection with the study of flour stocks it is found that the existing compilations of reports of stocks give no significant indication of the amount of change in total flour stocks or even of the time or direction of the changes in the total. The changes in total stocks between corresponding dates in successive years are found to be so large as appreciably to affect calculations of flour consumption, and the varying attitude of handlers and users of flour toward the accumulation of stocks is shown to be a major cause of variations in milling activity.

CONTENTS

Estimates of Annual Flour Production

A complete presentation of the basis for the estimates here given requires a somewhat lengthy and technical discussion involving consideration of a multitude of details. The broader outlines of the method, however, together with the principles involved, may be indicated quite briefly.

The only statistics of flour production which may be regarded as substantially complete are those obtained in the censuses of manufactures and the statistics compiled by the Food Administration Grain Corporation and its successor, the United States Grain Corporation, between July 1918 and May 1920. The census statistics are available only in the form of totals for calendar years: every ten years up to 1899, every five years from 1899 to 1919, and every two years since 1919. The Grain Corporation figures are given weekly and monthly through the nearly two years during which they appear to include 99 per cent of the total United States output. Even the census statistics, however, are not all entirely complete, owing chiefly to the omission of custom mills in the quinquennial and the biennial censuses.

To fill in the gaps between the census years and to put all the data on a crop-year basis, which is more useful for most purposes, either of two methods may be employed. One method is to attempt to raise certain incomplete figures to 100 per cent of the total. Such incomplete figures are available in compilations made by the *Northwestern Miller,* over a long period, and more recently by the Grain Corporation and the Department of Commerce. These give weekly or monthly statistics of the output of a portion of the mills of the country representing in the aggregate a fraction of the total ranging from about 30 to about 90 per cent.[1] By devising methods of raising these partial figures to 100 per cent, it is possible to approximate the monthly total flour production over a long period, and from the monthly figures to compute crop-year totals.

The estimates thus obtained are subject to considerable error. To raise the partial figures to 100 per cent, it is necessary to estimate the percentage of the total represented in the available figures. For census years the percentage is readily calculated, but applying the percentage thus obtained to calculations for intercensal years involves the assumption that the changes in the reported figures are accurately representative of the changes in the total. Our investigations indicate that even the recent Department of Commerce statistics, including about 90 per cent of the total production, do not reflect the changes in total production as accurately as might be desired.[2] Less complete statistics may be expected to reflect changes in the total even less accurately.

The second possible method of estimating annual flour production is made available by the fact that, except under such extraordinary conditions as arose during the war, actual consumption of flour, per capita, in the United States apparently changes very little from year to year, except with the gradual change in consumption habits.[3] Per capita consumption, therefore, follows very closely a trend which may be represented graphically by a smooth curve, and since a number of points on that curve can be located by calculation from the accurate consumption statistics available for census years, a curve can be drawn through these points which will represent very accurately the per capita consumption for any crop or calendar year within the period covered.

Given the per capita consumption of flour

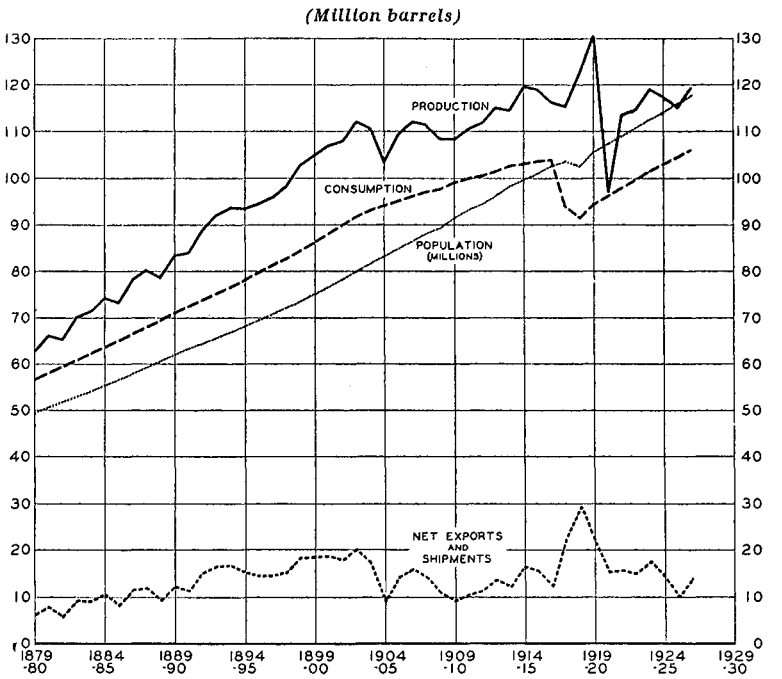
[1] As noted above, the Grain Corporation figures cover 99 per cent of the total over a part of the period.

[2] See below, p. 69.

[3] The statement that the only important changes in per capita consumption of flour in the United States, except under such extraordinary conditions as existed during the war, are the result of gradually changing habits of consumption and that consumption does not change appreciably with changes in the price of wheat, in the price of other foods, or in the volume of unemployment, is supported by a large amount of evidence. The best statistics available show only such changes in apparent per capita consumption of flour as would be expected from changes in consumption habits and the known defects of the statistics. The facts of common observation indicate great stability in flour consumption, and we know of no evidence indicating material changes in flour consumption from year to year, even among the poorest classes. When statistics of sufficient accuracy are available over a considerable period of years, we shall undoubtedly find evidence of some changes in per capita flour consumption other than those resting on changes in consumption habits, but it seems clear that these changes must be of an order of magnitude in the neighborhood of 1 per cent or less. As will be shown in later pages, this is less than the apparent probable error of the best statistics on flour consumption now available.

in each year, it is a simple matter to calculate the total domestic consumption. The total production in any period must obviously equal the domestic consumption plus the exports in the same period, neglecting differences in total stocks of flour at the beginning and at the end of the period.

Chart 1.—Flour Production and Disposition in the United States, by Crop Years, 1879–80 to 1926–27*



* Data in Appendix Table I. Domestic consumption of flour increased in direct proportion to the increase in the population up to about 1903, but between 1903 and 1917 the increase in consumption was less rapid than the increase in population. In the last half of 1917, flour consumption was sharply reduced under the pressure of war conditions and has since increased only in proportion to the increase in population. The present level of domestic consumption, however, is nearly equal to that which would have resulted if the pre-war trend had continued without interruption. Annual flour production, though following a trend very similar to that of domestic consumption, varies more from year to year, owing to changes in net exports and changes in flour stocks. Fairly large exports and the accumulation of heavy stocks of flour during the year combined to make 1919–20 the record year in American flour production, despite the relatively low domestic consumption.

Thus we have a method for closely approximating the total production in each year.

These differences in total stocks of flour at the beginning and at the end of each period are not always negligible. They constitute the chief obstacle in the way of arriving at accurate estimates of annual flour consumption by the second method and the principal source of the errors in estimates of total production arrived at by that method. It nevertheless appears, as a result of careful study of the various sources of error involved in both methods, that, for the years 1879–80 to 1916–17 and 1921–22 to 1922–23, total flour production can be calculated most accurately by adding together the estimates of domestic consumption and the statistics of net exports and shipments to possessions, with an error probably never over 3 per cent and usually under 1 or 2 per cent. For the years 1917–18 to 1920–21 and 1923–24 to 1926–27, the total flour output may best be arrived at from existing statistics of flour production, the errors in the estimates for these years being probably never in excess of 2 per cent.

The complete series of estimates of production and domestic consumption of flour, by crop years since 1879–80, are given in Appendix Table I and shown graphically in Chart 1.

Estimates of Wheat Ground and Millfeed Produced

The estimates of total wheat ground and millfeed produced each year are obtained by calculation from the estimates of flour production and a new series of estimates of amounts of wheat required per barrel of flour. We find that use of the customary figure of 4.5 bushels of wheat per barrel of flour for this purpose leads to underestimating the quantity of wheat milled annually in recent years by some 20 or 25 million bushels. Furthermore, the wheat required per barrel of flour varies appreciably from year to year, enough in extreme cases to make a difference of over 16 million bushels in the amount of wheat required to produce the same amount of flour in two successive years.

The actual average wheat requirements per barrel of flour for each year can be obtained very accurately for recent years from the monthly milling reports of the Department of Commerce by raising the reported figures 1.5 per cent. The reports represent chiefly the larger mills of the country, which obtain a flour yield slightly above that for the country as a whole. For earlier years, we find that the wheat requirement per barrel of flour can be estimated with only slightly less accuracy from the average test weight of the crops, as estimated by the Department of Agriculture. For the war years, Grain Corporation figures on wheat requirements per barrel of flour are available. The estimates of wheat requirements per barrel of flour for each crop year since 1885–86, based on these data, are given in Appendix Table I and shown graphically in Chart 10 (p. 98).

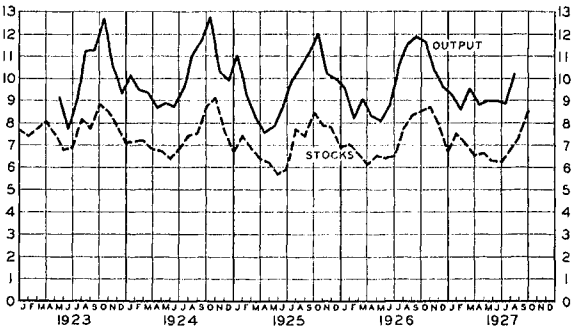
With these figures on wheat milled per barrel of flour and the estimates of total flour produced annually, it is a simple matter to calculate the total quantity of wheat ground and of millfeed produced in each crop year since 1885–86. The resulting estimates are given in Appendix Table I and shown graphically in Chart 11 (p. 99).

Monthly Flour Production since May 1923

The estimates of monthly flour output in the United States since May 1923 are given in Appendix Table II and shown graphically in Chart 2. They are based primarily on the monthly milling reports of the Department of Commerce, but include corrections for errors which result where these figures are raised to "100 per cent" by the usual method. When the reported output shown by the monthly figures of the Department of Commerce is raised to "100 per cent" on the assumption that the production of the reporting concerns represents the same percentage of the total output in the month or year in question as in the previous census years, the resulting figures tend to be always too high.

Chart 2.—Monthly Flour Output and Commercial Stocks, May 1923 to October 1927*

(Million barrels)



* Data in Appendix Table II. Mill output is not only highly seasonal, but there is a wide variation in the output in corresponding months of successive years. The variations in milling activity are found to depend very largely on the disposition of buyers to accumulate stocks of flour. (See pp. 79–81.) Such speculative accumulations do not appear in the primary commercial stocks, as reflected in Russell's series shown here. These are scarcely *stocks* at all, but a *stream* of flour flowing to the consumer at a very uniform rate, though in varying volume depending on the rate of milling.

The assumption that the reporting concerns produced the same percentage of the total output in the month or year in question as in the previous census year implies the assumption that the total output of all other concerns showed the same percentage change between the two periods as the reporting concerns. This is never to be expected, since the list of reporting concerns always includes new establishments which produced nothing during the previous census year, while a list of all the other concerns would show many which went out of business in the interval, their mills being dismantled, taken over by other concerns, or remaining inactive. The tendency toward overestimation involved in the usual method of raising the reported figures to "100 per

cent" increases with the interval between the previous census and the month or year for which the estimate is made, the overstatement amounting to about 1.8 million barrels on a year's production for each twelve months in the interval.

A second correction is required to take account of the output of custom mills. When the output shown by the monthly milling reports is raised to a true 100 per cent, as nearly as that can be approximated, it represents an estimate of 100 per cent of the output of the class of mills covered by the biennial censuses—merchant mills with a value of product amounting to $5,000 or more. The output of the merchant mills omitted may be neglected, but not the output of the custom mills. This is estimated at 1,205,000 barrels, the production shown in the census of 1919.

Changes in Total Flour Stocks

We have found it necessary, as mentioned above, to make a study of changes in flour stocks in the United States in order to determine how closely production in any year corresponds to domestic consumption plus net exports. Our estimates of total flour stocks on the first of each month, in terms of deviations from a 4-year average, are given in Appendix Table II and shown graphically in Chart 5 (p. 78). Several very interesting conclusions have come out of this study.

Total flour stocks in the United States are always several times larger, it appears, than would be indicated by any of the existing statistics. Even more important, it appears that the existing statistics cover classes of flour stocks which are not at all representative of the changes in total flour stocks. The two statistical series available are the monthly figures compiled jointly by the *Daily Trade Bulletin* and the *Daily Market Record* and the series compiled originally by the Grain Corporation and continued by Russell. The *Daily Trade Bulletin* statistics range usually, in recent years, between 1.8 and 2.5 million barrels, while the statistics of Russell and the Grain Corporation range between about 6 and 9 million barrels. The latter series, running about three times as large as the former, shows the same general type of movement, though with numerous differences in detail. The two series are shown graphically in Chart 5 (p. 78) and Chart 6 (p. 79). Both series cover what may be termed *primary commercial stocks*, and the more complete series compiled by Russell and the Grain Corporation probably reflects more accurately the movements of these primary commercial stocks.

Primary commercial stocks of flour, as reflected in the statistical series, clearly represent chiefly flour passing through trade hands to the final user at a very uniform rate. Since the deflation of 1920–21, Russell's stocks figures on the first of each month seem to have equaled almost exactly the total flour production during the previous 20 or 25 days. (See Chart 2.)

Total flour stocks show very different characteristics. Whereas primary commercial stocks represent the volume of a stream of flour flowing at a relatively uniform rate from the mills to the consumer, total flour stocks represent the level of a lake into which the stream flows. The level of the lake is rising most rapidly when the stream is at its highest stage and continues to rise until the flow in the stream has fallen to the point of just equaling the outflow from the lake. Similarly, the level of the lake is falling most rapidly when the stream is at its lowest stage, and does not begin to rise until the flow in the stream has increased to the point of exceeding the outflow from the lake. In consequence of this relationship, the high and low points of total stocks are reached from one to four months after the high and low points, respectively, of commercial stocks. The range of variation is much greater also, total flour stocks having moved through a range of over 7 million barrels during the three years ending with August 1927.

Even more important, it appears that total flour stocks are at times markedly affected by speculative accumulation of flour when prices are expected to rise, and by restriction of buying when prices are expected to fall. Total stocks remained unusually low during the autumn of 1927, for example, under the influence of steadily declining wheat prices, while the sensational rise of prices in 1924–25 led to an accumulation of non-commercial stocks on March 1 nearly 4 million barrels larger than the corresponding figure for the previous

March. Statistics of primary commercial stocks, on the contrary, show no evidence of speculative accumulation in these positions since the deflation of 1920–21.

Order of Detailed Presentation

In the investigation which provided the basis for the estimates here presented, the problem was first visualized much as it has been presented in the foregoing summary. As the study proceeded, it was found that the primary problems under investigation could not be solved satisfactorily until after certain secondary problems had been solved. The trend of flour consumption could not be determined accurately without a basis for estimating changes in total flour stocks between the beginning and the end of census years. This required a knowledge of the characteristics of total flour stocks which was not in existence. To obtain information on the characteristics of total flour stocks, it was necessary first to derive more accurate estimates of monthly flour output over a period of years than have been available hitherto, and from these to obtain a series reflecting fairly well the changes in total flour stocks over several years.

In the detailed presentation of the study, to which we now proceed, it is necessary to follow the order employed in the investigation rather than the superficially more logical order of presentation used in the foregoing summary. We start by developing a method of deriving more accurate estimates of monthly flour output from the incomplete figures reported by the Department of Commerce since May 1923. We next investigate the characteristics of total flour stocks, making use of data which may be derived from the Grain Corporation statistics and Russell's estimates of monthly flour output, and especially of a new series which we derive, showing the monthly movement of total flour stocks since May 1923. With this information in hand, we are able to develop improved estimates of annual flour consumption for the crop years 1879–80 to 1916–17. Estimation of annual flour consumption since July 1917, requiring the assembling of much additional information, is next undertaken. On the basis of the estimates of annual consumption and other statistics of disposition, we are then able to prepare annual estimates of total flour production which, with direct estimates of production for certain years, provide a trustworthy continuous series of production estimates by crop years from 1879–80 to 1926–27.

To obtain estimates of quantities of wheat ground and of millfeed produced annually, it is necessary first to make a study of variations in the quantity of wheat ground per barrel of flour, as reflected in the census statistics, the Grain Corporation statistics, and the milling reports of the Department of Commerce. This study provides a basis, with other data, for annual estimates of wheat ground per barrel of flour by crop years from 1885–86. These estimates and the estimates of total flour output by crop years permit calculation of the approximate quantities of wheat ground and of millfeed produced annually from 1885–86.

II. MONTHLY FLOUR PRODUCTION SINCE MAY 1923

Available Data and Their Shortcomings

In connection with each of its monthly milling reports, instituted in May 1923, the Department of Commerce publishes a statement of the percentage of the total output reported at the previous census, which was produced in that census year by the mills (or concerns)[1] currently reporting. It publishes also a statement of the production over several months of a group of identical concerns, all of which reported each month,[2] together with their percentage of the total output reported at the previous census. Making use of these published percentages, the reported production for any month or year is commonly raised to 100 per cent by

[1] Prior to March 1927, the statement was worded, in general, as follows: "These mills produced approximately .... per cent of the total wheat flour reported at the biennial census of manufactures in 19...."

In the report for March 1927 and in subsequent reports the statement runs, in general, as follows: "Of these ..... concerns, ... which were in operation in 1925 produced approximately ..... per cent of the total wheat flour reported at the biennial census of manufactures for that year."

The statement now used is the more precise description of the practice which has been followed from the beginning in the computation of these percentages.

[2] The concern is treated by the Department of Commerce as the real unit in these tabulations and the

dividing by the corresponding percentage, it being assumed that if a given group of mills produced, for example, 85 per cent of the total output in the previous census year, it likewise produced 85 per cent of the total in the latest month or year. This method of calculation may be applied either to the reports for the groups of identical concerns or to the total for all the mills reporting.

This customary method of estimating the total flour output from the Department of Commerce reports yields results which appear to be invariably somewhat too high. The amount of the excess is not uniform from year to year, having varied apparently from about 2 per cent to 6 or 7 per cent since 1923. It nevertheless exhibits characteristics over a period of time such that a correction can be applied which removes the larger part of the error.

Prior to January 1925 the current milling reports had to be raised to 100 per cent on the basis of percentages derived from the census of 1921. In the milling report for January 1925, the results of the 1923 census having become available, the necessary data were given for raising the 1924 reports on the basis of a percentage derived from the census of 1923. Employing the new basis for the calculation, the total production during 1924 appeared to be 5,100,000 barrels less than it had appeared when calculated with the percentage derived from the census of 1921. Similarly, when the results of the 1925 census became available, the new basis of calculation yielded an estimated total production for 1926, 3,500,000 barrels less than had been indicated by the calculations using the percentage derived from the census of 1923. With publication of the results of the 1925 census it became apparent also that the 1925 total as previously estimated by the customary method was about 2,600,000 barrels too high.

These facts may be summarized conveniently in the following tabulation, in million barrels, covering the three calendar years for which the data are available.[1]

	1924	1925	1926
Reports raised on basis of percentage for previous census year	120.8	117.3	117.7
Reports raised on basis of percentage for next earlier census year	125.9	....	121.1
Census enumeration	....	114.7	....
Difference	5.1	2.6	3.5

An explanation of the tendency for the estimated totals to run too high is found in a combination of several facts. Probably most important is the fact that, with new concerns being established each year and old concerns going out of business, any large and representative group of concerns in operation during a given year tends to produce a larger percentage of the total output in that year than in a previous year; such a group naturally includes some concerns that were not in existence in the previous year and of course includes none of the concerns which have gone out of business in the interval. Of the 866 concerns which reported in time for the monthly milling report of August 1927, 22 were not in operation in 1925. There is no record of the change in number of mills operated by the 844 concerns which were in operation in 1925 as well as in 1927, or of the number of concerns which were in operation in 1925 but not in August 1927, but the changes in both respects must have contributed toward the production by the reporting concerns of a larger percentage of the total output in 1927 than in 1925.[2]

A further cause of the tendency for the estimated totals to run too high is to be found in the fact that the larger mills are much more completely represented in the monthly reports than the smaller mills and that there has been under way in the milling industry for many years a tendency for the larger mills to turn out, year by year, a larger percentage of the total output of the country. In the monthly milling reports the trend toward increased production by the larger mills is reflected quite completely, while the offsetting trend toward decreased production by the smaller mills has little effect on the reported totals.

term "identical mills" formerly used has recently been replaced by the more accurate term. It should be noted that concerns are included in these groups which were not in operation during the previous census year.

[1] For the calculations based on the monthly milling reports the figures for "identical concerns" have been used in each case.

[2] An interesting summary of recent changes in the Northwest is given by Robert T. Beatty in the *Northwestern Miller*, November 16, 1927, p. 625. He states, for example, that "the outstanding feature of these annual figures is the apparent steady increase in production of the larger interior mills and the gradual elimination of the small grist mills."

These conditions leading to overstatement of the total production when estimated from the monthly milling reports by the usual method may be supposed to be operating fairly uniformly, so that the overstatement from these causes in any year should be approximately the same as in any other year, given equal intervals between the year for which the percentage was calculated and the year to which the calculation applies.

There are other conditions leading to errors in the estimated totals, however, which do not operate systematically. Among these are the variations in percentage of the total output produced by the classes of mills most completely represented in the reports, arising from variations in the size and quality of the wheat crop in different areas, variations in export demand, and other causes. The combined result of these two sets of conditions is that the estimated totals as usually obtained are probably always above the actual output, but by varying amounts, hence the variation in the differences shown in the tabulation above.

Method of Deriving Estimates of Total Production

It is impossible to make correction, on the basis of the published data, for the effects of conditions which operate irregularly from year to year; but the general tendency for the estimated totals to run too high, as a result of the conditions (discussed above) which probably operate quite uniformly from year to year, may be readily corrected. Such conditions naturally lead to an overestimate roughly proportional to the length of the interval between the year for which the percentage is calculated and the month or year for which the estimate is made. The amount of the overestimate which results when the interval is two years may be judged either by comparison of a census figure with an estimate for the same year, based on a percentage derived from data for the previous biennial census year, or by comparison of two estimates for the same year, based on percentages derived from data for two successive biennial census years. The first of these comparisons is possible for the calendar year 1925 only, the second only for the calendar years 1924 and 1926. The three possible comparisons, shown in the tabulation on page 69, above, show discrepancies, in chronological order, of 5.1, 2.6, and 3.5 million barrels or an average discrepancy of 3.7 million barrels.

It appears, therefore, that the conditions which tend uniformly to produce an overestimate of total flour output, as calculated from the monthly milling reports, result in an overestimate of about 3.7 million barrels whenever the percentage employed in the calculation is derived from data of a period two years earlier. It appears, further, that the influence of other conditions may modify this error, in either direction, by something like 1 or 1.5 million barrels.

On the basis of this information, we have adopted the following method for calculating the revised series of estimates of monthly flour production in the United States since May 1923. We first raise the reported figures to 100 per cent by the usual method, using by preference the totals for all mills reporting as revised in the statement following that in which they are first given. These totals are presumably somewhat more representative than the totals for the identical concerns, and their use yields a further advantage from the fact that since all the percentages, over most of the period, are published only to two digits, the resulting inaccuracies in the estimated totals for any year will probably be smaller when the varying percentages for all reporting concerns are used rather than the constant percentage for a group of identical concerns. It is desirable, however, to raise the reported figures on the basis of the most recent percentage figure available. Throughout 1924 and 1926 a more recent percentage figure may be used by employing the reports for identical concerns.

Having raised the reported output, monthly, by the usual method, we apply a correction for the uniform tendency to overestimation. This tendency may be regarded as a bias, the effect of which accumulates uniformly with the increase in the interval between the period from which the percentage is derived and the period for which the estimate is made. Since the effect of the bias amounts to about 3.7 million barrels on the total annual production at the end of a 2-year interval, the monthly accumulation of error may be taken in

round figures at 150,000 barrels, on the total annual production, or on the monthly production, one-twelfth of this amount, or 12,500 barrels.[1] To apply this correction, the reported output for each month raised to "100 per cent" is reduced by 12,500 barrels, times the number of months intervening between July of the census year for which the percentage was calculated and the month for which the estimate is made.

For the calendar year 1925 the monthly figures thus obtained are further adjusted by addition of 184,000 barrels each month to make the total for the twelve months equal the census figure for that year.

Account must also be taken of the fact that the biennial censuses of manufactures omit the production of custom mills and of merchant mills with a value of product under $5,000. The steps described above result in estimates of flour output comparable in their inclusiveness with the enumeration of the biennial censuses and therefore taking no account of the flour output omitted in those censuses. The output of the merchant mills omitted in the biennial censuses is apparently under 0.3 per cent of the total output,[2] and may be neglected. Adopting the method employed by the Department of Agriculture,[3] the annual output of custom mills may be estimated, in the absence of better information, at the figure shown by the last decennial census, 1,205,000 barrels, or with sufficient accuracy, 100,000 barrels per month. Adding this amount monthly to the figures previously derived brings the figures to their final form as given in Appendix Table II and shown graphically in Chart 2 (p. 66).

Possible Error in These Estimates

It is desirable to form some idea of the degree of error to be expected in these estimates of monthly and yearly flour production.[4] Though they constitute a material improvement on previous estimates, they necessarily fail of perfection, and in the uses subsequently to be made of the estimates it is important to know the approximate magnitude of the errors to which they are subject.

Reviewing the possible sources of error, it must be recognized that since the base points for the entire calculation are obtained from the census data, any deficiencies in the census figures must affect the estimates by a like amount. We know of no evidence that the census figures are not substantially accurate,[5] and accordingly we regard this possible source of error as probably negligible. The rough character of the estimate for production of custom mills cannot introduce appreciable error, since the amounts involved are so small relative to the total; complete omission of the figures would introduce an error of only 1 per cent in the total. The only important possibility of error seems to lie in the fact that the mills included in the monthly milling reports are not entirely representative of all the merchant mills of the country.

[1] The nature of the error for which this correction is made suggests the subtraction of a steadily increasing *percentage* of each month's production as probably more appropriate than the subtraction of a steadily increasing number of barrels. In view of the very slight difference in the figures that would be obtained by the two methods and some uncertainty as to which is really the more accurate procedure, the simpler method has been adopted.

[2] In 1921 the value of products of merchant mills in the "less than $5,000" class was 0.3 per cent of the total value of the products of all merchant mills; in 1919, 0.2 per cent. (Cf. *Census of Manufactures, 1921*, Table 60, p. 96.)

[3] For example, in *Wheat and Rye Statistics* (U.S. Department of Agriculture, Statistical Bulletin 12, January 1926), Table 85, note 2.

[4] Throughout this study we have undertaken, wherever possible, to indicate approximately the degree of error to which the estimates seem to be subject. In preparing all the principal estimates we have carried our investigations far enough to know fairly well the importance of factors the influence of which could not be given consideration in the estimates, and this knowledge may be summed up most effectively in the form of estimates of the errors which may have resulted in consequence of such omissions. It is quite possible that some sources of error may have escaped our attention, but we believe the estimates of possible error, as given, provide a trustworthy basis for judging the degree of confidence to be placed in the figures and for warning against drawing conclusions not justified by the limited accuracy of the figures.

[5] It is clear, however, that there is a small volume of flour production not included in any of the census figures even as supplemented, where necessary, by estimates of output of custom mills. The *Census of Manufactures, 1923*, states (p. 103, note 1) that "In addition, flour, meal, and other products normally belonging to the flour-mill and grain-mill industry were reported as subsidiary products by establishments classified in other industries (principally the manufacture of breakfast foods) to the following values: For 1923, $5,997,789; for 1921, $5,596,421; for 1919, $17,431,368; for 1914, $9,046,449." The value of these products, only a portion of which is wheat flour, represented in 1923 less than 0.6 per cent of the value of products reported for the industry.

The only available indications of the possible error from this source must be obtained from data such as that shown in the tabulation on page 69 above, with allowance for the greater accuracy resulting from our correction for a uniform bias as revealed in those figures. On this somewhat narrow basis it appears that our estimates of annual production for other than census years are probably always within 1.5 million barrels, or say 1 to 1.5 per cent of the figures that would be shown by a census covering the same years. The percentage error in the estimates for individual months may be expected to run slightly larger, with 2 per cent as the probable maximum error.

III. CHANGES IN TOTAL FLOUR STOCKS

Evidence of Large Changes

If any of the available series of monthly statistics or estimates of flour production in the United States[1] be taken as the basis for a calculation of monthly domestic disappearance, the resulting figures show a degree of variation which cannot possibly be considered to represent variations in actual consumption of flour. In almost any year, two or more successive months will be found in which the domestic disappearance is more than 50 per cent above that in other series of months. The conclusion is unavoidable that the periods of rapid disappearance (usually from September to November) represent periods in which substantial flour stocks are being accumulated, and that the periods of low disappearance represent periods in which these stocks are being reduced. Moreover, the disappearance figures show practically the same characteristics when adjustment is made for the changes in stocks covered by the existing statistics as when no such adjustment is made. Apparently the available statistics of stocks are very incomplete, perhaps not at all representative of the changes in total stocks.

For illustration, we may take the monthly flour disappearance figures calculated by the United States Grain Corporation for the two crop years 1918–19 and 1919–20. The monthly flour production statistics for this period are probably more accurate than the monthly figures for any other period, being comparable with census enumerations. The total of the production figures shown for the twelve months of 1919 is 132,334,000 barrels, almost exactly equal to the figure of 132,465,000 barrels for merchant mills subsequently obtained by the decennial census. Calculation of the domestic disappearance for each month on the basis of these production statistics, the Department of Commerce statistics of exports, the records of shipments for the American Expeditionary Forces, the American Red Cross, the Belgian Relief, and the Northern and Southern Relief (none of which is included in the Department of Commerce export statistics), and the stocks at the beginning and at the end of each month, as compiled by the Grain Corporation, yields the figures shown in Table 1 and graphically in Chart 3.

[1] Including Russell's estimates, the Grain Corporation statistics, the estimated monthly totals as usually calculated from the monthly milling reports, or our revised estimates of monthly production.

Table 1.—"Apparent Consumption" of Flour, Monthly, 1918–19 and 1919–20*

(Thousand barrels)

Month	1918–19	1919–20
July	4,562	5,215
August	6,445	8,376
September	10,660	9,917
October	8,825	11,902
November	8,526	10,833
December	11,281	10,871
January	4,797	13,416
February	5,437	7,844
March	8,800	7,462
April	8,498	5,164
May	7,829	7,207
June	5,401	7,592

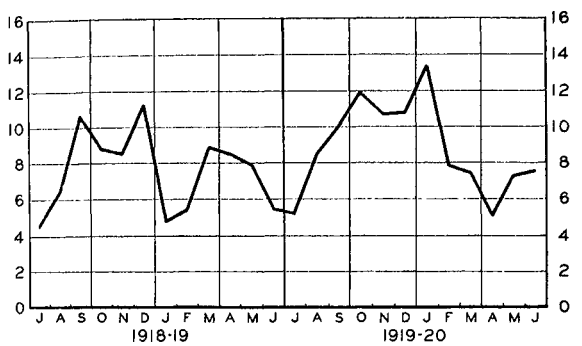
* Data from United States Grain Corporation, *Supplement to Grain and Flour Statistics during the War* (1920), p. 22.

If the disappearance statistics be totaled separately for the two halves of each crop year, July–December and January–June, it develops that the disappearance during the first half of the 1918–19 crop year was 9.5 million barrels more than during the second half of the crop year. In 1919–20 the difference between the disappearance in the first half of the crop year and that in the second half was 8.5 million barrels.

These differences in disappearance cannot be accounted for, even in small part, on the ground of differences in actual consumption of flour between the two halves of each crop year. Indeed, such difference as exists between the actual consumption in the two halves of each crop year must be in the direction of larger consumption in the second half. Bread consumption, and therefore flour consumption, is supposed, probably rightly, to be somewhat heavier in cold weather than in warm weather, and there is slightly more cold weather in the six months following January 1 than in the six months preceding that date. The steady growth of the population of the United States, amounting to some 750,000 every six months, tends to increase consumption in the second half of each crop year about a third of a million barrels over that in the first half. In 1918–19 there was the added fact that nearly three-fourths of the first six months of the crop year fell in the period before the armistice, when the rate of flour consumption may have been lower than in subsequent months. The only significant factor we think of that tends toward smaller consumption during the last six months of a crop year lies in the fact that those months include three less days (in a leap year, two less days) than the six months from July to December inclusive. Altogether, it appears that differences in disappearance of flour between the first six months and the second six months of a crop year must be accounted for largely on the ground of changes in flour stocks.

CHART 3.—"APPARENT CONSUMPTION" OF FLOUR, MONTHLY, 1918–19 AND 1919–20*

(Million barrels)



* The data on which this chart is based (Table 1) were compiled by the Grain Corporation and represent the most trustworthy monthly statistics of this sort obtainable for any period. The production statistics used in the computation represent actual reports comparable with the censuses in completeness. From the output for each month are subtracted the net exports and other shipments and changes in flour stocks, as reported to the Grain Corporation. It is quite inconceivable, however, that actual consumption varied in anything like this degree. There must have been heavy accumulations of unreported flour stocks between September and December of 1918, and still heavier accumulations between September 1919 and January 1920.

Given these facts regarding flour consumption, it is still not possible to determine from the differences in disappearance of flour between two halves of a crop year precisely what changes have taken place in flour stocks between July 1 and December 31 and between January 1 and June 30, but one can state with certainty that between the beginning and the end of one of these periods the change in stocks must have been at least as great as half the difference between the two disappearance figures. It is also clear that half of this difference gives the excess of flour stocks on January 1 over the mean of the totals at the beginning and at the end of the crop year.[1] Accordingly, it appears that since the flour disappearance during the six months July–December 1918 was 9.5 million barrels greater than during the six months January–June 1919, after allowing for the change in statistics of flour stocks, stocks not covered in the statistics must have been some 4.7 million barrels larger on January 1, 1919 than the mean of the corresponding figures for July 1, 1918 and July 1, 1919.

[1] Taking c_1 = flour consumption in the six months, July–December,
c_2 = flour consumption in the six months, January–June,
d_1 = flour distribution in the six months, July–December,
d_2 = flour distribution in the six months, January–June, and
s_1, s_2, s_3 = total stocks of flour in all positions on July 1, January 1, and June 30, respectively; then

$$c_1 = s_1 + d_1 - s_2,$$

and

$$c_2 = s_2 + d_2 - s_3$$

And if $c_1 = c_2$, as has been shown above to be substantially the case,

$$s_1 + d_1 - s_2 = s_2 + d_2 - s_3,$$
$$d_1 - d_2 = (s_2 - s_1) + (s_2 - s_3),$$

and

$$\frac{d_1 - d_2}{2} = s_2 - \frac{s_1 + s_3}{2}$$

Furthermore, if $s_1 = s_3$,

$$s_2 - s_1 = s_2 - s_3 = \frac{d_1 - d_2}{2}$$

Otherwise, either $s_2 - s_1$ or $s_2 - s_3$ must be greater than $\frac{d_1 - d_2}{2}$.

A calculation of disappearance for the same months, neglecting the statistics of stocks, shows a difference of 15.2 million barrels, from which it appears that total flour stocks in the United States on January 1, 1919 were some 7.6 million barrels larger than the mean of the totals for July 1, 1918 and July 1, 1919. The same calculation for 1919–20 reveals a difference in disappearance between the two 6-month periods amounting to 22.6 million barrels, indicating that total flour stocks on January 1, 1920 were 11.3 million barrels larger than the mean of the totals for July 1, 1919 and July 1, 1920.

These figures are large enough to suggest the desirability of making similar calculations for all the years for which monthly data are available. Using the Grain Corporation figures discussed above for the crop years 1918–19 and 1919–20, Russell's estimates of monthly output for the crop years 1914–15 to 1917–18 and 1920–21 to 1922–23, and our revised estimates of monthly output for the crop years 1923–24 to 1926–27, we obtain the following figures for the excess of total flour stocks on January 1 of each year over the means of the totals on July 1 preceding and July 1 following, in millions of barrels:

1915.... 8.5	1919.... 7.6	1923.... 7.9
1916.... 6.3	1920....11.3	1924.... 3.7
1917.... 6.8	1921.... 2.2	1925.... 5.2
1918....12.7	1922.... 8.0	1926.... 5.2
		1927.... 4.6

The conclusion is inevitable from these data that the quantity of flour on hand in the United States on the first of January varies from year to year through a range of several million barrels. The data forming the basis for these calculations are not perfect—Russell's estimates of flour output over the period from July 1920 to May 1923, in particular, are based on a decidedly incomplete record of milling output—but such errors as may exist can account for only a small portion of the variation shown by the figures in the table above. Indeed, the figures for years for which the data are most reliable show some of the most extreme values: the next to the highest figure in the table, indicating flour stocks on January 1, 1920, 11,330,000 barrels above the mean of the stocks figures of the preceding and of the following July 1, is derived from the very accurate data of the Grain Corporation, and the next to the lowest figure, indicating stocks on January 1, 1924, only 3,700,000 barrels above the mean of stocks on the preceding and on the following July 1, is derived from our revised estimates of monthly flour production.

Interpreting these figures in terms of variation in total stocks of flour in the United States on January 1, it appears that a change of 2 million barrels between successive January's is not uncommon and that under extreme conditions the change may be several times as large. This being the case, the domestic disappearance of flour during a calendar year, when calculated without allowance for changes in stocks, may not infrequently exceed the actual consumption (or fall short of it) by as much as 2 million barrels; under extreme conditions the disappearance may differ from the actual consumption by several times this amount.

This question of the changes in total flour stocks under varying conditions is worth pursuing farther, since it is now apparent that figures on flour disappearance for calendar years, such as those obtainable for census years, may safely be interpreted in terms of actual consumption only after giving due consideration to the change in total flour stocks between the beginning and the end of the year.

Monthly Changes in Total Stocks

Our revised estimates of monthly flour output since May 1923 provide a basis for a calculation which will throw much additional light on the subject. The change in total flour stocks in any month is obviously the difference between the production and the combined total of net exports and consumption in that month. We have the estimates of production, with sufficient accuracy, and excellent statistics of imports and exports. The monthly consumption since May 1923 may readily be estimated, probably with at least the accuracy obtaining in the production estimates.

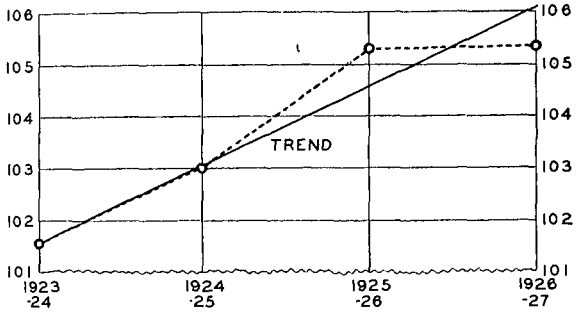
To estimate the monthly consumption of flour, we start with the assumption that since May 1923 the average daily consumption of flour each month has exceeded that of the month before by a uniform, readily

determinable amount. This assumption is probably in error in neglecting a small seasonal variation in the rate of flour consumption, perhaps also in neglecting other slight irregularities in the rate of flour consumption. After making the calculations on this basis, we shall consider the degree to which errors in this assumption may have affected the results.

As a basis for estimating the average daily rate of flour consumption each month we need to calculate the average daily rate for any one month and the average change in this rate from month to month. For this purpose, the statistics of apparent annual consumption by crop years, 1923–24 to 1926–27, may be used. The data are shown graphically in Chart 4. The statistics are

CHART 4.—DOMESTIC DISAPPEARANCE OF FLOUR BY CROP YEARS, 1923–24 TO 1926–27*

(Million barrels)



* Domestic disappearance of flour, when calculated by crop years, seldom differs much from the actual domestic consumption. The figures for domestic disappearance, derived from our revised estimates of flour production, provide a reliable basis for calculating the trend of flour consumption, represented by the light solid line. A steady increase in consumption is indicated, at practically the same rate as the increase in population of the United States, the trend line reflecting a consumption of slightly over nine-tenths of a barrel per capita in each year.

taken by crop years rather than by calendar years, partly because there are four complete crop years in the period covered by the statistics and only three complete calendar years, chiefly because changes in stocks appear to be usually much smaller between corresponding dates in midsummer than between corresponding dates in midwinter, making the apparent consumption by crop years the more reliable index of actual consumption.

The trend of the annual consumption statistics shown in Chart 4, indicated by the light solid line, shows the apparent trend of actual consumption during this period, in terms of the totals for 12-month periods. It appears that the actual consumption in 1924 was 102,296,000 barrels, and that it has been increasing at the rate of 1,508,000 barrels a year.[1] Converting these figures to the basis of average daily consumption and rate of change per month in the daily consumption gives an indicated average daily consumption of 275,450 barrels for May 1923, with an increase in each succeeding month of 344 barrels in the average daily consumption.

Taking from Appendix Table II the monthly figures for domestic disappearance and domestic consumption, the apparent change in total stocks between the beginning and the end of each month is readily calculated (Table 2, column 3, p. 76), as also the total apparent change from the first of May 1923 to the end of each succeeding month (column 4). The figures may be placed in still more significant form by expressing them in terms of deviations from the average first-of-the-month total stocks for the four crop years, July 1923 to June 1927 inclusive.[2] This is done in column 5 of Table 2.

These estimates of total flour stocks in the United States on the first of each month, expressed in terms of deviations from the average total stocks for the four complete crop years covered, are shown graphically in Chart 5 (p. 78), and reveal several very interesting facts, to be discussed shortly. In connection with the estimates of total

[1] It is interesting to note that this reflects a practically constant per capita consumption at a rate of .902 barrels per year.

[2] We have no statistical basis for calculating this average, but such a calculation is unnecessary. Let X represent this average; S_0 represent total stocks on the first of May 1923, and S_i total stocks on the first of any other month we may choose to take; C_i represent the change in total stocks between the first of May 1923 and the first of any other designated month (or the end of the previous month), and x represent the mean of these values, as tabulated, for the 48 months from July 1923 to June 1927.

Since X is the mean of the values of S_i over a 48-month period and x is the mean of the values of C_i, therefore of $S_i - S_0$, over the same period, we may write:

$$x = X - S_0 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

By definition,

$$C_i = S_i - S_0 \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Subtracting equation (1) from equation (2),

$$C_i - x = S_i - X$$

Since we have in column 4 of Table 2 estimates of C_i for each month, the values of $C_i - x$ may readily be calculated and treated as values of $S_i - X$, subject only to such errors as may exist in the estimates of C_i.

flour stocks, monthly, it is useful to have also the data for flour stocks outside the primary commercial stocks covered by Russell's figures. These are readily derived in terms of deviations from the 4-year average, and are given in Appendix Table II.

TABLE 2.—CALCULATION OF CHANGES IN TOTAL FLOUR STOCKS, MONTHLY FROM MAY 1, 1923

(Thousand barrels)

Year and month	Domestic disappearance[a]	Consumption[a]	Change in total stocks: During month[b]	Change in total stocks: Since May 1, 1923[c]	Total stocks first of month[d]	Year and month	Domestic disappearance[a]	Consumption[a]	Change in total stocks: During month[b]	Change in total stocks: Since May 1, 1923[c]	Total stocks first of month[d]
1923	(1)	(2)	(3)	(4)	(5)	1925	(1)	(2)	(3)	(4)	(5)
May....	8,127	8,539	— 412	— 412	—1,097	Sept....	10,272	8,552	+1,720	+ 659	—2,158
June...	6,928	8,274	—1,346	—1,758	—1,509	Oct.....	10,938	8,848	+2,090	+2,749	— 438
July....	8,130	8,560	— 430	—2,188	—2,855	Nov.....	9,255	8,573	+ 682	+3,431	+1,652
Aug.....	9,950	8,571	+1,379	— 809	—3,285	Dec.....	8,928	8,870	+ 58	+3,489	+2,334
Sept....	9,692	8,305	+1,387	+ 578	—1,906	1926					
Oct.....	10,549	8,592	+1,957	+2,535	— 519	Jan.....	8,794	8,880	— 86	+3,403	+2,392
Nov.....	8,741	8,326	+ 415	+2,950	+1,438	Feb.....	7,484	8,030	— 546	+2,857	+2,306
Dec.....	7,458	8,614	—1,156	+1,794	+1,853	Mar.....	8,335	8,902	— 567	+2,290	+1,760
1924						Apr.....	7,417	8,625	—1,208	+1,082	+1,193
Jan.....	8,298	8,624	— 326	+1,468	+ 697	May....	7,362	8,923	—1,561	— 479	— 15
Feb.....	7,882	8,078	— 196	+1,272	+ 371	June...	8,010	8,645	— 635	—1,114	—1,576
Mar.....	7,937	8,646	— 709	+ 563	+ 175	July....	9,637	8,944	+ 693	— 421	—2,211
Apr.....	7,538	8,377	— 839	— 276	— 534	Aug.....	10,027	8,955	+1,072	+ 651	—1,518
May....	7,860	8,667	— 807	—1,083	—1,373	Sept....	10,218	8,676	+1,542	+2,193	— 446
June...	7,522	8,398	— 876	—1,959	—2,180	Oct.....	10,181	8,976	+1,205	+3,398	+1,096
July....	8,712	8,688	+ 24	—1,935	—3,056	Nov.....	8,968	8,697	+ 271	+3,669	+2,301
Aug.....	10,021	8,699	+1,322	— 613	—3,032	Dec.....	8,317	8,997	— 680	+2,989	+2,572
Sept....	10,188	8,429	+1,759	+1,146	—1,710	1927					
Oct.....	10,782	8,720	+2,062	+3,208	+ 49	Jan.....	8,179	9,008	— 829	+2,160	+1,892
Nov.....	8,646	8,449	+ 197	+3,405	+2,111	Feb.....	7,654	8,146	— 492	+1,668	+1,063
Dec.....	8,387	8,742	— 355	+3,050	+2,308	Mar.....	8,598	9,030	— 432	+1,236	+ 571
1925						Apr.....	7,733	8,749	—1,016	+ 220	+ 139
Jan.....	9,946	8,752	+1,194	+4,244	+1,953	May....	7,825	9,051	—1,226	—1,006	— 877
Feb.....	8,235	7,915	+ 320	+4,564	+3,147	June....	8,075	8,769	— 694	—1,700	—2,103
Mar.....	6,772	8,774	—2,002	+2,562	+3,467	July....	8,013	9,072	—1,059	—2,759	—2,797
Apr.....	6,544	8,501	—1,957	+ 605	+1,465	Aug.....	9,082	9,083	— 1	—2,760	—3,856
May....	7,063	8,795	—1,732	—1,127	— 492	Sept....	9,716	8,800	+ 916	—1,844	—3,857
June....	7,742	8,522	— 780	—1,907	—2,224	Oct.....	10,023[e]	9,104	+ 919[e]	— 925[e]	—2,941
July....	8,986	8,816	+ 170	—1,737	—3,004	Nov.....	.....	.....	.....	.....	—2,022[e]
Aug.....	9.503	8.827	+ 676	—1.061	—2.834						

[a] Cf. text and Appendix Table II. [b] Domestic disappearance minus consumption. [c] Values in column 3 cumulated.
[d] Deviations from 4-year average, July 1, 1923, to June 1, 1927. Obtained from column 4 by subtracting 1,097 from the calculated change, May 1, 1923, to the end of the previous month. Cf. p. 75.
[e] Preliminary.

For brevity they may be called "total noncommercial flour stocks."

LIMITATIONS OF THESE ESTIMATES

In examining the figures on changes in total flour stocks, it is well to bear in mind certain limitations of the estimates, arising from the method of derivation and from the possibility of errors in the data employed. The most significant limitation relates to the trend of the curve. The method of calculation made it inevitable that total stocks on July 1, 1927 should appear the same as total stocks on July 1, 1923;[1] in other words, a substantially horizontal trend was assumed, by implication, at the outset. As a matter of fact, there has probably been a slight upward trend in total flour stocks over this period, with the growth in population and total flour consumption in the United States.

If the trend of daily flour consumption in the United States has differed slightly from that employed in the calculations, the form

[1] The total consumption over this period was assumed equal to the total distribution.

of the trend of flour stocks is slightly in error. If consumption increased more rapidly than indicated by our calculations, the flour stocks curve should have been bowed upward in the middle, following a parabolic trend. If consumption increased less rapidly than indicated by our calculation, the flour stocks curve should be bowed correspondingly downward. It seems quite unreasonable, however, to assume any error of significant magnitude in either direction. The changes required in the flour stocks curve on either of these assumptions would make it conform much less closely with other evidence as to its probable course. Even more weighty evidence of the substantial accuracy of the slope of the calculated trend of flour consumption is revealed subsequently (pp. 89–91) when it is found that this consumption trend, extended back four and a half years, agrees very well with the statistics of flour production and distribution for the entire period since January 1919, or, with an adjustment for the absence from the United States of the men in the American Expeditionary Forces, with the statistics of flour production and distribution since January 1918.[1]

The assumption of a steady upward trend in daily flour consumption throughout the year ignores a seasonal variation which probably exists. Even though daily flour consumption is considerably higher in cold weather than in warm, however, the average daily consumption between July 1 and January 1 and between January 1 and the next July 1 cannot differ materially from the average of the figures given by the trend used, for each half year includes nearly the same amount of hot and of cold weather. In consequence, the calculated stocks on January 1 and July 1 cannot be materially affected by neglect of the seasonal variation. The chief effect of this neglect must appear in the form of the curves between January 1 and July 1. Stocks during the late summer and the fall must be slightly understated, stocks during the late winter and the spring slightly overstated, the amount of the under- and overstatement in these periods depending on the amplitude of the seasonal variation in daily flour consumption. One may doubt whether the discrepancies from this source are sufficient to be perceptible on a chart without close comparison of the correct and the erroneous curves. In any case, they have no bearing on the features of the stocks curve which we shall shortly point out as most significant.

Possible errors in the flour production estimates may be of greater consequence. If the production estimate over a 12-month period is a million barrels above or below the facts,[2] it will result in a spurious increase or decrease of a million barrels in the stocks figures over the same period. Some such errors must be expected, and it is quite possible that they may be as great as 1 or even 1.5 million barrels over a 12-month period.[3]

Relation of Total Stocks to Primary Commercial Stocks of Flour

The most significant fact to be derived from a study of the series reflecting changes in total flour stocks comes to light when this series is compared with previous compilations of flour stocks statistics. In Chart 5 (p. 78) are shown, in addition to the estimates of total stocks, expressed as deviations from their 4-year average, the statistics of flour stocks compiled jointly by the *Daily Trade Bulletin* and the *Daily Market Record* and those compiled by Russell for the same period. There is no similarity whatever between the movements of the two series representing a small portion of the total stocks and the series representing the changes in the whole. Not only do they regularly reach their high and low points

[1] To obtain the best agreement, the slope of the trend must be slightly altered to show total consumption increasing 1⅜ per cent a year instead of 1½ per cent. This difference of 1/16 of one per cent in the rate of increase shown by the two methods of calculation is negligible. Existing statistics are not accurate enough to show which of two figures, differing by such a small amount, is nearer the facts. Both may be regarded as indicating a substantially constant per capita consumption of flour since the war.

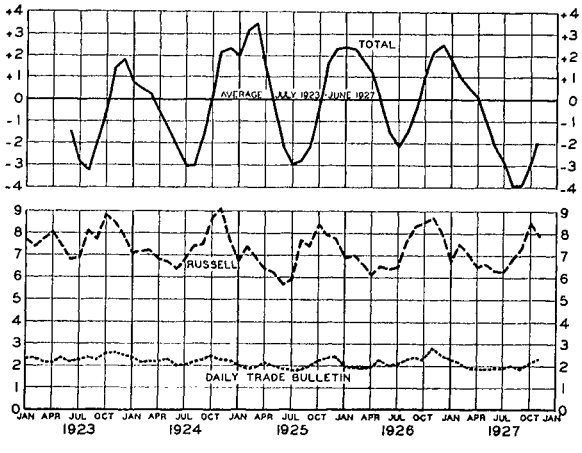
[2] We assume that the estimates are as likely to be over the facts as under. If, owing to defects in the census data or some other unrecognized circumstances, the estimates all tend to be too high or too low, error will be introduced in the stocks figures only to the degree that the error in the production estimates is variable. The consumption estimates being derived from the production estimates, a constant error in the one must be present to the same degree in the other, leaving the estimates of changes in flour stocks unaffected.

[3] The possible errors in the production estimates are discussed above, pp. 71–72.

at different times, but even the direction of the changes in the two partial series between corresponding dates a year apart shows no regular correspondence with the direction of the changes in total stocks over the same intervals.

CHART 5.—MONTHLY MOVEMENT OF TOTAL FLOUR STOCKS AND TWO STATISTICAL SERIES FOR COMMERCIAL FLOUR STOCKS*

(Million barrels)



* Data as of the first of each month, from Appendix Table II and from the Chicago *Daily Trade Bulletin*. The statistical series for commercial flour stocks are in no sense representative of total flour stocks, and are of no value in estimating the changes in total stocks of flour. Total flour stocks are usually built up rapidly in the fall to a high point on the first of December. Thereafter, stocks are normally allowed to decline fairly steadily until July or August, but, when higher prices are feared, stocks may be maintained at high levels for several months. The large changes in the level of stocks which may occur between successive January's sometimes result in material differences between domestic disappearance, as calculated for calendar years, and actual domestic consumption of flour.

The reason for the lack of similarity between the two partial series and the series representing changes in total flour stocks appears clearly from a little study of the two partial series. As plotted in Chart 5, Russell's series and the *Daily Trade Bulletin* series (which runs about one-third as large) show little resemblance between themselves. When plotted with a logarithmic vertical scale, however, so that the chart reflects truly the relative size of the changes, the two curves show a very fair degree of correspondence. In Chart 6, the two series are so shown over the entire period for which the more inclusive series is available. Comparing Russell's statistics of flour stocks with the monthly flour output (Chart 2, p. 66), a striking resemblance is discovered. Russell's statistics of stocks on the first of each month average about 75 per cent of the total output of the previous month, and in only 3 out of 51 months have risen above 82 per cent or fallen below 67 per cent of the output for the previous month. More concretely, Russell's statistics of flour stocks represent, with only a few minor exceptions, the flour output of the previous 20 to 25 days.[1]

It appears, therefore, that the two series of statistics of flour stocks currently compiled represent stocks of flour in certain primary commercial hands, better regarded not as *stocks* but as a *cross section of a stream* of

[1] It should be noted that the correspondence between Russell's estimates of flour stocks and the output of the previous month results in part from the fact that about half of Russell's total represents an estimate based directly on his estimate of the flour output for the previous week. The facts may best be described by quoting from a letter from Mr. Russell, dated November 18, 1924. He says, in part, that the figures on flour stocks are obtained by "a formula which I built up at the Grain Corporation when we had all the information that was available. There is no way of obtaining the stocks in the hands of dealers and bakers, and I never have attempted to estimate it. . . . . In addition to the items of New York stocks and [the Chicago *Daily Trade*] *Bulletin's* stocks, an estimated total of mill holdings and transit holdings is given. This is a percentage figure. It was found as a result of three years' experience that the amount of flour in mill stocks and warehouses unshipped was about 137 per cent of the week's output, while the transit stocks averaged about 60 per cent of the week's output. In periods of traffic congestion the transit stocks were very much larger, but eliminating the periods of congestion, we found these figures were approximately correct.

"We obtained from the mills at the Grain Corporation their figures of transit stocks by having them report the amount of sight draft flour and arrival draft flour outstanding at the end of each week. Of course, it was only the big merchant mills that did business outside of their own local territory.

"On the basis of this theory, which we found to be the most reliable we could work out at the Grain Corporation, I have continued to estimate the flour stocks. As there has been no period of traffic congestion the last year or two, the figures are possibly as near correct as can be devised, unless it would be possible for the Census Bureau to obtain each month a statement from the mills of their mill holdings and of their transit holdings."

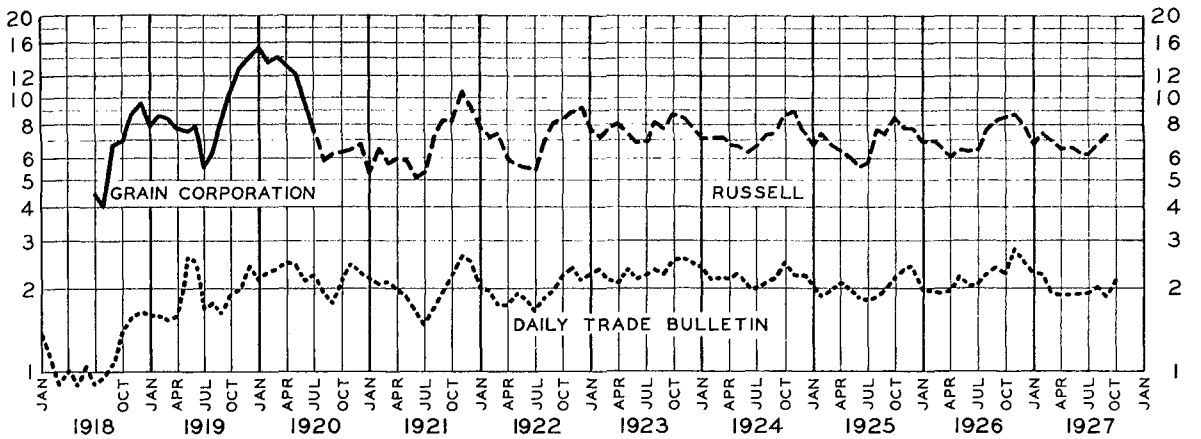
In the text we have examined Russell's figures, without qualification, first because they are widely used and constitute the most comprehensive available series, and second, because we believe them satisfactorily to reflect the changes in commercial stocks. Russell's judgment is worthy of confidence, and comparison of his series with the *Daily Trade Bulletin's* series reveals the same general type of movement, as noted in the text. The reports of mill stocks compiled by the Department of Commerce for June 30 and December 31, 1925, and quarterly since the latter date, also reveal the same type of movement, so far as one can judge from the eight cases thus far available for study.

flour flowing from the mills into secondary commercial hands or into export, and varying in size with the output of the mills. The analogy is worth pushing farther, for while the primary commercial stocks are to be regarded as measuring the volume of a stream, the series representing total stocks is to be regarded as measuring the level of a lake into which the stream flows. The level of the lake continues to rise after the flow in the stream has reached its highest stage and begun to subside, the highest level of the lake being reached, in fact, only when the flow in the stream has decreased to the point of just equaling the rate of discharge from the lake. Similarly, the level of the lake does not reach its low point when the stream is at its lowest stage, but continues to fall until the rate of inflow has increased sufficiently to equal the rate of discharge from the lake.

While the statistics of primary commercial stocks have in recent years shown no evidence of including speculative accumulations varying with the prospects for flour prices, the series compiled first by the Grain Corporation and continued by Russell shows such accumulations during 1919 and 1920 (Chart 6). This was undoubtedly largely a temporary phenomenon, but it may well be that there was more tendency toward speculative accumulation of flour in primary commercial hands under favorable conditions before the war than is observable in recent years. It should be noted, however, that the *Daily Trade Bulletin* series shows no such accumulation, even in 1919 and 1920.

CHART 6.—MONTHLY MOVEMENT OF COMMERCIAL FLOUR STOCKS AS REFLECTED IN TWO STATISTICAL SERIES SINCE 1918*

(Million barrels)



* When plotted on a logarithmic vertical scale, showing *relative* changes in their correct proportion, the statistics of flour stocks compiled jointly for many years by the Chicago *Daily Trade Bulletin* and the Minneapolis *Daily Market Record* show much the same general characteristics as the more comprehensive series compiled by the Grain Corporation and continued by Russell. Both are closely related to the mill output of the previous month, and, with the exception of the Grain Corporation series in 1919 and 1920, include no appreciable speculative accumulations at any time. In both respects the two series of commercial stocks contrast sharply with the series representing changes in total flour stocks. (See Chart 2, p. 66, and Chart 5.)

CHARACTERISTICS OF CHANGES IN TOTAL FLOUR STOCKS

Returning to a consideration of the curve of total flour stocks, as shown in Chart 5, it appears that the lowest first-of-the-month stocks have uniformly occurred either in July or August. The July 1 level is in each case about 3 million barrels under the 4-year average for all months, and is much more nearly uniform than the August 1 level, showing a range of variation considerably less than one million barrels in the five July's covered by the figures. The level of flour stocks on August 1 has sometimes risen above the July 1 figure, and sometimes fallen considerably below it, apparently depending chiefly on the movement of the winter-wheat crop.

In each of the first four years covered by the figures, stocks increased considerably between the first of August and the first of September, and still more in the next two months, reaching nearly the same levels, about 5 million barrels above the July 1 figure, on the first of November. A slight further rise occurred each year to December 1. In 1927, however, total flour stocks showed no increase between August 1 and September 1 and only a moderate increase to October 1. The November 1 figure, the latest available as we go to press, is over 3 million barrels below the figure for any of the four previous November's.

From December 1 to March 1, there is a wide diversity in the movement of stocks, the January 1 levels varying through a range of nearly 2 million barrels, and the March 1 stocks showing a range of over 3 million barrels.

The normal course seems to be for total flour stocks to reach their peak about December 1, and thereafter to decline, at first slowly, then more rapidly, to the low levels of midsummer, 5 or 6 million barrels under the high point of the early winter. This normal course seems to be subject to a wide variation, however, depending largely on the general opinion as to the probable future of wheat and flour prices. In the winter of 1924–25, the general fear of a serious shortage of wheat and of still higher prices later led to heavy accumulation of flour stocks, continuing into February or March. In the winter of 1925–26, a somewhat similar situation led to much the same results, despite the painful lesson of the previous year. With the fear of shortage less acute, an earlier decline in prices, and probably some influence from the experience of the year before, stocks were maintained at high levels through the winter, but not increased materially above the level of December 1.

The abnormally low levels of flour stocks in the months beginning with August 1927 are clearly to be attributed in large measure to the downward tendency in wheat prices which began in June and continued with little interruption through October. It may be significant, also, as a further indication of the influence of opinions regarding the future of wheat and flour prices, that in the fall and early winter of 1923–24 flour stocks remained somewhat below the levels for corresponding dates in the next three years. Beginning in September of that year, wheat prices moved uncertainly up and down, through a considerable range, but without definite trend, except that for spring wheat the declines were generally larger than the advances. This situation probably tended to restrict the accumulation of stocks. The fact that prices of the better milling wheats were considerably above Canadian prices may have had some influence also.

It should be noted, however, that the amount by which the stocks figures from October 1 to December 1 of 1923 differ from the figures for corresponding dates in subsequent years is within the limits of the possible errors in the data, and the evidence of unusually low stocks during this period may be spurious. None of the other characteristics of the stocks curve thus far noted is subject to such suspicion.

Conclusions

Summarizing and generalizing on the basis of the foregoing detailed discussion of flour stocks, it appears first of all that the statistics of flour stocks which have been compiled in past years are in no way representative of changes in total flour stocks. They include a small portion of the total, representing a class of stocks which varies quite closely with the mill output during the previous month and gives no reliable indication of the amount or even the direction of the changes in total flour stocks.

The period of only a little over four years for which we have derived monthly figures reflecting the changes in total flour stocks is relatively short, and the data are subject to certain limitations, so that generalizations must be drawn with caution. It appears clear, however, that total flour stocks on the first of January, the beginning of the calendar year, are subject to wider variations from year to year than total flour stocks on the first of July, the beginning of the crop year for the United States. The level of total flour stocks on January 1 is materially affected by opinions regarding the probable future course of wheat and flour prices. The period covered seems probably to include nearly the extreme range of conditions influencing the level of

January 1 stocks, with the exception of such extraordinary conditions as obtained during the war period. In consequence, it seems probable that changes in the level of flour stocks between the beginning and the end of a calendar year seldom, if ever, exceed 2 million barrels, except under such extraordinary conditions as obtained during the war and the immediate post-war period. Under such conditions, the changes may be several times as great.

An incidental conclusion of considerable interest to millers follows as a corollary of the foregoing statements. Since the level of flour stocks in the winter months is largely dependent on conditions influencing the disposition of buyers to accumulate flour stocks, the rate of milling activity must also be dependent on the same conditions. Variations in the amount of forward buying must have some influence also, leading to variations in mill stocks held against such orders. The recent Department of Commerce statistics of mill stocks, however, suggest that such accumulations must be small in comparison with other accumulations, so that the influence of forward buying on milling activity must be much less than the influence of actual accumulations of stocks by buyers.

IV. ANNUAL FLOUR CONSUMPTION, 1879–1917

In previous numbers of WHEAT STUDIES, we have pointed out the fact that the general trend of flour consumption in the United States may be determined very closely from calculations of domestic disappearance in census years.[1] We have shown further that all the available evidence points to the conclusion that, except under such extraordinary conditions as prevailed during the war, actual per capita consumption seems to change very little from year to year, except in periods of change of consumption habits, during which the change must be gradual and relatively uniform. In consequence, a curve showing the trend of flour consumption prior to the war may be regarded as representing the actual consumption in each year almost as accurately as it represents the level and trend of consumption over a period of years.

The calculation of the trend of flour consumption may be made with considerably greater accuracy by supplementing the statistics of flour disappearance in census years with estimates of changes in total flour stocks between the beginning and the end of each census year, thus obtaining a closer approximation to the actual consumption in those years. The facts brought out in the study of changes in total flour stocks (pp. 79–81, above) throw light on the amount of change to be expected under special conditions, which, taken in connection with the conditions obtaining in each year, permits of very fair estimates of the changes in flour stocks which occurred in those years. In consequence, it becomes possible to calculate the trend of flour consumption for pre-war years with greater confidence in the results than has previously been possible.[2] As thus obtained, the estimates of annual flour consumption between 1879 and 1917 appear to be probably within 1 per cent of the facts for each year, with the possible exception of a few years between 1900 and 1917 when consumption habits were changing rapidly and perhaps with sufficient irregularity to result in actual consumption in occasional years as much as 2 or 3 per cent above or below our estimates.

FLOUR DISAPPEARANCE IN CENSUS YEARS

The basic data for calculating the trend of flour consumption, prior to the war period, are furnished by the statistics of domestic disappearance in census years. The statistics for each census year since 1879 are given in Table 3 (p. 86). In making the calculations we have taken the census reports of total flour output, adding to the reported figures for quinquennial and biennial censuses an estimate of the production of custom mills, omitted in those censuses. For these estimates we have followed the method employed by the Department of Agriculture in a similar computation two

[1] "Wheat Acreage and Production in the United States since 1866," June 1926, II, 240–41, and "The Decline in Per Capita Consumption of Flour in the United States," July 1926, II, 267–74.

[2] For example, in the studies just cited.

years ago,[1] estimating the output of custom mills in 1904 and in 1914 at the figure shown by the census of 1909, namely 1,351,816 barrels, and in 1921, 1923, and 1925 at the figure shown by the census of 1919, namely 1,205,068 barrels. In three respects we have departed in the subsequent calculations from the method employed in the Department of Agriculture compilation, the results of which we have previously used: we include shipments of flour to possessions of the United States as well as exports; we take account of flour shipped to the American Expeditionary Forces, the American Red Cross, and the Northern and Southern Relief organizations, none of which is included in the Department of Commerce export statistics; and we take no account, at this stage, of changes in flour stocks. The need for including the additional statistics of flour shipped out of the United States is obvious. The statistics of stocks are neglected because we have found that the existing statistics cover a class of stocks not at all representative of the changes in total stocks of flour.

Flour Stocks in Census Years, 1879–1914

Although the available statistics of flour stocks are of no value as an indication of the change in total flour stocks between the beginning and the end of each census year, useful estimates of these changes may be made on the basis of a study of the conditions obtaining in each year. The estimates cannot be highly accurate, but even if they are all in error by 50 per cent, their use will reduce by one-half the existing errors from this source in the calculated flour consumption.

The method of procedure to be followed in the subsequent paragraphs may be outlined briefly at the outset. Taking each census year separately, we note first the level and course of wheat prices during the six months preceding the beginning of the year and the six months preceding the end of the year, giving attention to any circumstances which appear likely to have influenced the level of flour stocks on January 1 and on December 31. Judging the results to be expected from these circumstances, in the light of the facts developed in the foregoing study of flour stocks, we estimate the probable direction and amount of the change in flour stocks during the year, expressing the amount qualitatively as negligible, moderate, or large. A check on these preliminary estimates is then obtained through the fact that unusually large or unusually small accumulations of stocks must be reflected in the rate of milling activity (due regard being paid to the influence of export demand) and in the tone of the flour market. Information on milling activity and on market conditions is collected for each year from contemporary trade publications. As it turns out, the available records of milling activity and market conditions in each year point to substantially the same conclusions as are reached from the study of the price movements and related conditions.

Finally, we crystallize the judgment of probable change in stocks into a quantitative estimate, to the nearest half-million barrels. For this purpose we assume that a "large," but not extraordinary, change in stocks is to be set at about 2 million barrels, under present conditions, and at about 1 million barrels under the conditions obtaining in the earliest years of the period under review. The evidence developed in the study of flour stocks would justify the use of somewhat higher figures, but it is safer to keep the estimates conservative.

The calendar year 1879 was preceded by two and a half months of very stable prices, following a decline of 20 cents between the middle of August and the middle of October. It ended with a period of rising prices, including a rise of 30 cents between the first of September and the middle of October, followed by decline of a little over 5 cents in the next three weeks and then another steady upward swing amounting to over 15 cents between the second week of November and the end of December. The relation of spot wheat to the December option was practically the same in the months preceding the beginning and the end of the year. These circumstances point to a moderate increase in flour stocks at the end of the year as compared with stocks at the beginning of the year.

The reports of activity in the milling industry and the flour trade, as published currently in the Chicago *Daily Commercial Bulletin*, indicate that production of flour

[1] *Wheat and Rye Statistics*, Table 85.

during the fall and early winter of 1879, while only moderately active, was considerably above that of the same period one year earlier. In summarizing the year's trade, the *Bulletin* states:[1]

> Trade for the past year has been quite satisfactory, and although not really active, it is gratifying in reviewing the market to note an increase in the aggregate business transacted and the movement in general. The usual intervals of dullness existed, but generally the movement was satisfactory. The receipts for the year show the production to have been unusually large—the arrivals for the past year exceeding the receipts of the previous year some 300,000 barrels, all of which increase occurred since September, or since the new wheat crop commenced to move. Millers, stimulated by prospects of high prices and the reported shortage of the crops of the world, have run their mills pretty well to their full capacity when able to do so.

While the indications all point to a substantial increase in flour stocks between the beginning and the end of the calendar year 1879, it must be borne in mind that the total annual flour output at this time was little over half that of recent years. In view of the state of development of the flour trade at the time, it appears probable that the increase in flour stocks amounted to something like half a million barrels.

The calendar year 1889 was preceded by a rise of 20 cents in wheat prices between the end of July and early October. A corner was run in September wheat at Chicago, but apparently had little influence on the subsequent course of prices. Prices remained fairly steady through October, at $1.10 to $1.20 for contract wheat at Chicago, but in early November a decline set in, carrying prices down about 15 cents by the end of December. The year ended with seven months of very stable prices, the price of contract wheat at Chicago remaining throughout between 75 and 85 cents, but showing a slight tendency to decline. The relation of spot wheat to the December and May futures in Chicago was very similar in both periods. The price situation was therefore such as to indicate that flour stocks at the end of the year must have been somewhat larger than at the beginning of the year.

The reports of milling activity published currently during the months preceding the opening of the calendar year reflect active milling and accumulation of stocks by consumers during the period of rising prices in September, but in early October purchases were sharply curtailed, the market being described as "demoralized." Throughout the remainder of the year the demand was recorded as "very light" and "extremely dull." In the corresponding months preceding the end of the calendar year there was no period of unusual activity, but apparently a fair volume of milling, for the season, throughout. This record indicates that early in the season preceding the opening of the calendar year, flour stocks were built up to fairly high levels, and then allowed to decline. Apparently they had reached very low levels by January 1, for during January it was remarked that the demand was improving despite a further decline in wheat prices. At the end of the crop year flour stocks were probably about normal. Some increase in flour stocks clearly occurred between the beginning and the end of the calendar year, probably amounting to something like half a million barrels.

The calendar year 1899 was preceded by five months in which prices remained close to 65 cents a bushel for contract wheat at Chicago, though with a slight tendency toward advancing prices. Cash wheat sold most of the time on a par with the December future, though prior to the end of September it showed a small premium. During the months preceding the end of the year, wheat prices moved through practically the same range as during the corresponding period one year earlier, but with a pronounced downward tendency after late September. Between the end of September and the first of December the decline, though very gradual, had amounted to nearly 10 cents. The relation of cash wheat to the futures was nearly normal throughout the period. The price trends were therefore such as to induce less accumulation of flour stocks prior to the close of the year than were carried into the year. The difference in premiums on cash wheat in the two periods was so small as probably to exert little influence.

The record of milling activity in 1899 shows milling generally very active, for the season, throughout the five months preceding the opening of the year. The corre-

[1] December 31, 1879.

sponding period preceding the close of the year was also a good one for the mills, but periods of dullness were more frequent and more pronounced, and there was never the enthusiasm over conditions which had prevailed during much of the earlier season. It seems quite clear that flour stocks were reduced during the year, probably by about half a million barrels.

The months preceding the opening of the calendar year 1904 were characterized by considerable irregularity in wheat price movements and diversity in the movements for different classes of wheat. There were no extended periods of general weakness or strength which might have materially affected the disposition to accumulate flour stocks, but the relatively low level of prices was favorable to the carrying of liberal stocks of flour. During the months preceding the end of the crop year, wheat prices averaged about 30 cents a bushel above the level of prices one year earlier. After a sharp rise during August, prices remained fairly steady, but with an upward tendency on the whole. Conditions were therefore again favorable to the accumulation of liberal supplies of flour.

The record of milling activity and general market conditions during these two periods is particularly difficult to interpret in terms of its bearing on the accumulation of flour stocks, owing to the great difference in the export demand in the two periods. During the six months July to December 1903, over 10 million barrels of flour were exported, while in the same months of 1904 exports amounted to only 4.7 million barrels. In consequence, milling activity, in the aggregate, was considerably less in the latter period. The current comments bearing on the domestic demand indicate active purchasing for domestic use in both periods, such as would have led to the accumulation of liberal stocks of flour, at about the same levels, by the beginning and by the end of the calendar year 1904. This is in agreement with inferences from the price situation in the two periods, and we therefore assume no significant change in flour stocks between the beginning and the end of this calendar year.

In the months preceding the beginning of the calendar year 1909, wheat prices moved quite steadily upward, prices of contract wheat in Chicago rising 20 cents between the first of July and the first of January. The relation of spot wheat to the futures was normal throughout the period. Stocks of flour must have been somewhat above normal by the first of January. In the months preceding the end of the year, prices of contract wheat in Chicago moved up by about the same amount as in the corresponding period one year earlier, but following a quite different course, most of the increase coming in September, followed by steady prices until December, when a slight further increase occurred. Throughout the fall and early winter, No. 2 Red Winter wheat in Chicago was at a heavy premium, ranging mostly between 10 and 15 cents, over the December and May futures, but spring wheat was at only a slight premium.

The reports published currently by the *Northwestern Miller* show flour output for the crop year to January 1 slightly higher in the Northwest in 1909 than in 1908, but elsewhere the output appears to have been considerably lower in 1909. Exports of flour for the same periods were half a million barrels less in 1909 than in 1908, compensating in part for the decreased output. The reports of output, therefore, seem to support the conclusion, indicated by the price situation, that flour stocks were reduced slightly during 1909, probably by something like half a million barrels.

In the months preceding the calendar year 1914, wheat prices showed a very slight upward tendency, but spot wheat of contract grades in Chicago remained almost continuously at a premium over the December future, part of the time at a premium over the May future. In July and August preceding the end of the calendar year, prices rose 40 cents a bushel, declined about 15 cents during September, and then rose fairly steadily to the end of the year. The relation of spot wheat to the futures was normal throughout these months. The price conditions were thus such as to lead to low stocks at the beginning of the calendar year and unusually high stocks at the close of the year. A further tendency toward high stocks at the end of the year was furnished by the fears engendered by the outbreak of the war in Europe.

The reports of milling activity published by the *Northwestern Miller* and the *Daily*

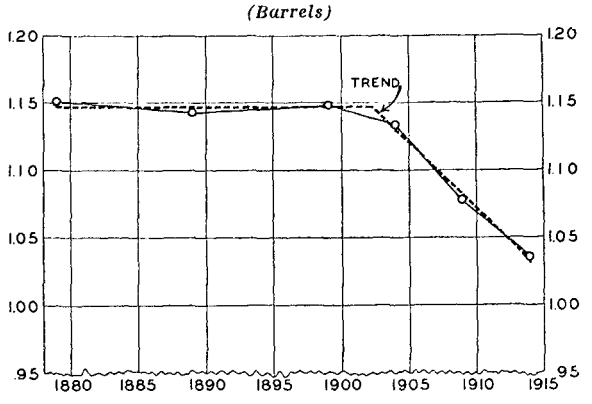
Trade Bulletin are in entire agreement with these conclusions. Flour output from August to December 1914 in the Northwest spring-wheat region was slightly under that of the same months in 1913, but elsewhere, especially in the hard winter-wheat districts, the output was greatly increased. Exports, on the other hand, were only slightly larger in these five months of 1914 than in the same period of 1913. Altogether, it appears that total flour stocks must have increased by 2 million barrels between the beginning and the end of the year 1914.

Trend of Flour Consumption

The foregoing estimates of changes in total flour stocks between the beginning and the end of each census year from 1879 to 1914 are brought together in one column of Table 3 (p. 86) and form the basis for calculating the approximate actual consumption from the total disappearance in each census year from 1879 to 1914. For later census years, the estimates of consumption are derived by another method, described in the next section, and the changes in stocks shown in the table for these later years are the changes necessary to harmonize the calculated disappearance with the estimated consumption.

The calculated flour consumption in each census year from 1879 to 1914, reduced to barrels per capita, is shown in Chart 7. The vertical scale in this chart is much exaggerated to facilitate a closer study of the changes in flour consumption. Study of the chart leads to raising the question whether the trend of flour consumption is properly to be represented by a smooth curve showing a decline which started slowly between 1890 and 1900 and gradually gained momentum, or by two fairly distinct trends representing a period of substantially stationary consumption per capita, merging rather sharply into a period of declining per capita consumption. On general grounds, it appears much more reasonable to assume that the decline in per capita consumption of flour started gradually and that the trend should be represented by a smooth curve, approximately horizontal in the early years and gradually turning downward with a steadily increasing slope. While the data do not accord with this theory, they cannot be said to clearly disprove it, for they could be brought into line by assuming that the calculated consumption figures for 1899 and 1904 are about 1 and 1½ million barrels, respectively, above the actual consumption in those years. Such errors are not impossible,[1] and it is advisable, before accepting the evidence of a fairly abrupt change in the trend of per capita consumption, to investi-

Chart 7.—Apparent Per Capita Consumption of Flour, 1879–1914*



* The data for apparent flour consumption are obtained from the census statistics of total output (raised, for other than decennial censuses, by estimates of output of custom mills) by subtracting the net exports and shipments to possessions, and then adjusting with estimates of changes in flour stocks between the beginning and the end of each census year. (See Table 3, p. 86.) Per capita consumption among many classes of the population began to decline early in the period, but the substitution of flour for corn meal by other classes, taking place most rapidly between 1897 and 1902, kept the general average rate of consumption practically constant until shortly before 1904. Thereafter, per capita consumption declined nearly 1 per cent a year up to 1914 at least, probably until the further sharp decline following our entry into the war.

[1] The consumption figures are of course affected by our estimates of changes in flour stocks. In view of the degree to which these estimates represent judgments with a somewhat intangible basis, the question may well be raised whether we have not allowed our judgment to be swayed by preconceptions of the results which should come out of the figures. We have of course made every effort to avoid any such warping of our judgments, and indeed the evidence in most years admits of less difference of opinion regarding the direction and amount of change in flour stocks than may appear to the casual reader. The year 1904 presented the most difficult problem of any in the period under review. It may be noted, however, that the judgment that flour stocks did not change appreciably between the beginning and the end of 1904 was reached at a time when we still held the view that the trend of per capita consumption should be represented by a smooth curve throughout. It was only after we had fixed on the figure for approximate consumption of flour in 1904 that we were led to the further investigation which culminated in the conclusion that per capita flour consumption must have suffered a fairly abrupt change of trend at about that date.

gate the conditions influencing flour consumption during this period.

The downward trend of flour consumption, up to 1914 at least, was a composite result of at least three different tendencies, two of which worked in opposite directions. First among these was a fairly general tendency toward the eating of less food, resulting perhaps chiefly from a decrease in the amount of physical effort required of the average individual. Second, there was a tendency, also fairly general, to substitute other food, chiefly sugar, in place of bread. Third, there was a pronounced shift from corn meal to flour, chiefly among the population of the South.[1] The decline in consumption of corn meal, as indicated by the figures of distribution in census years, was much greater between 1899 and 1904 than between any other two census years. A ready explanation is found in the fact that the tendency to shift from corn meal to flour, which had been in operation for some years, was accelerated in this period, especially in 1902 and 1903, by unusually high prices of corn meal, coupled with low prices of flour.[2]

It seems quite clear, therefore, that while there was undoubtedly a considerable decline in flour consumption among many classes of the population between 1899 and 1904 there was also an uncommonly rapid replacement of corn meal by flour in the diet of other classes in this same period. The decrease in apparent annual consumption of corn meal between 1899 and 1904 amounted to 27 pounds per capita for the entire population of the United States, a decline of such magnitude that the replacement of the corn meal by flour would have offset a very substantial curtailment of flour consumption on the part of other groups of the population.

With this information as to influences at work, it is evident that the trend of per capita flour consumption cannot be described by any single curve fitted by the method of least squares to the data for the entire period from 1879 to 1914. The best alternative is to represent the trend by two

TABLE 3.—PRODUCTION AND APPARENT DISPOSITION OF FLOUR IN THE UNITED STATES BY CENSUS YEARS, 1879–1925*

(Thousand barrels)

Census year	Production as reported	Unreported production (estimated)	Total production	Imports	Total supply excluding stocks	Exports, re-exports, and shipments	Domestic disappearance	Change in stocks	Estimated total consumption	Per capita consumption (bbl.)
1879.....	62,840	.....	62,840	15	62,855	6,134	56,721	+ 500	56,221	1.151
1889.....	80,949	.....	80,949	1	80,950	10,451	70,499	+ 500	69,999	1.142
1899.....	103,524	.....	103,524	1	103,525	18,717	84,808	— 500	85,308	1.148
1904.....	104,013	1,352	105,365	26	105,391	11,928	93,463	0	93,463	1.133
1909.....	107,108	.....	107,108	113	107,221	10,212	97,009	— 500	97,509	1.077
1914.....	116,404	1,352	117,756	79	117,835	13,286	104,549	+ 2,000	102,549	1.036
1919.....	133,671	.....	133,671	17	133,688	29,826	103,862	+10,762	93,100	.893[a]
1921.....	110,846	1,205	112,051	966	113,017	17,363	95,654	— 1,446	97,100	.896
1923.....	114,439	1,205	115,644	268	115,912	16,934	98,978	— 1,622	100,600	.902
1925.....	114,690	1,205	115,895	11	115,906	11,714	104,192	+ 392	103,800	.902

* The reported production figures are the census totals, to which are added, for quinquennial and biennial censuses, estimates of the output of custom mills, taken for 1904 and 1914 as equal to the output reported in 1909, and for 1921–25 as equal to the output reported in 1919. The imports, exports, and shipments to possessions are from publications of the Bureau of Foreign and Domestic Commerce, to which are added in 1919 the Grain Corporation statements of shipments to the American Expeditionary Forces, American Red Cross, and Northern and Southern Relief, totaling 2,755,400 barrels. Changes in stocks are independently estimated for the years 1879 to 1914 (see pp. 82–85) and the indicated consumption computed by subtracting the estimated changes in stocks from the domestic disappearance. For the years 1919 to 1925 the consumption is estimated independently (see pp. 90 f.) and the indicated changes in stocks computed.

[a] Expeditionary forces excluded from population estimate.

[1] Cf. "The Decline in Per Capita Consumption of Flour in the United States," WHEAT STUDIES, July 1926, II, 286–87.

[2] A ready comparison is available in the figures compiled by the Bureau of Labor Statistics on wholesale prices of both commodities in New York City. The average wholesale price of flour in this market in 1897 was $4.59 a barrel or $2.34 per 100 pounds, while the price of fine white corn meal averaged $.82 per 100 pounds. In 1902 the corresponding prices were $1.94 and $1.54 per 100 pounds, making corn meal 2¼ times as expensive, relative to flour, in 1902 as in 1897.

separate curves, one for the period 1879–1904, the other for the period 1904–1914. The information from which the form and position of the two curves must be determined is so limited that use of anything more complicated than straight lines is not justified. These lines, shown on Chart 7 (p. 85) have been obtained by assuming a horizontal trend for the earlier period, at the level indicated by the average for the three census years, 1879 to 1899 inclusive, and joining this with a straight line fitted by the method of least squares to the data for the three census years 1904 to 1914 inclusive.[1]

Flour Consumption by Crop Years

The rate of flour consumption per capita for each crop year from 1879–80 to 1916–17, as indicated by the trend, is readily calculated. Multiplying the per capita figures by the estimates of the population of the United States as of the middle of each crop year gives the estimated total flour consumption for each year shown in Appendix Table 1, and graphically in Chart 1 (p. 65). The calculation of domestic flour consumption on the basis of these trends cannot be applied to any of the period subsequent to about midsummer 1917, since the activities of the Food Administration profoundly affected the rate of flour consumption shortly after its organization.

The total annual consumption shows a rapid increase from 1879 to 1904, proportionate to the increase in population of the United States. After 1904 the rate of increase is slightly reduced, the natural effect of the growth of the population on total consumption being partially offset by the downward trend of per capita consumption.

V. ANNUAL FLOUR CONSUMPTION SINCE 1917

Peculiar Problems of the Period

The method of estimating annual flour consumption outlined above cannot properly be applied to the period of American participation in the war, and for a time thereafter when conditions were quite abnormal, and it is important to know as accurately as possible what changes in flour consumption occurred during these years. Additional data are available to throw light on the problem, chiefly from the compilations of the Food Administration and of the United States Grain Corporation and the estimates of flour production prepared by A. L. Russell, formerly statistician for the Grain Corporation. Taken by themselves, these data point to conclusions which seem difficult to accept, but when they are closely analyzed in connection with related information a very clear picture is obtained of the changes in flour consumption since 1917, forming the basis for estimates of domestic flour consumption between 1917–18 and 1923–24, which are probably within 1 per cent of the facts for each year.[2]

The most noteworthy feature of the results is the conclusion that flour consumption in the United States was reduced over 10 per cent during the last six months of 1917 and has not since risen appreciably above the level of about nine-tenths of a barrel per capita reached at that time. The figures that we had accepted previously, based on a calculation of flour disappearance derived from census statistics of production, indicated that the present low level of per capita consumption was not reached until 1920 or 1921.[3]

The major difficulty in determining the course of flour consumption during and after the war is raised by the figures covering the two crop years 1918–19 and 1919–20 and the calendar year 1921. These show an extraordinary variation in domestic disappearance of flour, the 12-month totals being respectively 92.9, 108.4, and 95.6 million barrels. The statistics are not open to the suspicion of error, except in negligible degree. The disappearance for 1918–19 and 1919–20 is calculated from the very complete statistics of output collected by the Grain Corporation during this period, raised

[1] The equations for the two curves are respectively
$$y = 1.147 \text{ and } y = 1.131 - 0.0097t$$
where y is consumption in barrels per capita, and t represents time, measured in years, with 1904 as the origin.

[2] The estimate for 1917–18 is open to more question than any of the others and may be somewhat more than 1 per cent above or below the facts.

[3] "The Decline in Per Capita Consumption of Flour in the United States," Wheat Studies, July 1926, II, 266–74.

by 1,337,000 barrels in each year, the difference between the Grain Corporation total for 1919 and the census total for the same year. The figure for 1921 is calculated from the output reported by the census of 1921, raised by 1,205,000 barrels to include the output of custom mills.

It is not unreasonable to suppose that flour consumption increased after the armistice; but that the consumption could have increased 17 per cent in 1919–20 over that in 1918–19 (only a little over one-third of the earlier period falling before the armistice), and then after an interval of only six months declined 12 per cent, is beyond belief. Clearly there must have been some extraordinarily large changes in flour stocks between the beginning and the end of some or all of these 12-month periods. Conditions were so abnormal during these years, however, as to leave little ground for estimating the changes in flour stocks. Instead of attempting to deduce actual consumption from the disappearance, together with estimates of changes in flour stocks, we proceed by assembling other information as a basis for preliminary estimates of consumption and checking these by examining the reasonableness of the changes in flour stocks which must be assumed to harmonize all the data.

Preliminary Estimates

The trend of flour consumption since 1923–24, as calculated in an earlier section (p. 75), may be regarded as representing the facts for these later years very accurately. There is ground for supposing that this trend represents a continuation of the trend in earlier years. Assuming that the trend of flour consumption calculated for the years 1923–24 to 1926–27 may be extended back to 1921, and checking this assumption against the flour disappearance in 1923, using the census production raised by the estimate for custom mills, it appears that the two are in perfect agreement, if allowance be made for a decrease of about a million barrels in flour stocks during the year 1923. That approximately this decrease actually occurred seems highly probable. It has already been shown (p. 80) that total stocks of flour on January 1, 1924 were appreciably below the average for that date in recent years, while the trend of prices prior to January 1, 1923 had been such as to favor the accumulation of liberal stocks.

A similar calculation for 1921 shows that allowance must be made for a decrease of 2 million barrels in flour stocks to bring the disappearance figures into agreement with the assumed rate of consumption. This is not so clearly reasonable. Prices fell sharply in the months preceding the opening of the calendar year 1921, with premiums for cash wheat at times fairly high. Prices were still declining, but less rapidly, in the months preceding the end of the year, and the relation of cash prices to the futures was nearly normal. These conditions suggest an increase in flour stocks between the beginning and the end of 1921.

It is entirely possible, however, that stocks at the beginning of the year were higher than might be expected from the course of prices during the preceding months, owing to the presence in some quarters of supplies still on hand from exceptionally large accumulations of the previous winter and spring. Furthermore, the wheat market during the fall and early winter was a peculiar one. Although prices declined 80 cents a bushel between August and December, the decline occurred entirely in two short separate periods. Between the end of July and the middle of September prices rose. An almost uninterrupted decline of over 50 cents a bushel during the next three weeks was followed by a month in which prices, though fluctuating, remained above the low point of the decline. Then came another decline of 50 cents a bushel, followed by a reaction of 15 cents, to a level at which prices remained firm throughout the month of December. Though the period was superficially one of sharply declining prices, it appears on closer analysis that major declines were in progress during less than one-third of the time between the first of August and the last of December. During over two-thirds of the time, the market was steady or rising. During each of the three extended periods of steady or rising prices, current prices appeared low by comparison with those of the previous year. There may, therefore, have been, through most of the time, a disposition to maintain flour stocks at approxi-

mately normal levels. On this interpretation, it appears quite reasonable to suppose that stocks at the beginning of the year were 2 million barrels above the level reached at the end of the year.

Since the assumption appears tenable that the trend of flour consumption over the last four years may be extended two and a half years farther back, it is worth trying the experiment of extending the same trend back through the war period, with certain modifications which are obviously necessary. This implies the assumption that per capita flour consumption has never recovered from the curtailment induced during the war. A good argument can be made, on theoretical grounds, for this contention.

Very good statistics are available for checking this theory. The primary requisite is a record of flour output over the three and a half years, July 1, 1917 to January 1, 1921. For two of these years, 1918–19 and 1919–20, we have the highly trustworthy and complete compilation of the Grain Corporation, already discussed. These, however, need to be raised by 1,337,000 barrels for each year, the difference between the Grain Corporation total and the census total for 1919. For the crop year 1917–18, Russell's estimates may be used with considerable confidence. They represent estimates with a strong basis in the extensive data compiled currently by the Grain Corporation and checked as to level by the practically complete data compiled through the next two years, and by the census of 1919.

For the six months July–December 1920, Russell's estimates may again be used, but here an adjustment is required. Beginning with July 1920, Russell was forced to take as the basis for his estimates the relatively incomplete data compiled by the *Northwestern Miller*, introducing a considerable opportunity for error. In each census year since that date, Russell's estimates of mill output have been close to 10 million barrels above the output indicated by raising the census figures by the amount of the output of custom mills in 1919. It seems probable, therefore, that Russell's estimate of flour output during the last six months of 1920 is too high by half the amount of his overestimate of the output during the 12 months of 1921. We therefore estimate the output for this 6-month period at 4.59 million barrels below Russell's figure, or 50,880,000 barrels

Making use of these data, we may calculate the domestic disappearance of flour by 6-month periods, beginning with July 1917. The resulting figures are shown in the third column of Table 4. To make the comparison more complete, we have added figures for the two halves of 1921, obtained by allocating the output shown by the census, plus the estimate for custom mills, between the two halves of the calendar year in the ratio shown by Russell's estimates.

TABLE 4.—PRELIMINARY TABULATION OF OUTPUT AND DISPOSITION OF FLOUR BY 6-MONTH PERIODS, JULY 1917—DECEMBER 1921*

(Million barrels)

Period	Output	Net exports and shipments	Disappearance	Estimated consumption	Change in stocks	
					During period	Since July 1, 1917
1917						
July–Dec...	66.64	7.68	58.96	49.00	+ 9.96	+ 9.96
1918						
Jan.–June..	48.75	15.26	33.49	46.00	—12.51	— 2.55
July–Dec...	62.90	9.96	52.94	46.00	+ 6.94	+ 4.39
1919						
Jan.–June..	59.56	19.61	39.95	46.50	— 6.55	— 2.16
July–Dec...	74.11	10.20	63.91	47.57	+16.34	+14.18
1920						
Jan.–June..	56.32	11.94	44.38	47.94	— 3.56	+10.62
July–Dec...	50.88	7.77	43.11	48.32	— 5.21	+ 5.41
1921						
Jan.–June..	46.36	7.59	38.77	48.70	— 9.93	— 4.52
July–Dec...	65.69	8.81	56.88	49.07	+ 7.81	+ 3.29

* See accompanying text.

In the fourth column of this table are shown the estimates of consumption which are to be checked. They have been obtained by extending backward the trend of consumption obtained for the years 1923–24 to 1926–27, with the following modifications. The value given by the trend is lowered roughly by the equivalent of one-half barrel[1] of flour for each man abroad in the American Expeditionary Forces,[2] for each

[1] Representing roughly the consumption to have been expected had they remained in the United States in their customary civilian occupations.

[2] Data from L. P. Ayres, *The War with Germany* (U.S. War Department, Washington, D.C.), revised edition, 1919, p. 15. The averages by 6-month periods beginning July 1, 1917 are (in thousands) 66, 353, 1,604, 1,384, and 82.

6-month period between January 1918 and June 1919. Shipments of flour to the American Expeditionary Forces have been included with exports. In calculating the disappearance for the last half of 1917 the consumption is placed about midway between the estimated consumption in the first half of 1918 and the estimated consumption in the first half of 1917, the latter derived, as described in the previous section, from the trend of per capita consumption between 1904 and 1914. This is done on the assumption that only half of the final influence of the Food Administration in reducing flour consumption made itself felt during this period.

Tests and Revision of Estimates, 1917–23

The changes in total flour stocks in each half-year necessary to harmonize these consumption estimates with the figures of flour disappearance are shown in the fifth column of Table 4. The changes may be studied more conveniently, however, when cumulated, as shown in the sixth column. This gives the implied total change in flour stocks between the July 1, 1917 and the end of each 6-month period. It is at once apparent that the estimates of consumption harmonize quite well with the statistics of flour disappearance. There is ground, however, for questioning whether flour stocks at the end of June 1921 were really quite 4.5 million barrels below their level on July 1, 1917. Apparently, the estimates of consumption are slightly excessive.

A very slight revision of the trend, involving the assumption that since the war the rate of increase in total flour consumption has been 1⅔ per cent a year instead of about 1½ per cent, as indicated by the trend calculated from the data for the last four years, suffices to bring the estimates of consumption into agreement with the statistics of flour disappearance. The revised figures are shown in Table 5. On a per capita basis they represent a rate of consumption about 1 per cent below the apparent level of per capita consumption in 1927. These results are highly interesting, for they demonstrate the complete agreement of the best available statistics with the theory that flour consumption per capita in the United States has never recovered appreciably from the level to which it fell during the war. The apparent increase of 1 per cent in ten years is within the limits of possible errors in the data.

Table 5.—Revised Tabulation of Output and Disposition of Flour by 6-Month Periods, July 1917—December 1921*

(Million barrels)

Period	Output	Net exports and shipments	Disappearance	Estimated consumption	Change in stocks	
					During period	Since July 1, 1917
1917						
July–Dec...	66.64	7.68	58.96	48.50	+10.46	+10.46
1918						
Jan.–June..	48.75	15.26	33.49	45.50	—12.01	— 1.55
July–Dec...	62.90	9.96	52.94	45.50	+ 7.44	+ 5.89
1919						
Jan.–June..	59.56	19.61	39.95	46.00	— 6.05	— .16
July–Dec...	74.11	10.20	63.91	47.11	+16.80	+16.64
1920						
Jan.–June..	56.32	11.94	44.38	47.52	— 3.14	+13.50
July–Dec...	50.88	7.77	43.11	47.94	— 4.83	+ 8.67
1921						
Jan.–June..	46.36	7.59	38.77	48.36	— 9.59	— .92
July–Dec...	65.69	8.81	56.88	48.78	+ 8.10	+ 7.18

* See accompanying text.

Though the statistics agree completely with this theory, they would of course agree also with a theory which assumed a decline to still lower levels in 1918, a rise to correspondingly higher levels following the armistice, and a subsequent decline in 1921 to or below the level here assumed. The theoretical ground for assuming such fluctuations in consumption, however, is not apparent. The only merit of such an assumption seems to be that it does not imply the accumulation of such heavy flour stocks in the winter of 1919–20. It is not unreasonable, however, to suppose that flour stocks did reach the levels indicated by the calculation in Table 5. There was a disposition to speculative accumulation of stocks of all kinds of commodities during this period unparalleled in recent history. Even the primary commercial stocks of flour (the series compiled by the Grain Corporation and continued by Russell), which have since reflected no influence from conditions leading to speculative accumulation of flour in other quarters, reached a level on January 1, 1920 nearly 10 million barrels above the figure for the previous July 1. After all, the figures for excess of stocks on January 1

and July 1, 1920 over the total on July 1, 1917, as shown in the last column of Table 5, indicate an excess over normal stocks for corresponding dates in other years amounting to no more than the current consumption during one and a half or two months. All the other figures in this column appear entirely reasonable. On the whole, we conclude that in the light of probable changes in flour stocks, the theory that per capita flour consumption in the United States has never risen above the war-time level accords better with the statistics of flour disappearance than any other theory, and that the estimates of consumption shown in the fourth column of Table 5 must be very close to the facts. The corresponding estimates of consumption by crop years are given in Appendix Table I and shown graphically in Chart 1 (p. 65). The population curve, shown for comparison in Chart 1, is adjusted for 1918 and 1919 to render it comparable with the consumption figures, by subtracting the figures for the number of men abroad with the American Expeditionary Forces.

VI. ANNUAL FLOUR PRODUCTION BY CROP YEARS SINCE 1879–80

Annual statistics of flour production are more useful if given by crop years than by calendar years, since the changes in production from year to year are closely related to the size and quality of the United States wheat crops and are therefore obscured in calendar year figures. There is also a technical advantage in making the estimates on a crop-year basis, owing to the fact that, for most of the period since 1879, production may be estimated most accurately by counting it equal to estimated consumption plus the net exports. Estimates of changes in flour stocks should also be included in such a calculation, but it is not feasible to attempt an estimate of the change in flour stocks between the beginning and the end of each year since 1879, and the neglect of these changes will introduce much less error with the figures on a crop-year basis. While the volume of flour stocks on hand in all positions on the first of January is subject to a good deal of variation from year to year, it appears that, with very few exceptions, stocks on July 1 are reduced to very much the same low levels each year. Probably the only important exceptions occurred in the period between 1917 and 1921, for which direct estimates of production are available. The estimates of flour production must in any case be subject to somewhat greater errors than the estimates of flour consumption, but with the figures on a crop-year basis the additional error in the production estimates probably exceeds 0.5 per cent in only a few years.

For the crop years 1917–18 to 1920–21 and 1923–24 to 1926–27, independent estimates of total flour production have already been obtained (pp. 68–71 and 89). These figures are repeated in column 3 of Appendix Table I. For other years the estimates of production are obtained by adding the net exports and shipments to the estimates of consumption.

The resulting estimates of annual flour production we believe to be seldom, if ever, more than 1.5 per cent wide of the facts. We have previously appraised the possible error in the estimates of consumption at probably 1 per cent or less, with the possible exception of the estimate for 1917–18 and the estimates for a few years in the neighborhood of 1904, in which the possibilities of error are slightly greater (pp. 81, 87 f.). The additional error in the estimates of production (when derived from the consumption estimates) we have just appraised at probably not over 0.5 per cent, giving a total possible error of 1.5 per cent without allowing for the probability of errors from the two sources offsetting each other. In thus appraising the possible errors in the statistics we have assumed the census statistics to represent substantially accurate and complete enumerations of the output of the classes of mills supposed to be covered and have further assumed the statistics of exports to be substantially complete.

The estimates of total flour output for each year are shown graphically in Chart 1 (p. 65) and Chart 11 (p. 99). The steady and rapid increase in annual flour output up to 1902–3 is striking. After 1902–3 flour exports declined and have since remained generally below the levels of the decade

preceding 1902–3. At about the same time, domestic flour consumption, per capita, began to decline. The two circumstances, coming together, produced a sharp change in the trend of flour production about 1902. The sharp decline in domestic flour consumption in 1917–18 was more than offset by the increase in flour exports—in this and the following year. In 1919–20 flour exports declined somewhat, but the purchases of flour going into the excessive stocks which were accumulated in that year made 1919–20 the record year by a wide margin for American flour milling. The prosperity was short-lived, for the next year saw the lowest flour output since 1896–97. Since 1920–21 the American milling industry has continued to feel keenly the effects of the decline in domestic consumption of flour. With the growth in population of the United States, however, total domestic consumption has more than regained its pre-war level and, assuming no material reduction in flour exports, a steady increase in the annual output of American flour mills may confidently be anticipated.

VII. WHEAT GROUND PER BARREL OF FLOUR

Having obtained reliable estimates of annual production of flour since 1879–80, it is desirable to complete the statistics of milling over this period by adding estimates of wheat ground and of millfeed produced. For this purpose statistics or estimates of milling ratios are essential. We find that the milling ratio is not by any means a constant, the range of variation, excluding the war years when milling ratios were sharply reduced, being over 3 per cent. Data are available, however, for estimating the wheat requirement per barrel of flour for each crop year since 1885–86 with a possibility of error only rarely exceeding 0.5 per cent. We undertake, therefore, in this section a study of milling ratios, upon which is based a series of estimates of the wheat ground per barrel of flour in each crop year since 1885–86.

Customary Procedure and Its Defects

For many years it has been customary to convert flour statistics into terms of wheat or wheat into terms of flour at a rate of 4.5 bushels of wheat per barrel of flour. Such a conversion ratio is commonly obtained by large commercial mills grinding wheat of good test weight, and the figure is a convenient one for calculation; but the average wheat requirement per barrel of flour for all mills of the United States, large and small, grinding some wheat of high test weight, some of low test weight, is considerably above 4.5 bushels per barrel of flour. The United States averages for census years are readily calculated by dividing the total flour production into the total quantity of wheat ground, as reported by the census. The milling ratios thus obtained for each census since 1889 are shown in the first column of Table 6. Considering for the present only the combined figure for "all merchant mills," it appears that in most years the wheat requirement runs close to 4.7 bushels per barrel of flour.[1] Neglecting the year 1919, in which the milling ratio reflects the influence of the high extraction maintained during the war and immediate

Table 6.—Bushels of Wheat Required per Barrel of Flour, Based on Census Data for 1889–1925*

Calendar year	All merchant mills	Merchant mills producing			Custom mills
		100,000 bbls. or over	1,000 to 100,000 bbls.	Under 1,000 bbls.	
1889.....	4.765	.....	.....	.....	.....
1899.....	4.724	.....	.....	.....	9.765
1904.....	4.750	.....	.....	.....	.....
1909.....	4.695	.....	.....	7.942	5.170
1914.....	4.688	4.585	4.864	4.334	.....
1919.....	4.624	4.577	4.693	6.318	5.066
1921.....	4.702	4.604	4.882	7.715	.....
1923.....	4.704	4.621	4.791	16.503	.....
1925.....	4.653	4.604	4.714	12.632	.....

* Calculated by dividing "wheat milled" by "flour produced," as derived from the reports of the censuses of manufactures. Census publications show wheat milled and flour produced by all merchant mills, by custom mills, and by merchant mills producing 100,000 barrels or over and 1,000 barrels or over. These figures permit calculation of the corresponding data for the classifications of "merchant mills producing 1,000 to 100,000 barrels" and "under 1,000 barrels." See discussion on p. 96 below. Dots (....) indicate that data are not available.

[1] Cf. Wheat Studies, June 1926, II, 246, 261–62, in which the net exports of wheat and of flour in terms of wheat are recalculated, using the ratio of 4.7 bushels of wheat per barrel for the conversion of flour into terms of wheat.

post-war period, the extreme range is from 4.65 to 4.76 bushels per barrel.

Further study has indicated that the variations in the milling ratio for all merchant mills as shown in Table 6 are themselves significant and that changes in the average quality of the wheat crop of the United States from year to year explain most of the variations in the average milling ratio for the country. These variations are worth considering, for in a year in which the milling ratio is 4.65 bushels per barrel of flour the wheat requirement for an output of 115,000,000 barrels of flour is 5,750,000 bushels less than would be calculated if the ratio of 4.70 bushels were used. Similarly, in a year in which the actual milling ratio is 4.75 bushels per barrel, the wheat actually ground for such a flour output is 5,750,000 bushels more than would be calculated using the 4.70 ratio.

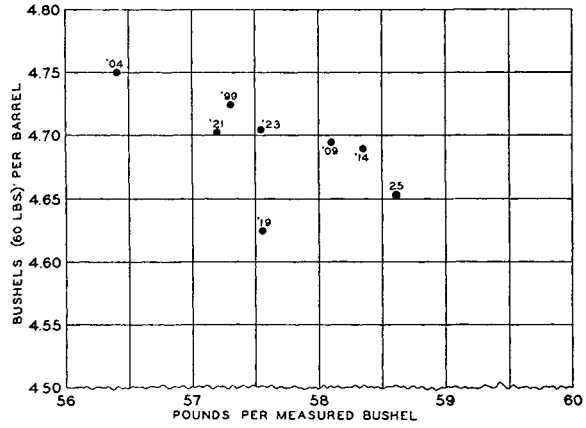
The Factor of Test Weight

The quantity of wheat required per barrel of flour is different for different types of wheat and different for the several varieties in any one type. For a given variety of wheat, the quantity required per barrel of flour varies materially with the test weight. More wheat, in pounds, is required to mill a barrel of flour from wheat of low test weight than from wheat of high test weight. The wheat requirement per barrel varies also with the type of flour milled and with the type of mill and method of operation. Taking the mills of the country as they are, however, with the qualities of flour actually produced and the types and varieties of wheat actually milled, the principal cause of variations from year to year in the milling ratio for the country as a whole is to be looked for in the variations in average test weight of the wheat milled.

Estimates of the average test weight of the wheat crop of the United States as prepared by the United States Department of Agriculture for each crop since 1885 are shown in Table 8 (p. 94). Through comparisons of the milling ratio shown by the census statistics with the estimated test weight of the crops milled in the census years, it appears that there is in fact a very close relation between the estimated test weight of the crops and the wheat requirements per barrel of flour as shown by the census data. This appears clearly in Chart 8. The census milling statistics apply to calendar years and therefore cover wheat from two successive crops. The recent monthly statistics of milling indicate that the wheat milled in one calendar year is derived in almost exactly equal amounts from the harvest of the preceding calendar year and the

Chart 8.—Relation of Wheat Required per Barrel of Flour to Weight per Bushel of the Wheat*

(United States averages)



* Data from Tables 6 and 8. The wheat ground per barrel of flour, as shown by the censuses of manufactures for all merchant mills, exhibits a close relationship with the average weight per bushel of the crops as shown by the Department of Agriculture estimates. The lower the test weight per measured bushel, the higher the number of 60-lb. bushels required per barrel of flour. The low wheat requirement in 1919 reflects the influence of the high extraction obtained during the war period.

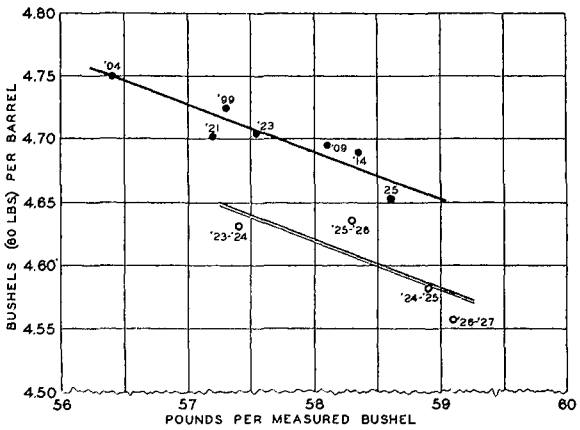
harvest of the calendar year to which the milling statistics apply. The test weight of the wheat milled in any calendar year may therefore be taken as the average of the test weights for the crops of that year and of the previous year. These are the weights per bushel used for Chart 8.

The wheat requirement per barrel shown for 1919 is clearly much below that to be expected from the estimated weight per bushel of the wheat milled in that year, judged in the light of the relationship between test weight and wheat requirement per barrel of flour for other years. The high flour extraction in 1919 thus indicated is undoubtedly an effect of the war-time restrictions on flour milling, and may be neglected in determining the normal relationship between estimated test weight and

wheat requirements per barrel of flour. The formal restrictions were removed by the opening of the year, but much short patent flour continued to be milled for export and shipment to relief organizations at least.

In addition to the data on wheat requirements per barrel of flour obtainable from the census figures, we have for the period since 1923–24 similar data available from the monthly milling reports. These figures may be computed for crop years, as shown in Table 7, and set against the estimated weight per bushel of the crop in question. The results are shown in Chart 9, together with a repetition of the data in Chart 8, omitting 1919.

CHART 9.—RELATIONS OF WHEAT REQUIRED PER BARREL OF FLOUR BY TWO DIFFERENT CLASSES OF MILLS TO WEIGHT PER BUSHEL OF THE WHEAT*



* Data from Tables 6, 7, and 8. With the same weights per bushel of the crops, the wheat ground per barrel of flour by the mills included in the monthly milling reports of the Department of Commerce (the hollow circles) averages about 1.5 per cent less than that for all merchant mills as shown by the censuses of manufactures (the solid dots). For each group, an increase of one pound in test weight of the wheat lowers the wheat requirement 0.038 bushels per barrel.

The wheat requirements per barrel of flour shown by the monthly milling reports, as they appear in Chart 9, show the same general correspondence with the estimated weight per bushel of the crop as the wheat requirements per barrel calculated from the census data, but on a lower level. This is to be expected from the fact that the mills covered in the monthly milling reports are larger than the average for the country and in general obtain a higher extraction than is shown in an average for all merchant mills.

To determine the normal relationship between average weight per bushel of the wheat crop of the United States and the quantity of wheat required per barrel of flour, the two straight lines appearing in Chart 9 have been fitted to the two groups of data shown on the chart. It has been assumed that the effects of changes in test weight are the same for the mills included in the monthly milling reports as for the larger group included in the censuses, the only difference being that the wheat requirement per barrel is higher at all test weights for the larger group, which includes more small mills. The lines have therefore been fitted using an adaptation of the method of least squares which gives the best

TABLE 7.—BUSHELS OF WHEAT REQUIRED PER BARREL OF FLOUR, ACCORDING TO UNITED STATES GRAIN CORPORATION DATA, 1917–18 TO 1919–20, AND MONTHLY MILLING REPORTS, DEPARTMENT OF COMMERCE, 1923–24 TO 1926–27

Year July–June	Bushels	Year July–June	Bushels
1917–18	4.533[a]	1923–24	4.631[b]
1918–19	4.450[a]	1924–25	4.582[b]
1919–20	4.645[a]	1925–26	4.635[b]
		1926–27	4.570[b]

[a] Calculated from "wheat milled" and "flour produced" as reported to the U.S. Food Administration Grain Corporation and the U.S. Grain Corporation in *Supplement to Grain and Flour Statistics during the War* (1920), p. 22.

[b] Calculated from "wheat milled" and "flour produced" by all reporting mills as shown by the monthly milling reports of the U.S. Department of Commerce.

TABLE 8.—ESTIMATED WEIGHT PER MEASURED BUSHEL OF UNITED STATES WHEAT CROPS, 1885–1926*

Crop of	Pounds per bushel	Crop of	Pounds per bushel	Crop of	Pounds per bushel
1885	58.3	1899	56.9	1913	58.7
1886	57.0	1900	56.3	1914	58.0
1887	58.4	1901	57.5	1915	57.9
1888	58.5	1902	57.6	1916	57.1
1889	56.5	1903	57.3	1917	58.5
1890	57.7	1904	55.5	1918	58.8
1891	57.2	1905	57.5	1919	56.3
1892	58.5	1906	58.3	1920	57.4
1893	57.5	1907	58.2	1921	57.0
1894	57.6	1908	58.3	1922	57.7
1895	58.3	1909	57.9	1923	57.4
1896	57.6	1910	58.5	1924	58.9
1897	57.1	1911	57.8	1925	58.3
1898	57.7	1912	58.3	1926	59.1

* Data from U.S. Department of Agriculture, *Wheat and Rye Statistics* (January 1926), and *Crops and Markets, Monthly Supplements.*

possible fit for two straight lines under the condition that the lines shall be parallel.[1]

This calculation indicates, in the first place, that a test weight of 58 pounds per measured bushel for the wheat crop of the country results, on the average, in a wheat requirement for all the merchant mills of the country of 4.69 bushels (of 60 lbs.) per barrel of flour. The mills included in the monthly milling report, averaging larger, show a wheat requirement of 4.62 bushels per barrel for the same test weight per bushel of the crop. From the above it follows that the wheat requirements per barrel of flour shown by the monthly milling reports should be raised 1.5 per cent to render them comparable with the figures for all merchant mills. In the second place, it appears that with each pound of increase or decrease in the test weight per bushel the wheat requirement decreases or increases by 0.038 bushel per barrel.

Other Factors Affecting Milling Ratio

While the wheat requirement per barrel of flour is closely related to the test weight of the crop, several other conditions occasionally haye some influence upon it. A certain fraction of the crop is always exported, the exports consisting chiefly of the less desirable milling wheats. In a year of large crop the mills may grind relatively little of the lighter wheats, for which the wheat requirement per barrel is high. This results, as in the year 1926–27, in an average wheat requirement lower than would be expected from the weight of the crop as a whole. Milling of large quantities of Canadian wheat, which permits a high extraction, will similarly lower the average wheat requirement.

In some years certain peculiarities of the crop not reflected in the test weight modify the wheat requirement per bushel. The winter-wheat crop of 1925, though showing a good test weight, was disappointing in its flour yields, owing to unusual thickness of the coat of the berry, resulting in high bran yields and a considerably larger wheat requirement per barrel of flour than should have been expected from the test weight of the wheat. The average wheat requirement shown by the monthly milling reports for 1925–26 was 4.635 bushels per barrel of flour, nearly 0.03 bushels or 1.8 pounds per barrel greater than would have been expected from the estimated weight per bushel of the crop. (See Chart 9.)

Changes in the average quality of the flour milled will markedly affect the wheat requirement per barrel of flour. The wartime regulations, limiting the production of short patent flour, apparently lowered the wheat requirement per barrel of flour by about 4 per cent (see p. 98, below). In ordinary times, however, the proportions of short and long patent flour milled in the United States are practically constant from year to year.

The introduction of the roller process of milling in the United States greatly reduced the wheat requirement per barrel, but this change seems to have been practically completed by the time the census of 1900 was taken. The wheat requirement per barrel of flour in 1899 was almost exactly at the figure to be expected in the light of subsequent milling experience. The wheat requirement shown by the census of 1889, however, was nearly 1 per cent higher than would have been expected for an equal weight per bushel of the crop under present milling conditions.

It would seem reasonable to suppose that the gradual elimination of the smaller mills should have resulted in a progressive reduction in the country-wide average wheat requirement per barrel of flour, even after the use of the roller process became prac-

[1] The equations for the two lines are:
for wheat requirement, based on census data,

$$r = 6.896 - 0.03805w;$$

for wheat requirement, based on monthly milling reports data,

$$r = 6.826 - 0.03805w;$$

where
r = bushels of wheat (60 lbs.) required per barrel of flour, and
w = estimated weight of the wheat in pounds per bushel.
The constants for the equation above were obtained in a single solution, using the equation of relationship,

$$r = a + bw + ck;$$

where r and w are defined as above and
$k = 0$, for observations in which r is derived from the census data, and
$k = 1$, for observations in which r is derived from the monthly milling reports.
Solution by the method of least squares yielded the equation,

$$r = 6.896 - 0.03805w - 0.070k,$$

which is more readily used in the form of the two separate equations given above.

tically universal. The statistics, however, yield no evidence of this. Apparently the effect of the elimination of the smaller mills has been too small to be observable in the statistics, or else some other influence has produced an approximately equal opposite effect on the average wheat requirement per barrel of flour. Some such influence may have been exerted by the establishment of the maximum moisture content of flour at 13.5 per cent, made generally effective about 1908 under the Food and Drugs Act.

Despite the presence of these and other influences modifying the annual average wheat requirement per barrel of flour, it appears that the principal factor involved is the weight per measured bushel of the wheat. The evidence for this conclusion appears clearly in the close grouping of the actual observations about the two lines of relationship shown in Chart 9 (p. 94).

Supporting Evidence on Influence of Size of Mills

The conclusions stated above may be checked by comparison with other information bearing on the same questions. The difference between the average wheat requirement per barrel of flour for all the merchant mills of the country included in the censuses of manufactures and that for the larger mills of the country, such as predominate in the data from the monthly milling reports, may be checked from the census statistics for mills in different size groups. The census gives statistics of flour produced and wheat ground for all merchant mills included at each census, and for merchant and custom mills, combined, at each decennial census. Beginning with 1909 a separate tabulation is shown for merchant mills producing 1,000 barrels of flour and over. Beginning with 1914 a separate tabulation is shown also for mills producing 100,000 barrels of flour and over. From these statistics it is possible to compute for several censuses the wheat requirement per barrel of flour for all merchant mills, for all custom mills, and for merchant mills falling into three different size groups. The average wheat requirements thus obtained are shown in Table 6 (p. 92), the figures for all merchant mills being those used in the foregoing discussion.

The wheat requirement shown for all merchant mills is in two years 0.10 bushel per barrel over the figure for mills producing 100,000 barrels or over, in a third year, 0.08, and in 1919, only 0.05 over the latter figure. Omitting 1919, which probably represents abnormal conditions, the evidence is that the wheat requirement for all merchant mills runs quite uniformly about 2 per cent above the wheat requirement for mills producing 100,000 barrels or over.

The mills producing between 1,000 and 100,000 barrels of flour show in two years a wheat requirement 6 per cent over that for the mills producing 100,000 barrels or over. In a third year this wheat requirement is less than 4 per cent higher than that for the large mills, and in 1919, less than 3 per cent higher.

The figures for mills producing under 1,000 barrels of flour and for custom mills show an extraordinary variation. The figures for custom mills in 1909 and in 1919 appear reasonable and may be trustworthy. The figures for merchant mills producing under 1,000 barrels are in all cases quite unreasonable and are clearly of no value. The errors may be due to inaccuracies in the original schedules or they may be the result of errors in the tabulation of the data. It must be remembered that the figures for wheat ground and flour produced by mills producing under 1,000 barrels have to be arrived at by subtracting the corresponding figures for mills producing over 1,000 barrels from the figures for all merchant mills. In 1923 all merchant mills were reported to have ground 538,312,078 bushels of wheat, of which 531,935,511 bushels were ground by mills producing over 1,000 barrels of flour. This left 6,376,567 bushels to be accounted for by the mills producing under 1,000 barrels of flour. A relatively insignificant error in the tabulation of wheat ground by the mills producing over 1,000 barrels of flour, for example, would result in an equal error in the figure for mills producing under 1,000 barrels (obtained by subtraction from the total), and in the latter figure such an error might be very serious.

The difference of 2 per cent between the wheat requirement per barrel for all merchant mills and the wheat requirement for mills producing over 100,000 barrels of flour accords perfectly with our finding of a dif-

ference of 1.5 per cent between the wheat requirement for all merchant mills and that for the mills included in the monthly milling reports. The monthly milling reports include many mills producing less than 100,000 barrels of flour and therefore differ less from the average for all merchant mills than do the mills producing 100,000 barrels and over. In 1923 the 247 mills producing over 100,000 barrels of flour had an average output per mill of 344,031 barrels. In 1923–24, the most nearly comparable period available, the 955 identical mills included in the monthly milling report had an average output of 106,338 barrels per mill.

Experimental Evidence on Influence of Test Weight

As a check on the statistical evidence of the effect of variation in test weight on wheat requirement per barrel of flour, there are available numerous tests under experimental conditions. The United States Department of Agriculture has published the results of extensive milling experiments on the wheat requirements per barrel of flour for the principal classes of wheat of various test weights per bushel.[1] Averaging these figures for the five principal classes of wheat, with due allowance for the differences in the quantities of each class milled in the United States, gives the wheat requirements shown in the last column of Table 9.

The weighted average of the experimental results shows an average change in wheat required per barrel of flour amounting to about 0.042 bushel for each pound change in test weight, agreeing quite closely with the figure of 0.038 derived from the statistics. The experimental results are also in remarkably close agreement with the statistics as regards the wheat requirements indicated for each test weight. For a test weight of 58, they show a wheat requirement of 4.70 bushels per barrel, agreeing almost exactly with the requirement of 4.69 bushels indicated by the statistics. The close agreement in this respect is largely fortuitous and is chiefly significant in indicating that the efficiency of the test mill, as operated, was less than that of large commercial mills, but greater than that of the smaller commercial mills, yielding results closely representative of average milling conditions in the United States.

[1] Cf. *Wheat and Rye Statistics*, p. 86.

Table 9.—Wheat Requirements per Barrel of Flour for Different Test Weights, by Classes, and Weighted Average*

Test weight, pounds per measured bushel	Wheat required per barrel of flour (60-lb. bushels)					
	Hard red spring	Durum	Hard red winter	Soft red winter	White	Weighted average[a]
56	4.80	5.02	4.63	4.85	4.88	4.78
57	4.73	4.89	4.62	4.81	4.78[b]	4.73
58	4.69	4.75	4.61	4.78	4.72	4.70
59	4.61	4.72	4.58	4.69	4.69	4.64
60	4.60	4.65	4.55	4.69	4.65	4.62
61	4.55	4.60	4.51	4.62	4.64	4.57

* Data from *Wheat and Rye Statistics*, p. 86, based on experimental milling tests by the milling laboratory, Bureau of Agricultural Economics, in terms of dockage-free wheat.

[a] The weights used in calculating the averages are, in the order in which the classes of wheat are listed: 2, 0.4, 3, 3, 1.

[b] Owing to a typographical error, this figure appears as 4.88 in the Department of Agriculture bulletin.

Annual Estimates of Wheat Milled per Barrel of Flour

The foregoing study of wheat requirements per barrel of flour provides a basis for estimating the average quantity of wheat milled per barrel in each crop year since 1885–86. For the years 1885–86 to 1916–17 and 1920–21 to 1922–23, the estimates must be obtained by calculation from the estimated test weight per bushel on the basis of the relationship discussed above.

For the years 1917–18 to 1919–20 and 1923–24 to 1926–27, there are available the statistics compiled by the Grain Corporation and by the Department of Commerce from which the milling ratios for those years may be obtained with less chance of error than if the estimates were based on the reported average test weight of the crop. The milling ratios derived from the Grain Corporation figures for 1918–19 and 1919–20, representing practically complete reports for all merchant mills, may be taken as they stand. It has been shown above (pp. 94–95) that the wheat requirements per barrel of flour shown by the monthly milling reports of the Department of Commerce must be raised 1.5 per cent to obtain the approximate average for all merchant mills. It appears also that the milling ratio shown by

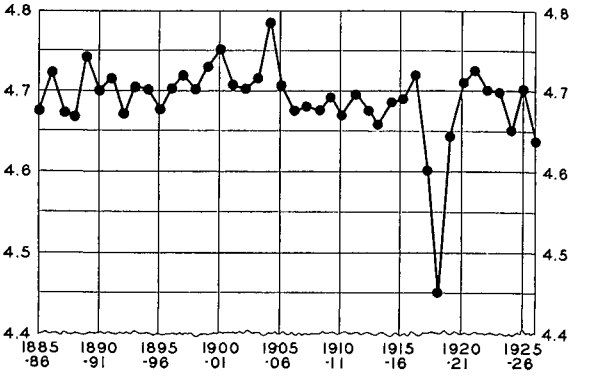
the Grain Corporation figures for 1917–18 must be raised by a like amount. The reports obtained for 1917–18 cover about the same percentage of the total output as is included in the monthly milling reports, and seem, like the latter reports, to represent chiefly the larger mills of the country.

The estimates of wheat milled per barrel of flour, as thus obtained for each crop year since 1885–86, are given in Appendix Table I, column 2, and shown graphically in Chart 10. Neglecting the years affected by war-time regulation, the average is very close to 4.7 bushels per barrel, the figures ranging from 4.639, in 1926–27, when the average weight of the crop was reported as 59.1 pounds per bushel,[1] to 4.784, in 1904–5, when the average weight of the crop was reported as only 55.5 pounds per bushel. Under the influence of the high rate of extraction enforced during the war, the milling ratio fell to 4.450 in 1918–19. This very low wheat utilization was made possible in part, however, by the good weight of the crop of that year, reported at 58.5 pounds per bushel. With wheat of this weight the average milling ratio would ordinarily be only 4.659 bushels per barrel. The Food Administration restrictions apparently resulted in saving about 13 pounds of wheat per barrel of flour in this year.

The maximum error to be expected in the estimates of the quantity of wheat milled per barrel of flour seems for most of the period to be in the neighborhood of 0.5 per cent, judged by the deviations of individual observations from the lines of average relationship shown in Chart 9 (p. 94). Exception must be made, however, of the estimates for the first ten years or so, which are probably mostly too low. It seems clear that the average wheat requirement per barrel of flour, for any given weight per bushel, was slightly higher in these early years, when the transition to the roller process of milling was still in progress, than it has been subsequently. We have found no trustworthy basis, however, for determining the adjustment required, and have neglected this factor in making our calculations.

CHART 10.—WHEAT GROUND PER BARREL OF FLOUR, 1885–86 TO 1926–27*

(Bushels)



* Data in Appendix Table I. About 4.7 bushels of wheat are required per barrel of flour, as an average over a period of years for all merchant mills in the United States; but following our entry into the war the wheat requirement was reduced to 4.45 bushels per barrel. The range of variation, omitting the crop years 1917–18 and 1918–19, is from 4.64 to 4.78 bushels per barrel, depending chiefly on the average weight per bushel of the wheat crop of the country. This variation, under normal conditions, amounts to only about 3 per cent, but on a total output of 115 million barrels of flour it may affect the amount of wheat ground by over 16 million bushels.

VIII. WHEAT GROUND AND MILLFEED PRODUCED ANNUALLY SINCE 1885–86

Having obtained estimates of the total flour output of the mills of the United States in each crop year since 1879–80 and of the wheat ground per barrel of flour in each year since 1885–86, it is a simple matter to calculate the approximate total quantity of wheat ground and of millfeed produced in each crop year since 1885–86. The quantity of wheat ground is given directly by multiplying the estimate of total flour production by the estimate of wheat ground per barrel of flour. The resulting figures are shown in column 1 of Appendix Table I.

Such errors as exist in the estimates of total quantity of wheat milled each year are the result of a combination of errors in the production estimates and errors in the estimates of wheat ground per barrel of flour. If the possible magnitude of these errors has been correctly appraised, the errors in

[1] Calculation on the basis of the usual relationship between test weight and wheat requirement would have given a figure of 4.647 bushels per barrel for this year. The figure of 4.639, 0.2 per cent lower, is based on the data in the monthly milling reports.

the estimates of total wheat milled can seldom, if ever, exceed 2 per cent.[1]

The average millfeed output per barrel of flour is readily calculated from the figures for wheat ground per barrel. The latter figures are in terms of 60-pound bushels, hence with a wheat requirement of 4.7 bushels per barrel, 282 pounds of wheat are ground to obtain 196 pounds of flour, leaving 86 pounds of millfeed. Similar calculations yield the theoretical output of millfeed per barrel of flour for any stated wheat requirement per barrel.

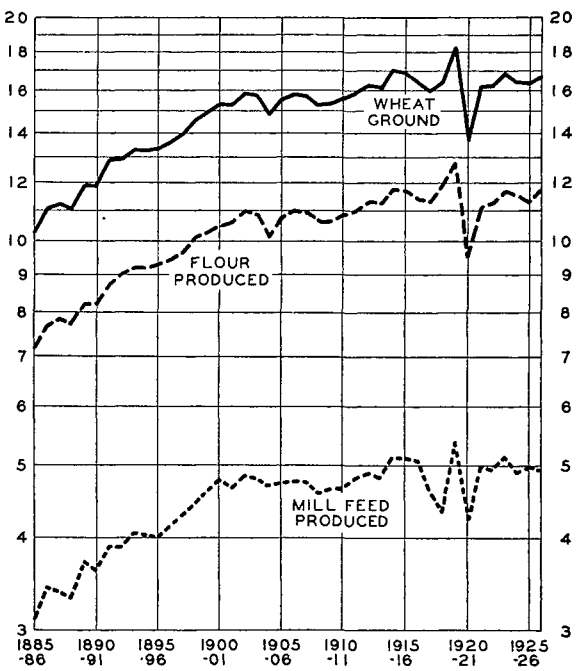
There is almost always an "invisible loss" in milling, the combined weight of the products being less than that of the wheat passing into the rolls, a consequence, chiefly, of loss of moisture in the milling process. In terms of weight of wheat purchased and weight of products available for sale, however, there is not uncommonly an "invisible gain." Dry wheat requires the addition of a considerable amount of moisture to temper it for grinding, and the moisture content of the flour and millfeed may be appreciably in excess of the moisture contained in the equivalent quantity of wheat as it came from the cars. This is uniformly the case with Pacific Coast wheats and frequently the case with wheat from other sections. As far as we can determine from available statistics, a slight gain in weight of the products, for the country as a whole, is the general rule, but the amount involved is too small and uncertain to deserve further consideration in these estimates.

Taking the output of millfeed at the theoretical value for each year, based on the quantity of wheat milled per barrel of flour, we obtain the annual estimates of millfeed produced, as shown in column 4 of Appendix Table I. These figures are subject to somewhat larger percentage errors than any of the other estimates included in the appendix tables. If the errors in the estimates of wheat milled per barrel of flour occasionally amount to 0.5 per cent or more, there are occasional errors of 1.6 per cent in the estimates of millfeed produced per barrel.[2] Combining these possible errors with those which may exist in the estimates of flour production leads to the conclusion that the errors in the estimates of millfeed produced may occasionally reach 3 per cent.[3]

The estimates of wheat ground and flour and millfeed produced annually since 1885–86 are shown graphically in Chart 11. To facilitate direct comparison in a single chart, all the figures have been expressed in tons of 2,000 pounds. A logarithmic vertical scale has been used for this chart in order to render the percentage changes in the several series more readily comparable. The three series necessarily show the same trend and roughly similar fluctuations from year

CHART 11.—WHEAT GROUND AND FLOUR AND MILLFEED PRODUCED, 1885–86 TO 1926–27*

(Million tons)



* Data in Appendix Table I. Plotted to a logarithmic vertical scale, showing the relative changes in their correct proportion, the quantities of wheat ground and of flour and millfeed produced annually show the same general trend, and the change in trend about 1904 appears even more pronounced than when the data are plotted on an arithmetic scale. (Compare with the curve of flour production in Chart 1, p. 65.) The changes in the three series from year to year differ somewhat, owing to changes in the quantity of wheat ground and of millfeed produced per barrel of flour.

[1] Again making no allowance for offsetting errors, the approximate maximum percentage error is

$$100(1.015\times1.005)-100=2.$$

[2] An error of 0.5 per cent in the wheat requirement is equivalent to 1.4 pounds per barrel of flour, and would involve an equal error in the estimate of millfeed produced per barrel, which is 1.6 per cent of the average amount of millfeed produced with each barrel of flour.

[3] $100(1.015\times1.016)-100=3.$

to year. Changes in the wheat requirement per barrel of flour, however, introduce divergencies in the year-to-year movements of the three curves. This effect is most conspicuous during the war-time period of high flour extraction.

This study has been prepared by Holbrook Working. The directors of the Institute and other members of the staff have contributed information on a number of points. Most of the tabulations and computations have been made by Adelaide M. Hobe, and the charts have been prepared by Douglas L. King

APPENDIX

REFERENCES AND EXPLANATION FOR APPENDIX TABLES

TABLE I

The flour trade statistics are from publications of the Bureau of Foreign and Domestic Commerce, with additions in 1917–18 and 1918–19 noted below the table. The remaining figures are new estimates prepared by the Food Research Institute by the methods explained in the text. For the years 1879–80 to 1916–17 the estimates of per capita flour consumption are derived first (see pp. 85–87), and from these the total consumption is calculated. For the years 1917–18 to 1926–27 the total flour consumption is estimated from calculated trends, slightly adjusted in 1917–18 and 1918–19 to reflect the influence of special circumstances (see pp. 75 and 89–90), and the per capita consumption calculated from the estimated totals. Total flour output is estimated independently for the years 1917–18 to 1920–21 and 1923–24 to 1926–27 (see pp. 70–71 and 89). For other years it is obtained by adding the net exports and shipments to the total estimated consumption. The quantity of wheat ground per barrel of flour is estimated independently for each year beginning with 1885–86 (see pp. 97–98). The estimates of total quantities of wheat ground and of millfeed produced are obtained by calculation from the estimates of total flour output and of wheat ground per barrel of flour.

TABLE II

The flour trade statistics are from the *Monthly Summary of Foreign Commerce of the United States,* except shipments to possessions, which are no longer published monthly and have been supplied by the Department of Commerce. The "commercial stocks" are Russell's estimates, from *Russell's Commercial Review.* The remaining figures are new estimates prepared by the Food Research Institute. The estimates of monthly output are derived from the monthly milling reports of the Department of Commerce, as described on pp. 70–71, above. The monthly domestic disappearance is the estimated output, less net exports and shipments to possessions. The monthly consumption is estimated by computing the trend of consumption per day and multiplying the monthly ordinates of trend by the number of days in the month (see pp. 74–75). Changes in stocks between the beginning and the end of each month are estimated by subtracting the estimated consumption from the domestic disappearance, and from these figures are derived the estimates of total stocks on the first of each month, in terms of deviations from the 4-year average (see pp. 75–76). The estimates of "non-commercial" stocks are derived from the estimates of total stocks by subtracting Russell's estimates of commercial stocks, expressed as deviations from the 4-year average.

TABLE I.—WHEAT MILLING AND FLOUR DISPOSITION BY CROP YEARS FROM 1879–80 TO 1926–27*

Year July–June	Wheat ground		Flour output	Millfeed output	Flour consumption		Flour trade (thousand barrels)				
	Total (thous. bushels)	Per bbl. (bushels)	(thous. bbls.)	(thous. tons)	Total (thous. bbls.)	Per capita (bbls.)	Net exports and shipments	Imports	Re-exports	Domestic exports	Shipments to possessions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1879–80	.....	.....	62,800	.....	56,800	1.147	6,009	5.2	2.9	6,011	...[a]
1880–81	.....	.....	66,100	.....	58,200	1.147	7,945	2.4	1.5	7,946	...
1881–82	.....	.....	65,400	.....	59,500	1.147	5,915	4.2	3.3	5,916	...
1882–83	.....	.....	70,100	.....	60,900	1.147	9,205	2.5	1.7	9,206	...
1883–84	.....	.....	71,400	.....	62,300	1.147	9,150	1.8	0.2	9,152	...
1884–85	.....	.....	74,300	.....	63,700	1.147	10,647	1.3	...	10,648	...
1885–86	342,900	4.678	73,300	3,100	65,100	1.147	8,177	1.8	0.4	8,179	...
1886–87	369,100	4.727	78,100	3,420	66,600	1.147	11,517	1.0	...	11,518	...
1887–88	374,000	4.674	80,000	3,380	68,000	1.147	11,964	2.6	2.6	11,964	...
1888–89	368,600	4.670	78,900	3,320	69,500	1.147	9,374	1.2	...	9,375	...
1889–90	396,200	4.746	83,500	3,700	71,200	1.147	12,233	1.2	2.3	12,232	...
1890–91	395,200	4.701	84,100	3,620	72,700	1.147	11,344	8.4	8.4	11,344	...
1891–92	420,700	4.720	89,100	3,890	73,900	1.147	15,196	0.6	0.1	15,197	...
1892–93	429,600	4.670	92,000	3,870	75,400	1.147	16,620	0.4	...	16,620	...
1893–94	441,100	4.708	93,700	4,050	76,800	1.147	16,860	0.4	...	16,860	...
1894–95	440,200	4.704	93,600	4,040	78,300	1.147	15,267	1.9	...	15,269	...
1895–96	441,800	4.678	94,400	4,000	79,800	1.147	14,620	1.4	0.2	14,621	...
1896–97	451,200	4.704	95,900	4,140	81,300	1.147	14,569	2.2	1.3	14,570	...
1897–98	464,000	4.723	98,200	4,290	82,900	1.147	15,348	2.7	1.4	15,350	...
1898–99	483,900	4.701	102,900	4,430	84,500	1.147	18,486	0.9	1.0	18,486	...
1899–1900	496,300	4.731	104,900	4,610	86,200	1.147	18,698	0.7	0.1	18,699	...
1900–01	508,600	4.754	107,000	4,770	88,100	1.147	18,886	0.6	16.4	18,651	220
1901–02	508,200	4.708	108,000	4,670	90,000	1.147	18,002	0.4	0.2	17,759	243
1902–03	525,800	4.704	111,800	4,820	91,600	1.145	20,126	0.6	0.7	19,716	410
1903–04	519,100	4.716	110,000	4,790	92,700	1.135	17,374	46.9	36.1	16,999	386
1904–05	492,200	4.784	102,900	4,680	93,700	1.126	9,141	40.8	3.8	8,826	352
1905–06	513,300	4.708	109,000	4,710	94,700	1.116	14,292	45.3	...	13,919	418
1906–07	522,500	4.678	111,700	4,730	95,700	1.106	15,985	47.7	0.5	15,585	447
1907–08	519,400	4.681	111,000	4,710	96,600	1.096	14,319	39.6	0.1	13,927	432
1908–09	505,300	4.678	108,000	4,570	97,100	1.087	10,902	92.4	...	10,521	473
1909–10	506,700	4.693	108,000	4,620	98,600	1.077	9,391	144.8	...	9,041	495
1910–11	513,400	4.670	109,900	4,630	99,400	1.067	10,500	141.6	...	10,129	513
1911–12	522,700	4.697	111,300	4,770	99,900	1.058	11,366	158.8	0.1	11,006	519
1912–13	536,100	4.678	114,600	4,850	100,800	1.048	13,832	107.6	1.0	13,395	544
1913–14	532,600	4.662	114,200	4,780	102,000	1.038	12,267	89.9	1.4	11,822	534
1914–15	558,900	4.689	119,200	5,090	102,600	1.029	16,625	64.2	1.5	16,183	504
1915–16	557,100	4.693	118,700	5,080	103,000	1.019	15,751	329.9	10.2	15,521	550
1916–17	547,100	4.723	115,800	5,060	103,500	1.009	12,296	174.7	2.2	11,943	526
1917–18	530,900	4.601	115,400	4,620	94,000	.907[b]	22,932	675.1	79.5	23,096[c]	432
1918–19	545,000	4.450	122,500	4,350	91,500	.888[b]	29,579[c]	37.1	0.8	29,083[c]	532
1919–20	605,900	4.645	130,400	5,390	94,600	.895	22,141	159.1	12.8	21,652	635
1920–21	458,200	4.712	97,200	4,220	96,300	.897	15,364	1,420.9	45.9	16,180	559
1921–22	537,900	4.727	113,800	4,990	98,000	.898	15,820	619.1	84.2	15,797	558
1922–23	539,200	4.701	114,700	4,940	99,600	.900	15,068	429.4	13.3	14,883	601
1923–24	560,500	4.700	119,300	5,130	101,500	.901	17,708	169.1	13.3	17,253	611
1924–25	546,600	4.651	117,500	4,880	103,000	.902	14,508	6.7	5.4	13,920	590
1925–26	542,900	4.705	115,400	4,980	104,600	.902	10,103	17.4	11.0	9,542	567
1926–27	554,100	4.639	119,400	4,920	106,100	.902	14,025	6.1	3.6	13,385	642

* For explanatory notes see p. 100.

[a] Included in domestic exports to 1899–1900.

[b] Expeditionary forces excluded from population estimate.

[c] Including, in addition to the Department of Commerce figures, shipments to the A.E.F., A.R.C., and relief organizations as reported by the Food Administration and the Grain Corporation, totaling 1,216,000 barrels in 1917–18 and 4,890,000 barrels in 1918–19.

TABLE II.—FLOUR OUTPUT AND DISPOSITION, MONTHLY FROM MAY 1923*

(Thousand barrels)

Year and month	Output	Domestic disappearance	Consumption	Stocks (first of month)			Trade				
				Commercial	Non-commercial[a]	Total[a]	Net exports and shipments	Imports	Re-exports	Domestic exports	Shipments to possessions
1923	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
May	9,153	8,127	8,539	7,457	—1,292	—1,097	1,026	19.4	5.4	983	57
June	7,776	6,928	8,274	6,800	—1,047	—1,509	848	17.7	.2	806	60
July	9,048	8,130	8,560	6,900	—2,493	—2,855	918	18.2	.0	884	52
Aug.	11,239	9,950	8,571	8,100	—4,123	—3,285	1,289	18.7	.4	1,273	34
Sept.	11,284	9,692	8,305	7,700	—2,344	—1,906	1,592	13.6	.0	1,568	38
Oct.	12,667	10,549	8,592	8,800	—2,057	— 519	2,118	19.4	2.7	2,092	43
Nov.	10,558	8,741	8,326	8,500	+ 200	+1,438	1,817	20.1	.8	1,778	58
Dec.	9,311	7,458	8,614	7,900	+1,215	+1,853	1,853	19.2	1.1	1,789	82
1924											
Jan.	10,063	8,298	8,624	7,100	+ 859	+ 697	1,765	15.3	1.4	1,716	63
Feb.	9,454	7,882	8,078	7,150	+ 483	+ 371	1,572	13.9	4.3	1,538	44
Mar.	9,387	7,937	8,646	7,200	+ 237	+ 175	1,450	24.9	.8	1,426	48
Apr.	8,633	7,538	8,377	6,800	— 72	— 534	1,095	4.0	.0	1,038	61
May	8,871	7,860	8,667	6,700	— 811	—1,373	1,011	.6	.9	976	35
June	8,749	7,522	8,398	6,400	—1,318	—2,180	1,227	1.2	.9	1,174	53
July	9,543	8,712	8,688	6,800	—2,594	—3,056	831	1.5	1.2	789	42
Aug.	11,014	10,021	8,699	7,400	—3,170	—3,032	993	2.9	.0	949	47
Sept.	11,699	10,188	8,429	7,500	—1,948	—1,710	1,511	.4	.4	1,463	48
Oct.	12,691	10,782	8,720	8,675	—1,364	+ 49	1,909	.0	.0	1,852	57
Nov.	10,299	8,646	8,449	9,100	+ 273	+2,111	1,653	.1	.0	1,616	37
Dec.	9,897	8,387	8,742	7,700	+1,870	+2,308	1,510	.1	.0	1,452	58
1925											
Jan.	11,006	9,946	8,752	6,700	+2,515	+1,953	1,060	.1	.7	988	71
Feb.	9,211	8,235	7,915	7,400	+3,009	+3,147	976	.3	.0	936	40
Mar.	8,197	6,772	8,774	6,850	+3,879	+3,467	1,425	.1	2.5	1,387	36
Apr.	7,556	6,544	8,501	6,400	+2,327	+1,465	1,012	.7	.1	955	58
May	7,809	7,063	8,795	6,200	+ 570	— 492	746	.0	.0	690	56
June	8,601	7,742	8,522	5,700	— 662	—2,224	859	.4	.0	820	39
July	9,806	8,986	8,816	5,900	—1,642	—3,004	820	.1	.1	775	45
Aug.	10,413	9,503	8,827	7,700	—3,272	—2,834	910	.5	3.7	874	33
Sept.	11,126	10,272	8,552	7,400	—2,296	—2,158	854	.3	.0	800	54
Oct.	12,000	10,938	8,848	8,400	—1,576	— 438	1,062	2.6	1.2	1,012	49
Nov.	10,190	9,255	8,573	7,900	+1,014	+1,652	935	4.0	1.6	872	65
Dec.	9,976	8,928	8,870	7,800	+1,796	+2,334	1,048	2.1	1.8	1,009	39
1926											
Jan.	9,521	8,794	8,880	6,900	+2,754	+2,392	727	1.7	.5	676	52
Feb.	8,180	7,484	8,030	7,000	+2,568	+2,306	696	.5	.0	647	49
Mar.	9,068	8,335	8,902	6,600	+2,422	+1,760	733	1.0	.7	695	38
Apr.	8,301	7,417	8,625	6,100	+2,355	+1,193	884	1.2	.9	834	50
May	8,099	7,362	8,923	6,500	+ 747	— 15	737	.9	.2	679	59
June	8,709	8,010	8,645	6,400	— 714	—1,576	699	2.4	.4	667	34
July	10,485	9,637	8,944	6,500	—1,449	—2,211	848	1.1	.3	793	56
Aug.	11,430	10,027	8,955	7,660	—1,916	—1,518	1,403	.2	.1	1,363	40
Sept.	11,835	10,218	8,676	8,300	—1,484	— 446	1,617	.3	.2	1,560	57
Oct.	11,610	10,181	8,976	8,500	— 142	+1,096	1,429	.1	.3	1,385	44
Nov.	10,368	8,968	8,697	8,700	+ 863	+2,301	1,400	.2	.8	1,344	55
Dec.	9,587	8,317	8,997	8,000	+1,834	+2,572	1,270	.1	.0	1,208	62
1927											
Jan.	9,263	8,179	9,008	6,700	+2,454	+1,892	1,084	.8	.1	1,009	76
Feb.	8,559	7,654	8,146	7,500	+ 825	+1,063	905	.6	.6	874	31
Mar.	9,527	8,598	9,035	7,050	+ 783	+ 571	929	.3	.0	867	62
Apr.	8,795	7,733	8,749	6,500	+ 901	+ 139	1,062	.1	.0	1,016	46
May	8,987	7,825	9,051	6,600	— 215	— 877	1,162	.1	.5	1,099	63
June	8,989	8,075	8,769	6,300	—1,141	—2,103	914	2.1	.7	863	52
July	8,849	8,013	9,072	6,250	—1,785	—2,797	836	.1	.0	788	48
Aug.	10,179	9,082	9,083	6,800	—3,394	—3,856	1,097	.1	.7	1,052	44
Sept.	11,033	9,716	8,800	7,300	—3,895	—3,857	1,317	.1	.0	1,280	37
Oct.	11,523[b]	10,023[b]	9,104	8,490	—4,169	—2,941	1,500[b]	...	...	.....	..
Nov.	.....	.....	.....	7,900	—2,660[b]	—2,022[b]	.....	...	...	.....	..

* For explanatory notes see p. 100.

[a] Deviations from 4-year average, July 1923–June 1927. [b] Preliminary.

WHEAT STUDIES *of the* FOOD RESEARCH INSTITUTE

Special studies (exclusive of review and survey numbers) in Volumes I–IV are listed below with prices.

VOLUME I

No. 2. *Current Sources Concerning Wheat Supplies, Movements, and Prices: A Select List, with Comments.* January 1925. $1.00
No. 4. *The Dispensability of a Wheat Surplus in the United States.* March 1925. $1.00
No. 6. *Farm Costs of Wheat Production in the North American Spring-Wheat Belt.* May 1925. $1.00
No. 7. *European Wheat Production as Affecting Import Requirements.* June 1925. $0.50
No. 8. *Canada as a Producer and Exporter of Wheat.* July 1925. $2.00
No. 9. *The Disposition of American Wheat Supplies: A Critical Appraisal of Statistical Procedures.* August 1925. $1.00

VOLUME II

No. 3. *A National Wheat-Growers' Co-operative: Its Problems, Opportunities, and Limitations.* January 1926. $1.50
No. 4. *Protein Content: A Neglected Factor in Wheat Grades.* February 1926. $0.50
No. 5. *Price Spreads and Shipment Costs in the Wheat Export Trade of Canada.* March 1926. $1.00
No. 7. *Wheat Acreage and Production in the United States since 1866: A Revision of Official Estimates.* June 1926. $1.00
No. 8. *The Decline in Per Capita Consumption of Flour in the United States.* July 1926. $1.00
No. 9. *A Selected Bibliography of Publications, 1920–25, Relating to the World Wheat Situation.* August 1926. $1.00

VOLUME III

No. 1. *American Importation of Canadian Wheat.* November 1926. $1.50
No. 4. *The McNary-Haugen Plan as Applied to Wheat: Operating Problems and Economic Consequences.* February 1927. $1.00
No. 5. *The McNary-Haugen Plan as Applied to Wheat: Limitations Imposed by the Present Tariff.* March 1927. $1.00
No. 7. *Comparative Levels of Wheat Prices in the United States and Canada.* June 1927. $0.50
No. 8. *India as a Producer and Exporter of Wheat.* July 1927. $2.00
No. 9. *Reactions in Exporting and Importing Countries to Changes in Wheat Prices.* August 1927. $0.50

VOLUME IV

No. 2. *Statistics of American Wheat Milling and Flour Disposition since 1879.* December 1927. $1.00

RECENT CONTRIBUTIONS FROM THE FOOD RESEARCH INSTITUTE

(Reprints available free on request)

G 36. "Wheat Prices and Marketing Policies," Holbrook Working. *American Co-operation,* 1926
G 37. Review of *The Agricultural Problem in the United States,* by National Industrial Conference Board, J. S. Davis. *Journal of the American Statistical Association,* March 1927
G 38. "Forecasting the Price of Wheat," Holbrook Working. *Journal of Farm Economics,* July 1927
G 39. "America's Agricultural Position and Policy," J. S. Davis. (Mimeographed) August 11, 1927

ER 16. "Physiological Phenomena at the Time of Flowering," H. L. Van De Sande Bakhuyzen. *Proceedings of the Society for Experimental Biology and Medicine,* 1926
ER 17. "Growth and Growth Formulas in Plants," H. L. Van De Sande Bakhuyzen. *Science,* December 31, 1926
ER 18. "The Growth Curve in Annual Plants," H. L. Van De Sande Bakhuyzen and Carl L. Alsberg. *Physiological Reviews,* January 1927
ER 19. "The Behavior of the Prolamins in Mixed Solvents: III. The Denaturation of Wheat Gliadin," M. J. Gottenberg and C. L. Alsberg. *Journal of Biological Chemistry,* June 1927

(More complete list on request)

FOOD RESEARCH INSTITUTE PUBLICATIONS

WHEAT STUDIES

Each volume contains a comprehensive review of the world wheat situation during the preceding crop year (price, $2.00), three surveys of current developments (price, $1.00 each), and six special studies (variously priced, see inside back cover).

Vol. I. December 1924–September 1925. 375 pages, bound in red buckram. Price $10.00

Vol. II. November 1925–September 1926. 367 pages, bound in red buckram. Price $10.00

Vol. III. November 1926–September 1927. 467 pages, bound in red buckram. Price $10.00

Vol. IV. November 1927–September 1928. Ten issues. Subscription, including temporary binder, $10

FAT AND OIL STUDIES

A new series of research studies in fats and oils of animal and vegetable origin, dealing primarily with economic aspects—production, trade, prices, and utilization—but with due reference to technical knowledge.

No. 1. *The Fats and Oils: A General View.* By C. L. Alsberg and A. E. Taylor. In press.

No. 2. *Copra and Coconut Oil.* By Katharine Snodgrass. In press.

No. 3. *Inedible Animal Fats.* By L. B. Zapoleon. In preparation.

MISCELLANEOUS PUBLICATIONS

No. 1. *Stale Bread Loss as a Problem of the Baking Industry.* By J. S. Davis and Wilfred Eldred. February 1923. 70 pp., 8vo. Paper, $0.50

No. 2. *The American Baking Industry, 1849–1923, as Shown in the Census Reports.* By Hazel Kyrk and J. S. Davis. September 1925. 108 pp., 8vo. Cloth, $1.50; paper, $1.00

No. 3. *Combination in the American Bread-Baking Industry, with Some Observations on the Mergers of 1924–25.* By C. L. Alsberg. January 1926. 148 pp., 8vo. Cloth, $2.00; paper, $1.50

For subscriptions, completed volumes, and individual publications, address

FOOD RESEARCH INSTITUTE

STANFORD UNIVERSITY, CALIFORNIA