



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search  
<http://ageconsearch.umn.edu>  
[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

# W H E A T   S T U D I E S

## *of the* FOOD RESEARCH INSTITUTE

VOL. XVIII, NO. 3

(Price \$.75)

NOVEMBER 1941

### WHY ENRICHMENT OF FLOUR?

*Alonzo E. Taylor*

*Director Emeritus, Food Research Institute*

"Enrichment" of flour is a new expression. A few years ago, specialists in nutrition discussed ways and means whereby valuable components of natural foodstuffs might be preserved from destruction during processing or in preparation for the table. Originally, the word "retention" was used to indicate avoidance of depletion, and "restoration" was used to indicate repair of unavoidable depletion. "Fortification," the oldest term, implied supplementation beyond the natural level. Recent years have taught us that loss of vitamins may occur all the way from harvesting through storage, processing, and preparation for the table, and, more or less, in all foodstuffs. Also, more or less, foodstuffs lose both water-soluble and fat-soluble vitamins.

Earlier attempts at restoration were made under the Seal of Acceptance of the Council on Foods of the American Medical Association. Under the provisions of the new Food, Drug, and Cosmetic Act, the Federal Security Agency is empowered to authorize and promulgate specific additions of vitamins and minerals to named foodstuffs. The first moves were made with reference to wheat flour, and others have followed. Enrichment of white flour has been proceeding in 1941, in advance of legal provisions scheduled to come into effect in 1942.

This issue of WHEAT STUDIES is devoted to a discussion of the background of the problem of enrichment or fortification of foods with vitamins and minerals, and the reasons which have prompted our government to take a formal step in enrichment of wheat flour by permitting the addition of specified amounts of thiamin, nicotinic acid, riboflavin, and iron.

STANFORD UNIVERSITY, CALIFORNIA

**WHEAT STUDIES**  
**OF THE**  
**FOOD RESEARCH INSTITUTE**

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 eight times a year by Stanford University for the Food Research Institute.

*Copyright 1941, by the Board of Trustees  
of the Leland Stanford Junior University*

# WHY ENRICHMENT OF FLOUR?

Alonzo E. Taylor

Director Emeritus, Food Research Institute

At the annual meeting of the Institute of Nutrition in Toronto in April 1939, a symposium was held on "Fortification of Foods with Vitamins and Minerals." Of the five papers read at this meeting, two were by officials of the United States government: Dr. W. H. Sebrell, representing the Public Health Service, and Dr. E. M. Nelson, representing the Department of Agriculture. Two papers were read by distinguished academic leaders in the field of nutrition: Professor Agnes Fay Morgan of the University of California, and Professor Lydia J. Roberts of the University of Chicago. The fifth address was given by the present writer. The atmosphere was that of scientific inquiry into a long-term reform. In particular, the addresses of the representatives of the federal government were conservative and cautious.

This symposium was made possible largely by two developments: expanding knowledge of the roles of vitamins and minerals in animal nutrition accumulated in the 1930's; and the circumstance that vitamins, in pure form, had become available for experimental and clinical use. The symposium had been preceded by a round-table meeting on "Nutrition and Public Health" held in March 1938 at the sixteenth annual conference of the Milbank Memorial Fund, under the title of *Modern Health Trends*; and it was followed by a program on *The Changing Front of Health*, presented at the eighteenth annual conference of the Milbank Memorial Fund in April 1940. It is a fair statement that those who attended these three meetings had feelings of gratification that a public start was being made in the recognition of the food supply as a factor in public health, in the "welfare" of the nation in the constitutional sense.

The new Food, Drug, and Cosmetic Act be-

came effective June 25, 1939, following extended hearings prior to enactment by the Congress. On January 19, 1940 the Food and Drug Administration began hearings on Definitions and Standards of Identities of Foodstuffs, and formally took testimony—for the first time—on the subject of addition of vitamins and minerals to foodstuffs. Hearings on wheat flour were begun on September 9 and concluded on November 16, 1940. Thus, within a time span measured in months, the topic was taken from the scientific forum to the witness stand. The earlier scientific and technical terms of *retention*, *restoration*, and *fortification* were replaced by the legal term "enrichment."<sup>1</sup> On May 27, 1941, two years

after the symposium in Toronto, promulgations were made for what may be termed tentative and unofficial enrichment of flour.

What now may be called World War II began in September 1939. Rapidly, throughout the United States, spread the conviction that extensive and intensive preparedness was necessary in the United States, in order that eventual involvement—in one manner or another, sooner or later—should be adequately envisaged.

In May 1941 a National Nutrition Conference for Defense was held in Washington under the auspices of the Federal Security Agency. Here was endorsed—in the "grand manner" but still somewhat after the manner of a town meeting—the social policy of providing adequate nourishment to all income classes of the country, including distribution of naturally protective foodstuffs and enrichment of depleted foodstuffs. This conference adopted the European concept of the so-called

## CONTENTS

	PAGE
<i>Background of the Nutritional Problem</i> . . . . .	79
<i>The Approach in the United States</i> . . . . .	82
<i>The Protective Foods</i> . . . . .	89
<i>Vitamins and Minerals in Cereals</i> . . . . .	92
<i>The Present Status</i> . . . . .	98

<sup>1</sup> Cf. R. M. Wilder, "Vitamin Restoration of Foods as Viewed by the Physician," *Scientific Monthly*, October 1941, LIII, 295-302.

"all-out" war, for which preparedness involves civilians quite as much as fighting forces, nutrition on the home front as much as nutrition on the fighting front. While strength and morale for conflict were stressed, the long-term objective of improved nutrition for low-income classes received emphasis.

*The subject of scientific inquiry in April 1939 had become accepted public policy two years later.* With full appreciation of the rapid diffusion of information in the modern world, it is still surprising that such a translation was effected within two years. Even if we date the movement for so-called "enrichment" of foods (either by retention, by restoration, or by fortification) back to the initial achievement of synthesis of vitamins, this department of nutrition is scarcely a decade old. The atmosphere of urgency and emergency in the meeting in Washington, therefore, calls for comment.

It is a safe rule in the social sciences that important public developments do not proceed from a single obvious cause; they are usually the cumulative effect of several or numerous factors. Looking back only two decades, that is, over the interwar period, we can trace the evolution of a number of influences which, in combination, resulted in the adoption of the policy of enrichment of foodstuffs with vitamins and minerals.

1. Knowledge of nutrition, since 1920, has widened and deepened. The use of animal experiments has done as much for the study of metabolism as for bacteriology. The availability of pure vitamins and minerals, synthetic or natural, has been of large advantage. The circumstance that workers could use either animals or clinical subjects favored the study of nutrition, compared with that of bacteriology or toxicology. It was of particular advantage that deficiencies occur in "subclinical" forms which lend themselves to study in a manner not available, for example, in bacteriology or in endocrinology. The number of workers engaged in the field of nutrition was enormously extended. Scientific knowledge is apt to accumulate as a snowball increases diameter rolling down hill. From the nutritional point of view the country was ready, late in the 1930's, for new public policies.

2. As a consequence of correlated studies on animals and human beings, tables began to appear in popular literature representing adequate diets in different regions and countries, and for different ages in the population. If one will compare the so-called "adequate diet" of the 1930's with that shown in the surveys of national food supplies during World War I, the difference becomes glaringly apparent. Also, the adequate diet became a civilian concept, not merely a stated ration for military forces, and especially also a diet for growth.

3. The sale of vitamins in drug form, at relatively high prices, expanded rapidly in the later 1930's. This prompted dieticians to sponsor vitamin additions to depleted foodstuffs.

4. The depression of the 1930's gave rise to extensive and intensive studies of national resources and income. In the course of these investigations, in different regions of the country, appeared statistical confirmation of the older social hypothesis of dependence of food selection upon family income, promulgated conspicuously by Ernst Engel (1821-96) in 1857 and subsequently elaborated by writers in many countries. Without awaiting statistical confirmation of the statement that a third of our population were underfed, underclothed, and underhoused, the mere fact that *any* large proportion should be undernourished in consequence of low family income, in a country with a political problem of agricultural surplus, was sufficient to validate nutrition as a factor in public health and within the definition of the "public welfare."

5. Circumstances in American agriculture operated strongly in favor of the new movement. As a whole, American agriculture was overextended, with reference to demands in the available markets at home and abroad. Crop gluts pressed everywhere, prices were relatively low, pecuniary remuneration in agriculture was unsatisfactory. It could not be claimed that the "ever-normal granary" served the needs of the low-income classes. Into this picture of ineffective demand came the doctrine of inadequate nutrition of a third of the population, a form of underconsumption. Surely, if the nutrition of all parts of the population were brought up to the desired plane, this would imply a larger intake of

many foods, and thereby a useful employment for millions of acres—therewith a net enlargement of agricultural income. Public distribution of protective foods through the Federal Surplus Commodities Corporation had, without question, a wide social and political—as well as scientific—influence. Rather paradoxically, enrichment of foods thus became an instrument for the restoration of agriculture. That the agricultures of wheat, cotton, tobacco, and sugar beets could take no part in the acreage enlargement or price enhancement through public distribution did not detract from the widespread influence of the doctrine of extension of public policy to effectuate adequate distribution of protective foodstuffs.

6. Finally, came World War II. Preparedness became as much a slogan of the isolationist as of the interventionist. Indeed, if the country were to become isolated, adequate nutrition of the encircled population with domestic foodstuffs might assume an importance as large as a program of nutrition of our country actively engaged in imports and exports of foodstuffs. Nutrition became a weapon of preparedness, whether for defense or for offense. Morale was quoted as often as metabolism. In the spirit of urgency which prevailed throughout the country, steps to-

ward enrichment were undertaken before we were technically ready, just as in Great Britain the policy of enrichment of flour was promulgated more than a year before the chemical means of enrichment were in hand. Here, we have announced a program of enrichment to take full effect at some deferred date, expecting in the interval to assume command of the means of enrichment.

In Great Britain, the obligatory enrichment of flour is paid for by the state. In this country, enrichment of flour was advocated as an offering by millers to purchasers of flour. Enrichment is already under way. But at present it does not seem possible that full enrichment of flour, on a definitive official basis, available to consumers all over the United States and to all income classes, can be put into effect before May 1942, if then.

Description and statistical appraisal of the flour-enrichment program must be deferred until official decisions have been reached and adequate supplies of enriching materials become available. Meanwhile, the background of the nutritional problem which has culminated in the policy of enrichment, and certain aspects of enrichment problems themselves, deserve to be sketched. It is the purpose of the following presentation, made as untechnical as possible, to supply such a picture.

## I. BACKGROUND OF THE NUTRITIONAL PROBLEM

In considering the national approach to enrichment of foodstuffs, we need to appreciate how a nutritional problem which wears the aspect of urgency can suddenly emerge in an age of enlightenment and in a country with a profusion of supplies of foodstuffs, feeding stuffs, and industrial raw materials. The recent movement was preceded by progressive changes in national diets which we have only gradually come to evaluate. When the background of the problem in the "white world" is roughly but concisely sketched, it becomes clear that the semi-emergency in which we seem to be placed is simply a late stage in a long process of social development.

In primitive society, geographical constraints confined spheres of public and private action. The commercial circulation of

foodstuffs was restricted by limitations of communications, transportation, and pecuniary exchanges. The population in a region—usually small rather than large—was mainly determined, as to size and growth, directly by resources. To some extent, even in early times, political forces burst the bonds of communication and transportation, and determined the circulation of food supplies—for example, during the later decades of the Roman Empire. Following the Middle Ages—indeed, as one of the causes of emergence from the social type of the Middle Ages—three changes of far-and-wide importance evolved.

1. The first was the extension of navigation from the Eastern to the Western Hemisphere, from which emerged travel between all continents. Later, intercontinental transportation

expanded further with the shift from sail to propeller, from direct to induced power. This enormously extended the radius of circulation of foodstuffs and raw materials (especially precious metals) and, of course, expanded the effectiveness of military power seeking to transfer the resources of one region to inhabitants of another. So long as populations were localized in regions, the tendency of pressure of population on food supply was inevitable. When, however, materials could be drawn from considerable distances, the food supply could become as well a stimulus to population as a repression. If one will trace the fragmentary history of what may be called the migration of foodstuffs from the Western Hemisphere to Europe, following the time of Columbus, one comes to realize that migration of food plants and products was second in influence only to migration of precious metals and infectious diseases.

2. The second major change lay in the harnessing of otherwise intractable energy, the conversion of potential into actual power. This wrought the Industrial Revolution. Beginning with the steam engine, one after another technological innovation took work from the shoulders of labor and placed it upon stored fuel. This had the effect of removing industry from the household and putting it in the factory. This drew population from the country to the town, creating health problems for the populous cities. Various developments enabled dense urban populations on one continent to be fed with food from overseas. The rapid growth of population in Europe during the last 200 years was the indirect result of the Industrial Revolution, which made the feeding of the inhabitants of European countries relatively independent of local soil and climate. The Industrial Revolution elevated the plane and standard of living, introduced new goods and services to a continuously widening circle of consumers, and thus represented, both directly and indirectly, enlarged mastery of man over natural powers and products.

3. The third large development was the elaboration of foreign exchange through monetary instruments—an innovation that made it possible to have goods and services of one

country exchanged for goods and services of another country through a system far more efficient than barter. The recent revival of barter by totalitarian governments does not contradict the historical appraisal.

As we now realize, the conversion of potential into actual power, the expansion of communications and transportation, and the development of foreign exchange are the tripod of modern civilization. It was in these extensions that talent in management took command over ownership of resources and processes.

Now, over the centuries, the expectation of life has been lengthened. At the beginning of the Christian era, the span of life was so short that it may fairly be said that many men died before they became old enough to become soldiers. It is not much longer today in parts of India and China. At present, in much of the Occident, the expectation of life is over 60 years. Whereas, a few hundred years ago, society sought to conserve elderly persons for their pecuniary usefulness, society now is concerned with the problem of security of elderly persons. This advance in the expectation of life has not been the result of improvement in the food supply to nearly the extent that it has been due to reductions in deaths in childbirth, lowering of infant mortality, and control of infectious diseases of children and adults through control of intestinal parasites and microorganismal infections. If the specific causes of death, as they occurred 200 years ago, had continued in Europe, the present population in Europe would never have accumulated. And if the present population of Europe ex-Russia were to be reduced to dependence on local domestic resources, even with the advantage of modern techniques, the result would be failure to sustain the present population, thus entailing widespread mortality or migration.

In the beginning, geographical factors—soil, climate, rainfall, absence of communications and transportation, and low agricultural efficiency—were the main factors limiting the diet of a people. But internal factors also operated. Thus religion and superstition had much to do with the evolution and limitation of the diet. Social stratification, evolved at a somewhat later stage, also had much to do

with introducing artificial distinctions, which were prominent during the feudal period and persisted until recent times in Russia, where the food supply of the landowning class was greatly superior to that of the serfs.

In other ways occupations introduced variables. Particularly with the extension of the Industrial Revolution, the workers in certain occupations such as coal mining suffered inferior diets. In general, over the last century, in Europe the diet on the land has been superior to the diet in the town. This may be seen by contrasting the food consumption of Edinburgh and Glasgow with that of the interior (almost barren) highlands, or the food consumption of Wales with that of the yeoman district of southern England. But in certain regions of this country, such as the Southeast, the food consumed in the country has (since the abolition of slavery) tended to be inferior to that in the cities. Indeed, a rural region with an agriculture devoted to an export industrial crop (cotton, jute, or hemp) may have a poorer food supply than the factory towns where these fibers are processed. And even in Argentina, in earlier days devoted largely to export of wool and hides, the country diet was poor despite the profusion of meat without the saving factor of refrigeration.

The availability of sea food has been of particular importance, in Europe especially, though not understood until recently. It was largely sea food that has given northern European countries dietary superiority over Mediterranean countries. Sea food furnishes protein, vitamin A, and vitamin D—all highly valuable nutrients.

Finally has evolved the influence of the national income. Here co-operated income and the state of the art of processing foodstuffs. The national income is the sum of goods and services annually at the disposal of the consuming population. This global sum is not partitioned pro rata among the number of individual persons in the population. Instead, the population is divided into income groups which, in this country, extend by gradations from the almost unbelievable depth of less than \$500 per year per family to \$5,000 per year per family and higher. Above some such level, however, additional income lacks sig-

nificant implications for food consumption, except for variety and diversification.

The variations in income classes between different countries are perhaps in even more marked contrast than are the gradations within countries—compare China and the United States. Other things equal, the smaller the family income, the larger the proportion of that income expended for food. The lower the family income, the greater is the attention unconsciously paid to calories, the more the reference to hunger (“hollow hunger” rather than “hidden hunger”) rather than to appetite, the more the diet represents staples against specialties, the more the insistence upon mere satiation as against protective foodstuffs, on bulk and calories versus vitamins and minerals. Ignorance, religion, superstition, and faddism, as well as price, have had much to do with the one-sided dietary, and we have illustrations enough of inadequate diets which do not rest on poverty.

Our experimental knowledge of protective foods is scarcely a generation old. Our clinical knowledge of deficiency in protective foods is not half a generation old. It is not surprising that the vitamin pendulum swings over too far for a time. The modern problem is quality, as well as quantity—long-term as well as short-term considerations in nutrition. The death rate has been greatly lowered for all ages, though there is question of interpretation of the death rate over 60. The maximum span of life is not being extended,<sup>2</sup> but expectation of life has been extended. *The problem of diet is to enable all classes to enjoy such (relative) purchasing power and such knowledge of foodstuffs as will enable them to possess nutritional health and working strength through the span of life.*

Confining ourselves to the centuries following discovery of the Western Hemisphere—in particular since the recording and dissemination of facts after the invention of printing—we may risk several broad statements in the light of modern knowledge.

1. Frequent famines were due to crop failure, most especially in the absence of public

<sup>2</sup> The outstanding change is in the number attaining old age. In this country, out of 100,000 born, about 60,000 reach the age of 65 years.



measures to provide work-relief to the impoverished working classes.

2. Plagues led to famine, mostly by neglect of agriculture and breakdown of transportation.

3. Famine was provoked, directly and indirectly, by wars; in this respect, wars seem to have been almost as effective prior to, as since, the drastic application of blockades.

4. The public did not differentiate between infectious diseases and deficiency diseases; indeed, the medical diagnosis of leprosy and bubonic plague as infectious diseases, and of beriberi and pellagra as deficiency diseases, was accomplished within the lifetime of living men.

5. Lack of mobility of population was one reason for high mortality, from both infectious and deficiency diseases.

6. In the light of modern knowledge, and looking backward over recent centuries, one is driven to the inference that ergotism, putrefaction of foodstuffs, and widespread use of tea in place of nutrients, may have caused almost as much disease in Europe as lack of nutrients, outside of periods of plagues.

7. The most prominent deficiency diseases in Europe were pellagra in the south, and rickets in the north, with scurvy more or less everywhere and particularly in countries active in naval warfare and merchant shipping.

8. There are occasional references in pre-Christian literature to what seems to have been beriberi, but, in a larger sense, beriberi is a relatively modern disease. This is explained by changes in processing which occurred within the last century on a widespread scale—the refining of sugar, the polishing of rice, and the grinding of refined flour by breaking and bolting.

9. Up to a century ago, in most countries, half or more of the calories of the diet were supplied by grains, consumed mostly as whole grain, coarsely comminuted. The primitive grinding of grain between stones yielded a “meal” rather than a “flour” and represented a relatively high extraction. The general consumption of white bread, polished rice, and crystalline sugar is really a by-product of the Industrial Revolution, despite the fact that in Great Britain, before 1800, there was a notable shift to white bread from oatmeal porridge and other cereal products.

10. If one reviews the development of foods as actually eaten, one cannot fail to be struck by the fact that refinement in processing of animal foodstuffs, including the outstanding effect of refrigeration, has been attended with recoveries and retention of nutritional elements, whereas refinement in processing of seeds, roots, and stalks has been attended with losses of nutritional elements.

## II. THE APPROACH IN THE UNITED STATES

Broadcasting has so extended the publicity of the spoken word that a topic of importance (or even of no importance) is immediately brought to the attention of the majority of Americans beyond the age of childhood. The sciences, medical and others, are actively publicized in popular interpretations. Crop reports are as closely perused as vital statistics. Especially since the onset of the depression of the 1930's, the relations of unemployment to health have been everywhere discussed. Our present population of 131 million has a high average income, an extraordinary availability of hospitals and public health officials, widespread and competent instruction on health in public schools, freedom of speech on matters of public health (including venereal

diseases), and careful death reports. Yet we have been warned that a third of our population stand near, or below, the line of adequate nourishment. Civilian Americans are now health-conscious to an extent not yet observed in any other large population.

To permit and encourage enrichment of flour implies public recognition of deficiency in unenriched flour. This action was taken while our nation was not at war. The “preparedness” movement, although it exerted strong influence in accelerating the “reform,” did not originate it. Therefore, it has seemed more than an innovation—clearly reflected through broadcast, daily press, and weekly and monthly periodicals—to have it recognized that the “staff of life” is no longer

regarded as strong enough to be leaned upon.

The urge for immediate action did not arise from public sense of direct need. There was no emergency in the food supply of the United States; on the contrary, taking the distribution of accessory foodstuffs under official program into account, the recent diet of the country was probably never so good as during the winter of 1940-41. But the atmosphere of national emergency prompted quick action. If we were to prepare for possible contingency of war, such preparedness ought to include bodies of soldiers on the fighting front and of civilians on the home front, as well as mechanical equipment. The spirit and example of Great Britain prompted emulation, and the example of Germany showed the military utility of such reform. Enthusiasts urged that enriched bread be called "defense bread." In a certain sense, enrichment arose like prohibition during the first World War. Even isolationists supported the movement, though one heard grumbling that "long-needed reform" should have to "climb aboard the war wagon." Social service workers and experts in nutrition saw the opportunity to bring about in a few months what might otherwise take years. In the haste to enrich, action was taken before the enrichment materials were available on the market in quality and quantity needed—soon to be a matter of only historical interest.

Nutritional experts have imperfectly recognized that for nearly a century a trend toward deterioration of the American diet, in certain aspects, has been under way, along with valuable improvements in many directions. The deterioration has been the cumulative result of a number of factors.

1. The modern processes of milling patent flour and crystallizing refined sucrose have been developed side by side, in a broad sense, since 1870; and we have also developed manufacture of sugars from starches. In the case of milling this was due to the introduction of breaker rolls and purifiers; in the case of refinement of sucrose it was due to concentration, decolorization, and centrifugation. Contrasting patent flour with wheaten meal, and granulated sugar with raw sugar and syrup, the end result for flour was heavy reduction

in vitamins and for granulated sugar practical elimination of vitamins.

2. There has been decline in the use of cereals, and increase in the use of sugar. The decline in human use of cereals over the past half-century in this country can be stated only in approximate terms. Accepting the historical survey given in a report of the National Resources Board<sup>3</sup> in 1934, the human use of all cereals at the turn of the century was 380 pounds per capita per year, and declined to 330 pounds at the outbreak of World War I and to 250 pounds in the early 1930's. A reduction from 380 to 250 pounds, or 34 per cent, in some 30 years is a striking decline. In terms of calories, it corresponds roughly to a decline from 1,600 to 1,060 calories per person per day. The use of wheat fell from 225 pounds of flour at the turn of the century to 207 pounds in 1914, to 174 pounds late in the 1920's, and is now 154 pounds. Thus we have the influence of lower cereal intake added to that of lower vitamin content.

3. It is probably not far from the fact to say that the average intake of calories in sugar is now five times what it was in 1870. A century ago, at least half the calories of the American diet were in the form of grains; at present, possibly half of the calories of the diet are in the form of grains *and* sugar.

4. A century ago, pork and beans were much more conspicuous in the American diet than today. We have no worthwhile statistics on such foods prior to the beginning of this century, but collateral evidence is convincing. "Pork and beans" in the North, and "hog and hominy" in the South, were prominent in the food component of the simpler consumption level of earlier generations; and pork and beans were as prominent on the frontier as in New England. Far more than beef, lamb, and poultry, fresh pork was the staple meat in winter, and cured pork the staple in summer. In 1870, out of a population close to 39 million, over 18 million lived on farms. As the proportion of the population living close to the soil has declined, the proportion dependent

<sup>3</sup> *A Report on National Planning and Public Works in Relation to Natural Resources . . . Part II. Report of the Land Planning Committee* (Washington, 1934), p. 114.

upon commercially processed foods has increased. This has unquestionably led to a reduction of per capita consumption of pork and beans, both rich in vitamins; the extent of this reduction cannot be measured, but undoubtedly it has been significant.

5. On the other hand, there have been few items the consumption of which has provided increased quantities of thiamin,<sup>4</sup> for example. It is doubtful whether milk consumption is higher than it was in some earlier periods, though probably it is in cities. The consumption of nuts, which are rich in thiamin, has perhaps increased to some extent. In summary, over the last century, the diet has contracted in seeds and roots and expanded in animal products, vegetables, and fruits.

All in all, when one views the diet in terms of thiamin, as illustration, it is clear that there have been few instances of increase, and these were light in comparison with several decreases which were heavy. There has been one direction, however, in which there has been relative increase in thiamin: less thiamin has been needed in the average diet with decline in calorie intake. Possibly the average intake of the diet of today is 1,000 calories less than it was three-quarters of a century ago. But it is difficult to interpret this in terms of lowered thiamin requirement, particularly since much of the reduction in calories has been balanced by increase in intake of sugar.

America has the most abundant and diversified food supply in the world, no matter how measured. Under normal conditions of international trade (and almost as much so without imports), our dietary resembles a catalog of the edible flora and fauna of the world. Our "national income realized" enables Americans to devote a relatively small proportion of their income to food—though a relatively large sum in absolute terms. The average American spends on his food a fourth of his per capita income, while the average Chinese spends nearly three-fourths; but in monetary terms

the American spends several times as much as the Chinese. Not only is the calorie intake high, but diversity and variety ought to render this high intake, in terms of items, fairly well adapted to competent nutrition. Two unrelated developments have made possible the extraordinary diversification and perfection of fruits, vegetables, and animal products during the last generation: the selection of improved types and varieties, and the application of refrigeration. Without these improvements, the domain of the protective foodstuffs would never have been enlarged to the present practically limitless boundaries.

The global figures for foodstuffs are misleading, through the illusory effect of the arithmetic mean. We do not distinguish between initial appearance, disappearance, utilization, and ingestion. In every careful tabulation of the food supply (or even the supply of a particular foodstuff) there is a statistical estimate of the crops, with a plus or minus error, and subject to later revisions; there is loss in harvesting; there is diversion to feed use on the farm; there is loss in transit to cities; there is likely to be loss in original grading and in subsequent regrading; there is diversion to feed use in the cities; there is loss in processing; and there is loss in public eating houses and in homes. With actual loss and waste all along the line, there may still be apparent gain through statistical errors. In the final analysis we provisionally accept a figure for supply in the form purchased for final consumption, and this we divide by the population to secure an "average" *consumption*. This really means *disappearance* less loss and waste prior to consumers' purchase. Somewhere below this—different from year to year, and with one foodstuff different from another—stands *ingestion*, always less than disappearance, just as consumption is less than disappearance.<sup>5</sup>

Even a correct figure for average per capita ingestion, however, would still be misleading. When we say that the annual per capita consumption of wheat flour in the United States is 154 pounds, what we really mean is that per capita consumption is not more than 154 pounds; how much less, we do not know. This does not imply that each one of the 131 mil-

<sup>4</sup> Also called vitamin B<sub>1</sub>. As indicated below, its importance in the diet has been emphasized by recent research.

<sup>5</sup> The point is more fully discussed in M. K. Bennett, "Wheat in National Diets," *WHEAT STUDIES*, October 1941, XVIII, 37-76, esp. 45.

lion inhabitants in a year uses 154 pounds of wheat flour. A few ingest twice that much, many ingest half that much. In a nutritional equation, heavy ingestion by some does not counterbalance light ingestion by others. When we say that the disappearance of fluid milk and cream in a year in the United States corresponds to 23 million short tons, this does not imply that each one of us annually ingests 350 pounds of fluid milk and cream. Many ingest much less, and some much more. In other words, in an interpretation of national nutrition, application to the statistical population can be made to only a qualified and limited extent.

When we come to determine per capita intakes of particular components of a foodstuff, the circumstances become inscrutable. We do not know, within a plus or minus error of, say, 5 per cent, the total intake of calories, protein, carbohydrate, fat, and each mineral and vitamin, for each individual in the population, or for the average adult male, or for random samples. If we were to try to measure *resorption*, instead of *ingestion*, the error would be still larger. We lack adequate information on the content of vitamins and minerals in most foodstuffs as raw materials; and even for those best understood we lack information on the extent of environmental variations from year to year. We have inadequate information on losses in harvesting, storage, and processing. And finally, we lack adequate information on losses in preparation for the table. Under these circumstances, it is not feasible at present even to begin to set up a table of recommended or actual ingestion of any vitamin or mineral, in the sense that we can try to set up a table of ingestion of protein, fat, and carbohydrates, or even a table of ingestion of wheat, meat, or apples. Leaving aside any precise idea of requirements of vitamins and minerals, we are not yet in a position to offer even an approximate estimate of the availability of vitamins and minerals in the total food supply, or even in any specified part thereof.

If we wish to use total food supply to measure nutrition, without being misled in important particulars, we must also use public health statistics, records of morbidity and

mortality, records of hospitals and other institutions, medical opinions as represented by medical experience, school records of growth of children, and specialized field studies devoted to particular nutritional diseases. Some of these are studies in the mass; others are studies of individuals, or of small groups of random or selected cases. Here we face the dilemma of deciding whether to judge the state of nutrition by the food supply, or to judge the food supply by the state of nutrition. In the past we have judged the state of nutrition too much by the statistics of the food supply; just now we are under temptation to judge the food supply too much by the state of nutrition, or by our impression of it. The difficulty lies partly in the lack of specific criteria of diagnosis and measurement. We have pathognomonic signs for most infectious diseases, but lack them for most nutritional diseases. Physicians face many ill-definable but often severe diseases which include allergies, endocrine disturbances, and vitamin deficiencies. Just as it is clear that persons may suffer at the same time from more than one bacterial infection, so it is true that dietary deficiencies, and hormone disturbances, are frequently multiple and mixed. Thus the problem of diagnosis in the mass becomes extremely difficult, and it is not solved by summation of individual cases.

An informative exposé of the present limitations of diagnosis, classification, and measurement is illustrated in the literature on measurement of the state of nutrition in children. In animal husbandry, a feeding ration is judged by rate of growth in weight of animals, the time required to reach full size of skeleton, and the return of edible products per unit of feeding stuff. Somewhat similarly, it has long been sought to judge diet and health in children by growth, weight, and dimensions, or by comparisons of all three. Most of these studies bear on attempts to express in indexes the ratios of age, height, weight, and dimensions, more or less regardless of heredity and type. The literature on this subject extends back a half-century; but study of child health and growth has been particularly intensive during the last two decades, since the recognition of vitamins.

This widespread search for physical criteria has sprung from more or less conscious recognition of inadequacies in household and medical evaluation. But emphasis on height, weight, dimensions, and other criteria, as applied to school children of stated ages, runs counter to the fact that a child may be demonstrably normal dimensionally but nevertheless sick, or may be abnormal dimensionally without being sick. Millions of German children who had rickets and xerosis conjunctivae between 1917 and 1925 are now effective soldiers in the German army; probably with appropriate tests, the signs of healed lesions would be found. One striking illustration of the inadequacy of specific criteria for the diagnosis of nutritional deficiencies and other factors of health lies in our persisting inability to explain the most prevalent single structural defect in the child, namely, decay of the teeth. It was originally faulty to assume that rapid growth and large size per se meant improvement in the race; no one pretends that, as such, the big Russian is superior to the little Japanese, in any walk of life. The experimental work of McCray, Maynard, and others has made it clear that in small animals high nutrition and rapid growth tend to be followed by shorter rather than longer life. Just as it is difficult to measure nutrition and health in childhood, so is it difficult to separate and measure allergies, endocrine abnormalities, and vitamin deficiencies in a population.

It is particularly important to bear in mind the difference between (a) official, obligatory enrichment of a foodstuff; (b) official, permissive enrichment of a foodstuff; and (c) commercial enrichment of a foodstuff without necessity of official approval. In this country, the Federal Security Agency, through the Food and Drug Administration, has merely set up a procedure whereby governmental permission may be sought and granted. The proposed "enriched flours" are not compulsory. The miller has the option to make either traditional, or enriched flour; the baker has the option to use in his bread either traditional, or enriched flour; the homemaker has the option to purchase traditional, or enriched flour. The advantage of such freedom of action will, it is hoped, become apparent with public ex-

perience in the utilization of enriched flour in the course of the next few years. Possibly experience in Great Britain may later lead to a movement here to have all flours compulsorily enriched during the period of war.

Prior to the enactment of the new Food, Drug, and Cosmetic Act, divers processors had taken steps in the direction of "enrichment." To illustrate, such isolated instances of enrichments have included additions of thiamin, riboflavin, vitamin A, and vitamin D, as well as iron, lime, and phosphate, to food products. These enrichments were made on the individual initiative of processors, in most cases under the Seal of Acceptance of the Food Council of the American Medical Association, which had a moral, but no legal, value. The extent to which these innovations contributed to the education of the public in acceptance of official enrichment is conjectural.

The hearings under the Federal Security Agency do not yet enable one to list the total possible number of enriching components. To date it may be said that permission to enrich natural foodstuffs, in accordance with stipulated specifications under the Food and Drug Act, will apparently be accorded to thiamin, riboflavin, nicotinic acid, vitamin B-complex extracts, vitamin A, vitamin D, ascorbic acid, iron, lime, and phosphate. Whether such special vitamins as E and K will later be added to the list cannot be foreseen. It is possible, of course, that vitamins still to be discovered may subsequently be included in the list.

When one considers even the present list of accepted enrichment materials and surveys the total field of foodstuffs, one comes to a realization of the complexity and extent of the problems of control and supervision. The expansion of the nutritional field has resulted in public extension of the term "preventive medicine" to nutrition. This term first included control of contagious and infectious diseases by isolation, quarantine, and disinfection. Later, it has come to include prevention of such diseases by immunization of one type or another. With the intensification of industrialism arose problems of protection of workers from various forms of physical and chemical injuries in occupations. At the same time there developed phases of preventive medi-

cine in construction of houses, disposal of sewage, devices for heating, lighting, and ventilation, and various protections of public assemblies. The standard textbooks on hygiene have been concerned largely with such forms of preventive medicine. Recently, however, it has come to be realized that this ought also to include the avoidance of deficiency diseases, due to lack or shortage of vitamins or mineral elements.

The original Food and Drugs Act was passed in 1906. Soon thereafter, regulations were adopted controlling or excluding addition to natural foodstuffs of harmful foreign substances, such as boric acid and copper sulphate. Before the introduction of refrigeration, it was often sought to delay or prevent decomposition of food by addition of preservatives, which had to be controlled; some were prohibited entirely, others permitted in minimum amounts. The control of spray residues in orchard fruit affords another illustration of preventive medicine by exclusion of toxic agents. Most of these applications were negative, acting by exclusion of an injurious agent, though the action was positive in the case of iodine in drinking water and table salt.

The new doctrine of so-called "enrichment" of foodstuffs is a positive form of preventive medicine and, indeed, is directly analogous to the addition of iodide to table salt. Slowly, during the course of the last ten years, it has become clear that maintenance of effective and advantageous levels of intake of vitamins and minerals cannot be trusted to so-called "natural selection" of foodstuffs. This follows from the simple circumstance that concentrations of vitamins and minerals in different foodstuffs vary widely, are not easily measurable, and are in no way related to other components. Because a foodstuff contains such and such proteins and calories does not imply that it contains vitamins and minerals in corresponding amounts. The ordinary use of foodstuffs is primarily the expression of need of calories in support of body heat and work; but when a diet is ingested to provide calories, this furnishes no assurance that it is correspondingly competent in terms of vitamins and minerals. Shortage of calories is quickly recognized by the individual, but shortage of vitamins and

minerals is not, partly because symptoms of deficiency may be long deferred and develop slowly, and are often classed with other diseases by the individual (or physician). A review of the teaching of nutrition in public schools up to recent years makes it clear that popular information on uses of foods in no way suffices to insure more than supply of calories, and not even that in many instances.

When the science of preventive medicine is expanded to include control of nutrition through supervision of the food supply, it becomes quickly apparent that to prescribe diets for different ages and for different seasons of the year must fail, in large part because of the assumption that recommended foods (often imperfectly recommended) are available, price and quantity considered, at all times to all classes. This is a false assumption. Field studies of diets of working classes, in schools and hospitals, and in rations of armies and navies, have made it clear that ingested diets frequently did not conform to requirements determined by experience and by experiment. When, later, studies of food purchases were expanded, it became clear that the food eaten by low-income families could not be counted on to be competent from the standpoint of vitamins and of minerals; and this incompetency was readily confirmed by analytical study of the diets themselves. It gradually became clear, therefore, that preventive medicine in nutrition faces large questions, including public policy in agriculture, relief of unemployment, the processing of food, and public education.

The question of enrichment of a food supply is relatively simple in a small, self-sufficient country, but becomes more and more complex as the country becomes larger and as foods are both imported and exported. Two illustrations will suffice. The United States exports flour but imports practically none; hence no problem arises in regard to the level of permitted enrichment in imported flour. Great Britain, on the other hand, normally imports flour from her Dominions and from foreign countries. Enrichment creates one set of problems for British domestic millers, and a totally different set of problems for British importers of flour. A second illustration is to be found

in margarin. In Britain today margarin must contain vitamin A. This may be procured from concentrates of natural vitamin A in fish-liver oils, or it may be obtained in certain raw materials, for example, palm oil; and it might also be secured from other sources. Great Britain imports both raw materials and finished margarin. Therefore, one set of problems arises for margarin manufacturers who use domestic raw materials, another for manufacturers who use imported raw materials, and a third for foreign manufacturers who ship margarin materials into the United Kingdom. Indeed, a fourth set of problems involves the makers of butter, who must meet the competition of enriched margarin.

Broad public questions—questions drawn partly from history—may be stated in several ways, to illustrate the variables:

1. Is it possible, by educational prescription, to ration a country according to nutritional knowledge so that all classes, but especially growing children, shall receive experimentally and clinically correct diets?

2. Is it possible, by general use of supplementary meals served in schools, to contribute to children the vitamins and minerals shown to be lacking in diets of low-income classes?

3. Is it possible, by subsidy with public funds, to achieve widespread distribution (free or cheap) to low-income classes, of the protective foods which they are not able or willing to purchase with their earnings?

4. Is it possible so to regulate the processing of raw foodstuffs that vitamins and minerals are not destroyed but retained and kept available, at the final stage of consumption as at the first stage of harvesting?

5. Is it widely practicable to add natural or synthetic vitamins to foodstuffs in replacement of vitamins and minerals inadvertently reduced or destroyed in processing foodstuffs?

6. Is it practicable to add vitamins and minerals to the diet, with regard solely to nutritional requirements, by using certain foodstuffs as carriers, as in the addition of iodide to salt in the goiter regions?

Animal experimentation and clinical experience have made it probable that it is practicable, cost aside, to administer all known

required vitamins and minerals in tablet form. In other words, one might conceivably disregard vitamins and minerals in foodstuffs by administering vitamins and minerals in assimilable form and in optimal amounts, in tablets or capsules. Enough is known of such administration in human beings in the experience of prospectors and explorers to know that this is practicable, and the experiences in studies of animal nutrition support such interpretations. We have analogies: in the cooking of foods no account is taken of the occurrence of natural chlorides, and entire reliance for intake is placed on table salt; we take account of iodine in drinking water, but pay no attention to iodine in foodstuffs. Such a procedure, of course, might transfer the entire provision of vitamins and minerals to the manufacturing chemist. American experience, however, is against governmental support of this procedure, partly because it represents a regulation of the diet regarded as sumptuary. The latest developments in enrichment of food follow the natural lines suggested above, and specifically avoid so-called vitamin medication in favor of procurement of vitamins and minerals in natural, processed, or enriched foodstuffs—by retention, restoration, or fortification.

The proposal to have foods enriched when only one component is removed, by processing, has more far-reaching ramifications in the domain of foodstuffs than is appreciated at first thought, when considered in connection with flour. Three illustrations will make this reasonably clear, and others could be readily adduced.

1. In the canning of fruits and of fruit juices, it is sought to save vitamin C. This requires particular methods of excluding oxidation, also of retaining flavors and colors, as the case may be; it involves expense. It might easily be true of a particular product that it were better to lose the vitamin C in the processing, and add it at the end, than to sacrifice colors and flavors at increasing costs. What needs clearly to be realized is that the point of occurrence of high vitamin content need not be identical with the point of occurrence of ripening, with which processor and consumer are familiar.

2. Winter butter is low in vitamin A, and in color, because of destruction of A and color in the practice of curing fodder. It can be avoided by much more expensive processes of feeding cattle in winter, such as are used in Finland. The law permits addition of color. If vitamin A were permitted also to be added, as is not now legal, this would restore winter butter to the position of summer butter in respect to color and vitamin A.

3. Finally, consider pork. Pork is, with cereals and nuts, one of the common foodstuffs richest in thiamin. There are considerable losses in processing and packing. The makers of sausage might add thiamin to bring the product up to the natural high level. But

to say that a frankfurter sausage with restored thiamin is a food for special dietary purposes, compared with ham, would be a nutritional absurdity.

In each particular line of processing, the most expert processors might find that a proposed enrichment would cause them no great difficulty. But to classify the products so enriched as foods for special dietary purposes would be quite a different matter. Viewing the entire domain of processed foodstuffs as a whole, to enrich all foodstuffs would seem to result in a multiplicity of items certain to be confusing. Enrichment should be introduced in the order of importance on nutritional grounds, rather than processing grounds.

### III. THE PROTECTIVE FOODS

The concept of protective foods dates back to 1906, when F. G. Hopkins introduced the term "accessory factors" of nutrition. The term "protective foods" was coined and introduced by E. V. McCollum in 1919, and represents still the best term for popular use.

These are not rigid terms. At the outset, the word "protective" referred especially to origin, and included milk, eggs, meat, fish, and certain leafy and root vegetables. Plant products with vitamin C were protective in the same sense. Now we realize that whole-grain cereals, legumes, and nuts are protective—less because of origin than on account of retention of native vitamins. Thus "protective" has come to include *origin and retention*; and the number of protective foods has grown so much that the list is really longer than that of calorie foodstuffs. The problem, in final analysis, is not shortage but cost.

The relations of staples to specialties, of calorie foods to protective foods, and perhaps even the requirements, are not the same in all countries. A net-food-surplus, food-exporting country is likely to enjoy freedom of selection denied to a net-food-deficit, food-importing country. A large country (unless heavily overpopulated) is likely to have freedom of selection denied to a small country. A country extending over wide latitude, through corresponding diversity of climate, is likely to enjoy freedom of choice denied to a country lying in

a narrow latitude. A country with free access to sea food has freedom of choice denied to a country without access to sea food; but even seafaring peoples differ—the protective foods of the Kanakas are not those of the Eskimos. Much, of course, depends on the level of civilization, and on food habits. When Bavarian peasants lived on whole-rye bread, pork, milk, and leafy vegetables, they did well; but when they replaced milk with beer, their diet was injured.

The role of protective foods in the diet is at the moment well illustrated in Great Britain. The protective native foodstuffs of Great Britain derive from location, soil, and climate: potatoes, leafy vegetables, milk, pork, poultry, and sea foods. Combining these with abundant amounts of oatmeal and wheat flour, the population of the British Isles has available, under war conditions, an exceptional diet in the strictly nutritional sense, despite low intake of butcher meat, fats, and sugar. The high latitude and the low supply of ultraviolet light in winter have always enforced dependence on fish oils for vitamin D, while vitamin A could be secured also through milk from abundant pasture and leafy vegetables in the diet. It is true that a diet low in meat, fats, and sugar (and also in alcoholic beverages, tea, and coffee) becomes monotonous; but the present British diet, with its free use of protective foods, is perhaps as nutritionally competent as



the average diet in the United States, which has variety and diversity in foodstuffs unknown in Great Britain.

A small country with a uniform topography and climate tends to have a common dietary, such as is not to be expected in countries of large extent like Russia and the United States. We have an extraordinary profusion of foodstuffs in this country—most of them more or less in annual surplus. With efficient refrigeration and rapid transport, even a large country may have a generalized dietary. This is true in our country, except for low-income classes. But it is not true for the low-income classes, and precisely here enter the deficiency diseases, in milder forms that are widely prevalent but not yet fully understood.

The native food supply of the lower Appalachian region is quite different from that of the upper; the food supply of the upper Mississippi is different from that of the lower; the food supply of the Pacific Coast is different from that of the Atlantic. It is to be recognized that low-income classes should not be penalized for geographical location. At the same time, it also would seem indicated that a majority in one region should not be regimented by compulsory addition of foodstuffs which are lacking in the diet of the destitute minority in another region. We do not yet compel all regions to have iodine in table salt.

The circumstances are made clear by comparison of pellagra with rickets. The consumption of meat, dairy products, and eggs is low south of the Ohio and east of the Mississippi; it is high in other parts of the country, especially in the upper Mississippi Valley. We should expect pellagra to be common in the Southeast, and uncommon or rare in the upper Mississippi Valley, apart from inmates in neglected institutions. A dermatologist in Atlanta would see many cases of pellagra, but one in Minneapolis would see few or none. Under these circumstances, it would seem far-fetched to compel the population of the upper Mississippi Valley to have nicotinic acid in all flour. In the case of rickets again, we have widespread geographical distinction. Although comprehensive measurements are lacking, it is certain that in our country the region south of 40° latitude receives more ultraviolet light

in a year than does the region north of 40°. Other things equal, one would expect the incidence of rickets to be higher in the northern tier of states than in the southern tier of states, and such is the case. While, therefore, it might seem to be indicated to add vitamin D to all milk in the northern states, this would not be indicated in the same way in the southern states.

It is not intended to employ such considerations in an exclusive argument; but certainly varying circumstances, which hold over regions in a very large country, deserve consideration when it comes to the introduction of compulsory enrichment of the diet, or to such general applications of enrichment as amount to compulsion in practice. Certainly, the problem of vitamin and mineral deficiency in a country like Sweden or Spain is much more easily envisaged than it is in the United States.

The frequently repeated statement that a third of our population is underfed, underclothed, and underhoused derives from studies during the depression of the 1930's. Comprehensive investigations under the National Resources Board and the National Resources Committee have revealed in explicit terms (possibly somewhat exaggerated, as would not be surprising under the circumstances) the extent to which low income reacts upon the plane of living. Under the Works Progress Administration, the Bureau of Home Economics in the Department of Agriculture, and the Bureau of Labor Statistics in the Department of Labor, extensive surveys of consumer incomes and expenditures were carried out in 1935-36; and they were preceded by general studies, and subsequently supplemented by special studies, of consumer income and food consumption in different regions and occupational groups.

These studies have served to revive in mass form the older views of students of social service on the relation between total income and expenditures for the necessities of life. As far back as 1845, the socialist Friedrich Engels (1820-95) published a revealing book on *The Condition of the Working Class in England*. Engels studied on the Continent, as well as in Great Britain, and his influence was reflected in labor policy in Europe until the ad-

vent of the totalitarian governments. His book was later followed by other studies, for example, Seeborn Rowntree's *Poverty, A Study of Town Life* (1901), and as late as 1935 by Allen and Bowley's *Family Expenditure*. The influence of the depression on planes and standards of living, not alone in our country but also abroad, as shown in the publications on nutrition issued by the League of Nations and in reports from the International Labour Office, has been to intensify study of the diet in poverty. The cumulative result of these studies is to show a direct effect of poverty on health, through lowering of the content of living. The reactions are not peculiar to whites; families in Peiping, described by Gamble,<sup>6</sup> behave like those in white countries.<sup>7</sup>

Broadly stated, when family income declines with constant price level, the proportion of the income expended for food tends to rise, though the absolute sum may not rise and, indeed, frequently falls. Many families choose unwisely between necessities and comforts, between food and clothing, between food and recreation. In the attempt to make a small food budget supply the customary satiation of the diet, expenditures are likely to be expanded in the direction of low-grade foods; the tendency is to have the food intake cover hunger rather than appetite, satiation rather than nutrition. One has only to contrast the price of milk per calorie with the price of sugar per calorie, or the price of lean meat per calorie with the price of corn meal per calorie, to observe the budgetary dilemma which is forced upon housewives by low income, whether in depression or otherwise. This leads to expansion of staples and contraction of specialties, to emphasis on calories rather than protectives. It has been, in fact, the recent knowledge of protective foods that has illustrated and explained the influence of low income on family diet, as well shown for Great Britain in numerous writings of Orr and Drummond.

As will become more apparent with accumulation of information, the difficulty is to determine at just what level in procurement of protective foodstuffs lies the danger line of subnormal nutrition, extending into specific deficiency diseases. The question must be approached realistically; it is to little effect to point out that the money spent for dispensables might be enough to provide the missing vitamins. When families are transferred from slums to model tenements on unchanged family income, some will reduce the already low food supply in order to keep up the dwelling; this, of course, should not be done, but it happens that it often is done. The solution is to make the protective foods cheap.

To some extent, neglect of protective foods in low-income classes can be combated through the public schools. Elderly persons tend to deny themselves in favor of children; thus improvement in children's diets by school lunches indirectly better the diet of the whole family. Probably the largest single contribution to dietary efficiency in this country would be to add a pint of milk to the daily diet of every school child. But for some regions this would entail distant shipments of milk or radical reconstruction of dairy husbandry.

It is noteworthy that in American analyses of diets of low-income classes, beverages other than milk are ignored, as though their purchase involved no drain upon income. In *Diets at Four Levels of Nutritive Content and Cost*, by Hazel K. Stiebeling and Medora M. Ward,<sup>8</sup> no mention is made of alcoholic beverages, soft drinks, coffee, tea, or chocolate, though more or less of these are consumed in practically every household. Whenever a country goes to war, it controls beverages; the motives for control lie in desire to reduce expenditure, in effort to restrict wastage, and in recognition of influences on agriculture and commerce. Family-budget studies indicate that when beverages and tobacco are grouped as dietary sundries, the item—like "sundries" in the nonfood household budget—is too large to be ignored. Whether these dietary sundries be regarded as dispensables or total waste, they should certainly be included in the picture of expenditure by low-income families.

<sup>6</sup> S. D. Gamble, *How Chinese Families Live in Peiping* (New York and London, 1933).

<sup>7</sup> For a popular book illustrating that the lower the income the more the stress on calories and the less the use of protective foods, see Gove Hambidge, *Your Meals and Your Money* (New York, 1934).

<sup>8</sup> U.S. Dept. Agr., Circ. 296, November 1933.

## IV. VITAMINS AND MINERALS IN CEREALS

We very much need dependable estimates of the natural content of vitamins and minerals in cereals.<sup>9</sup> Unfortunately, the analytical data are unsatisfactory in quality and quantity, also unevenly distributed over the field. Rather curiously, our information on minerals is surprisingly scattered. One difficulty with estimations of vitamins lies in the experience that for many of them we possess imperfect animal assays, as well as imperfect chemical measurements, so that the range of plus and minus error is wide. The objective over the entire field should be to acquire rapid, sensitive, and accurate methods of assay.

From our previous knowledge of variations in protein, carbohydrates, fat, and ash in cereals, we are prepared to find wide variations in respect of vitamins and minerals. Our best information on vitamins deals with thiamin. It must suffice here to present a short survey of the variations in thiamin in the common grains, without trying, with less success, to appraise nicotinic acid, riboflavin, or the minerals. Present data suggest that riboflavin varies less than thiamin.

The common grains differ in thiamin content; oats stand at the top, wheat and barley below oats, corn below them, and rye at the bottom.<sup>10</sup> The reported range extends from top values of over 4,900 micrograms to the pound of rolled oats, to less than 1,500 in the poorest grains! The thiamin content of each kind of grain varies from region to region, and from crop to crop. Within a region and in a crop year, it varies with varieties and types. Apparently variations due to environment are at

least as important as those due to type and variety. Variations occur from year to year.

We know little about effects on thiamin of storage from harvest to mill, from year to year. In some parts of the country wheats are binned according to variety, but as a rule wheats are mixed, both in country elevators and in terminals; such mixing, however, does not correspond to a weighting. Mixing favors median values.

It is important to realize in practice that no such thing exists as a "whole-wheat level of thiamin." According to reported analyses, the thiamin content of wheats may run from 1,450 to 3,800 micrograms per pound; possibly occasional samples might be found as low as 1,000 micrograms, with other samples over 4,000 micrograms. An arithmetic average covering the entire range of analyses has no meaning, just as an arithmetic average of protein in wheat has no meaning. Possibly one might use something resembling the median, or mode, but even this would vary from year to year, and especially from region to region. A representative but practically meaningless value for higher grades of wheat might be about 2,400 micrograms to the pound. When one recalls that the protein of different wheats ranges from 8 to 18 per cent, large variations in thiamin content are not surprising.

Allowance must be made for the assumption that some of the reported variations were due to the methods employed. According to recent data, however, the variations are wide enough to make it necessary to analyze even mixed wheats of a crop year, in order to evaluate the native thiamin which is to be raised by addition to a stated level.

Recently completed analyses of pure varieties of wheats of the Canadian-American crop of 1940, made with uniform methods standardized for cereals, indicated variations in thiamin from 1,500 to 2,900 micrograms per pound, in riboflavin from 400 to 600 micrograms per pound, in nicotinic acid from 21,000 to 35,000 micrograms per pound, and in iron from 11,000 to 28,000 micrograms per pound. The variations in vitamins between types and varieties are less than was previously inferred

<sup>9</sup> On the content in foodstuffs other than cereals, our information is even less comprehensive.

<sup>10</sup> The following figures indicate the range of reported variations in content of thiamin, in terms of micrograms per pound of grain. These include analyses of pure varieties and nondescripts (more than random samples), commercial grades and ungraded, from good and poor crops, stored for short and longer periods, with different methods of assay. The significant spreads cannot be as wide as those given.

Kind of grain	Thiamin	Type of wheat	Thiamin
Oats .....	2,200-4,900	Durum .....	2,100-3,800
Wheat .....	1,450-3,800	Hard spring ...	1,450-3,490
Barley .....	2,580-3,330	Hard winter ...	1,680-2,710
Corn .....	1,850-3,040	Pacific .....	1,760-2,440
Rye .....	1,880-2,280	Soft red .....	1,790-2,380

from widely scattered analyses, but variations with environment now appear possibly greater.

It was doubtless, in part, the desire to avoid wide ranges of "whole-grain levels" that induced the nutritional experts advising the Food and Drug Administration to adopt rather arbitrary figures for minimal and maximal contents. The minimum figure of 1,660 micrograms to the pound of flour, and the maximum of 2,500 micrograms, correspond to a range of 35–52 International units per ounce in the old nomenclature. For hard bread-flour wheats, 35 is too low, and even 52 does not include higher known values for some hard bread-wheats; but for practical purposes this range may be regarded as acceptable, provided that no penalty is imposed if the eventual thiamin content exceeds 2,500 micrograms per pound, which it might readily do occasionally in certain hard-spring-wheat flours. The minimum should be rigid, but the maximum should be flexible.

The enrichment of soft-wheat flour, low in thiamin and protein, will require heavier addition of thiamin than enrichment of hard-wheat flour, high in protein and thiamin. This may possibly have the commercial effect of inducing millers of soft-wheat flours to employ the minimum figure (provisionally set at 1.66 milligrams per pound), while millers of hard wheats might easily approach or exceed the maximum figure (2.5 milligrams). These considerations suggest that future experience may indicate the advisability of authorizing different ranges for different kinds of flour. In any event, there is little purpose in attempting to have enriched short-patent flour correspond in thiamin content with a predicated whole-wheat level. These variations have made it misleading to use yardsticks originally proposed a few years ago, when discussions of "restoration" first began. The wide variations justify, tentatively, the system of enrichment to a level with stated minimum and maximum, the level roughly reflecting both native content and need.

If our information on the thiamin content of grains is fragmentary, our information on the content of riboflavin and nicotinic acid in grains is still worse. Clearly, the grains con-

tain considerably less riboflavin than thiamin—which carries the implication that depletion of thiamin is more serious, and enrichment with thiamin (other things equal) much more important. In the case of thiamin, the authorities were in position to set up minimal and maximal levels of ingredients by proceeding from rough knowledge both of the natural content and the physiological requirement. With nicotinic acid and riboflavin this is not yet possible, because we possess so much less information in respect to both content and requirement. In the case of iron, we possess none too good estimates of either the iron content of cereals or physiological requirements for iron, in terms of a particular salt or of metallic iron, or of assimilability.

The proposal to "enrich" flour by addition of synthetic vitamins gives offense to the traditional supporters of Graham, and also to others who expect—in some way or another—to *retain* the native vitamins of the wheat kernel, rather than to *restore*, by additions, the vitamins lost in milling. We may expect, in the next few years, to see much technical (as well as writing-desk) experimentation in the direction of retention of native vitamins. Under these circumstances, a survey of the localization of vitamins in the wheat kernel seems appropriate. The practical question is the extent to which localization of the several vitamins in the different parts of the wheat kernel favors retention by adaptations in the process of milling.

Perhaps an analogy may furnish a contrasting illustration. Suppose it were desired (for example, for purpose of determining the meat intake in the national diet) to separate in the carcasses of slaughtered animals the component parts, edible and inedible. We might take, for example, the following subdivision of structure: (1) the blood and contents of alimentary tract at moment of slaughter; (2) the hide; (3) the viscera, including all organs; (4) the skeleton; and (5) the flesh. This sounds simple, but in fact it is not simple at all. Individual animals bleed with unequal profusion, and the contents of the alimentary tract depend upon previous diet and term of fasting before slaughter. The weight of hide depends upon type and age of

animal, and also on whether, in skinning, the fat is cleanly removed or is left on the hide. The viscera are readily isolated. It would be very difficult to dissect the flesh from the bones and joints, and more or less fat is trimmed off according to circumstances. Finally, the proportion and density of skeleton depend upon age and type of animal. The packing house, of course, carries out no such breakdown of the structure of the animal; this is merely an artificial statistical procedure, such as might be attempted to separate the edible from the inedible parts.

In the case of the kernel of wheat, the situation is less complicated, but not much less so. As shown in the accompanying chart, the kernel is divided into three parts: germ, endosperm, and coat. Under low magnification, the germ may be dissected out. By abrasion the branny coat might be removed down to the line of separation of coat and endosperm, with some loss according to rigor of application of the burnishing. One could then analyze samples of these three component parts of the wheat kernel and thus obtain an idea of the approximate localization of the vitamins and minerals. Quantities and localizations would vary with type and variety of wheat, also by environmental influence from year to year, from crop to crop, and from region to region. One would obtain one set of figures for soft red winter wheat, another for hard red winter, another for hard red spring, another for durum, and another for white Pacific wheat; and within each type one would obtain variations between different varieties. If into the act of milling one could insert such separation of the three parts, one could conjure up the technical possibility of flours containing different blendings of these three parts.

We have fairly good knowledge of the localization of thiamin, but not of nicotinic acid or riboflavin, or even iron. In a wheat that contains, for example, from 1,800 to 2,400 micrograms of thiamin per pound, it would be found that the germ contains from 9,600 to 14,400 micrograms per pound of germ; the endosperm contains from 480 to 720 micrograms per pound of endosperm; and the branny coat contains from 7,000 to 9,000 micrograms per pound of coat. Spreads might

be still wider over the whole field of types and varieties of wheat. Before these figures could be evaluated, however, one must know the proportions of germ, endosperm, and coat in the weight of the kernel of wheat.

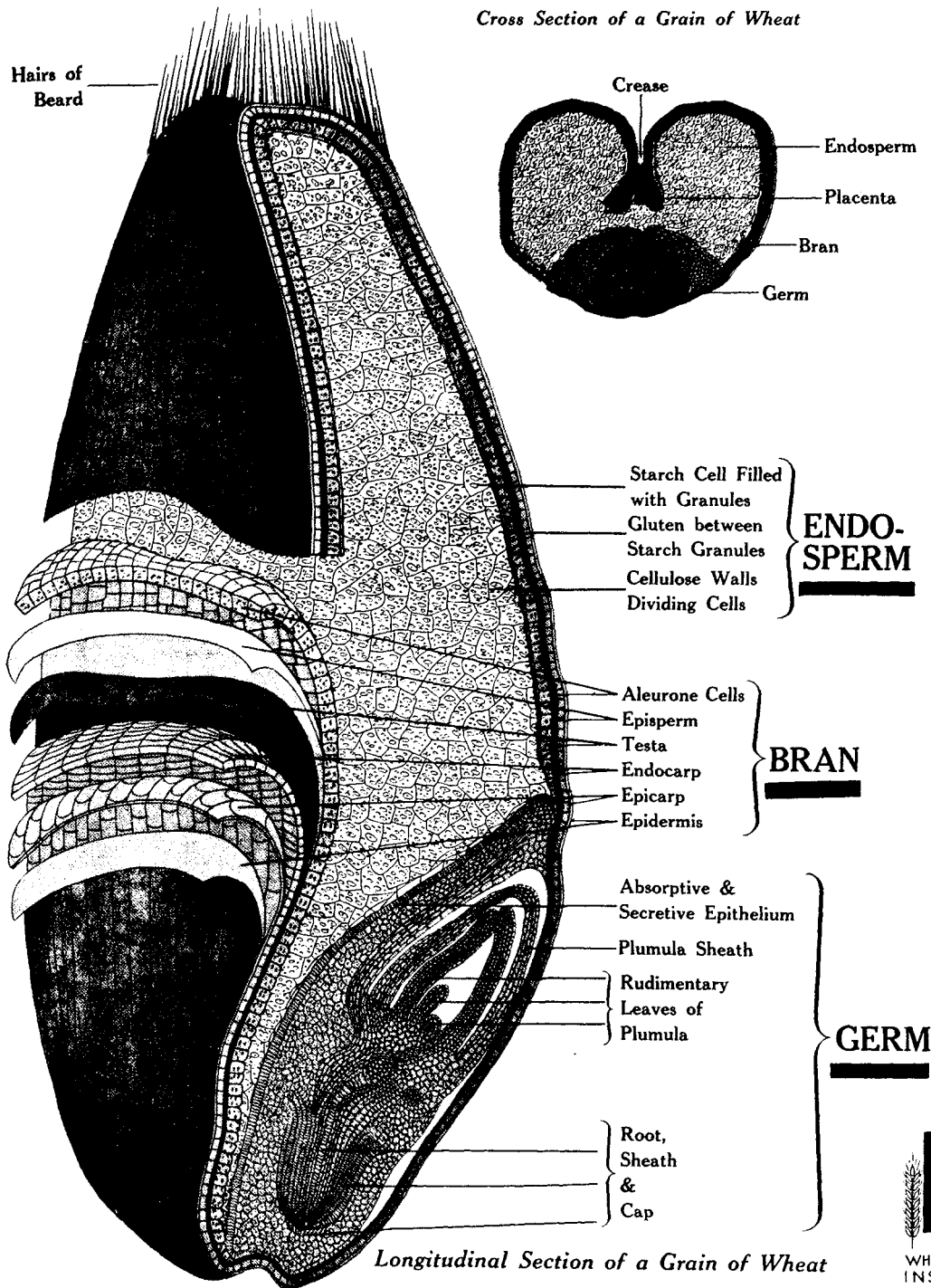
On the basis of scattered dissections of wheat kernels, supplemented by interpolations from mill grindings, we know that the range of quantity of germ runs from 2 to 3 (mostly around 2.5) per cent of the weight of the berry. The proportion of endosperm in different types and varieties of wheat, in different years and from different regions, seems to vary from 75 to 80 per cent of the weight of the kernel. Finally, the coat seems to have a weight of from 17 to 23 per cent of the total weight of the kernel. All these are figured on a uniform moisture basis. Obviously, a small inclusion of germ with endosperm would have a large effect upon the remaining quantity of germ, but only slight effect upon the accrued quantity of endosperm. A difference in separation of 1 or 2 per cent of the total could easily occur; including a tenth of the germ with the endosperm would mean a significant gain of thiamin in the flour, but diverting 1 per cent of endosperm to the germ would entail insignificant loss of thiamin in the flour.

By a combination of analysis and interpolation, we may say that in a sample of wheat divided into endosperm, germ, and coat, the endosperm might contain 20–25 per cent of the total thiamin, the coat 60–75 per cent, and the germ 10–15 per cent. But these figures are more abstractions than commercial data. It has recently become a common expression of commercial practice to say that of the total thiamin in the kernel of wheat, one-sixth is in the germ, one-sixth in the endosperm, and four-sixths in the branny coat. The figure for germ is probably close, but the partition between endosperm and branny coat is subject to wider variations.

Now as a matter of mere arithmetic, if the wheat kernel could be divided into three parts in the manufacture of flour, one could add to the endosperm all or any fixed portion of the germ, and all or any fixed portion of the coat. Practically, no such thing is possible; each fractionation must be studied empirically.

# A KERNEL OF WHEAT

*Cross Section of a Grain of Wheat*



Of course, milling does not divide the wheat berry into three parts—any more than the meat packer divides the carcass of an animal into five parts. Milling is not comparable with a dissection. The kernel is cracked between breakers and the finer particles are recovered through a sieve; the cracking is repeated a second time, and another lot of fine particles recovered with a sieve; by repetition on successive breaks, the fragments are broken down and the finer particles are collected by sieving; finally, there is the bolting of the assembled fine fractions, with exclusion of the wheat offal which includes bran and a number of other commercial fractions like red dog and shorts. By modifying the collection of particles and boltings, a mill secures a long-patent or a standard-patent or a short-patent, and usually one or perhaps two clear flours. There is no such process in modern practice as making a straight flour (a “hundred per cent” flour), later to be divided into patent and clears; these flours emerge as milling proceeds. The several flour fractions are the expression of sieving and bolting, quite as much as of the act of comminution or grinding.

A true whole-wheat flour, meaning the total milled product of clean wheat, would contain practically all of the native thiamin, which might run from perhaps below 1,800 to perhaps over 2,700 micrograms per pound, depending on type, variety, and environmental influences. If we could decorticate wheat after the fashion of manufacture of pearl barley, there would be little loss of total weight and less loss of thiamin. If we could remove the external layers of the coat, after the fashion of the polishing of rice, possibly as much as 3 per cent of the weight would be lost, but presumably less than 3 per cent of the vitamins and minerals would be lost. When, however, the yield of flour falls below 96 per cent of the weight of the wheat, the rejected parts become relatively rich in thiamin. The war flours on the continent of Europe, which run from 82 to 88 per cent extraction (i.e., the proportion of flour recovered to the initial weight of the wheat ground), contain 70–74 per cent of the native thiamin content, implying a significant loss. Some

believe that an 85 per cent extraction of flour might be so secured as to retain 75 per cent of the thiamin, which would be an acceptable recovery. In the next few years many practical attempts will doubtless be made so to modify the processes of milling as to enable such flours (not white, but gray) to be produced, retaining 70 per cent of the thiamin (and, presumably, of the nicotinic acid and riboflavin)—the loss of 15 per cent in weight consisting principally of fiber and the coarse materials of the outside coat.

With the old-fashioned procedure, which is widely followed in Europe in the milling of war flour, the grist of wheat yields but two products: a straight flour (or a meal) and the wheat offal. During World War I, American mills ground a straight flour of 73 per cent extraction, which left 27 per cent of the wheat in offal. At present, the British “National Wheat Flour” is a 76 per cent extraction, leaving 24 per cent in offal; the “National Wheat Meal” is an 85 per cent extraction, leaving 15 per cent in offal. While custom mills in this country still make a small amount of such meal, merchant mills have practically abandoned it, and obtain their straight flour (called a “hundred per cent” flour) by combining the flours obtained at the several successive stages in the milling process; and the proportion of the wheat going into the offal will run from perhaps 24 to 28 per cent. The concentration of thiamin in the flour is determined largely by the proportion of germ and coat which are included with the milled endosperm to form the final flour. A meal of 85 per cent extraction ought to carry at least 70 per cent of the native thiamin. A straight flour of 76 per cent extraction might carry 30 per cent of the thiamin; a straight flour of 70 per cent extraction might carry no more than 15 per cent of the thiamin.

A good idea of what happens to thiamin in modern milling practice is obtained by taking the thiamin content of a known wheat, and then following the milling into the usual subdivisions and obtaining the thiamin content in each of these. This means obtaining the thiamin content of the cleaned wheat, then of the short- or standard-patent flour, and then of the first- and second-clear flours. Also,

it is informative to take the red dog and the shorts and the final mixed millfeed and obtain the thiamin content of each of these. Enough of such tests have been carried through to furnish illustrations of the partition of thiamin. The following table was made up by combining analyses of many milled wheats. It is to be viewed not as an average but as an illustration. No germ is recovered as such; it is scattered among all fractions, mostly in red dog and shorts.

ILLUSTRATIVE DISPOSITION OF THE THIAMIN  
IN WHEAT AND WHEAT PRODUCTS

Product	Per cent of wheat	Micrograms per pound	Proportion of total
Cleaned wheat . . . . .	100.0	2,280	100.0
Patent flour . . . . .	63.0	310	8.0
First-clear flour . . . . .	7.0	1,360	3.9
Second-clear flour . . . . .	4.5	5,610	10.0
Shorts and red dog. . . . .	16.3	9,250	61.6
Other offal . . . . .	9.2	4,250	16.5

From these data two important conclusions emerge. The first is that the thiamin content of whole-wheat flour cannot be approached by adding germ to patent flour. If 100 ounces of wheat, containing 15,000 micrograms of thiamin, furnish 63 ounces of short-patent flour (containing, let us say, 1,200 micrograms of thiamin), the addition of 2.5 ounces of germ (containing, let us say, 2,250 micrograms of thiamin) will bring the total to less than 4,000 micrograms, whereas 15,000 would be the content if the original wheat had been converted into whole-wheat flour. In other words, adding to short-patent flour from a batch of wheat the total amount of germ contained in the wheat from which that patent flour was made will yield a mixture containing not over one-fourth of the original thiamin in the wheat. Therefore, to return to the patent flour the germ from the same wheat would not approach full "restoration." This restoration with germ could be accomplished only if 15 parts of high-grade germ were added to 85 parts of short-patent flour. This is impracticable on account of lack of adequate supplies of germ, entirely apart from injury to the baking qualities (also to keeping quality) of the short-patent flour by addition of the large amount of germ.

Second, it is clear that as little as 15 to as

much as 70 per cent of the thiamin of a wheat can be retained in wheaten flour, according as the extraction rises from, let us say, 70 to 85 per cent. A higher percentage than 75 per cent of the original thiamin can be secured in a meal, or a war flour milled according to traditional practices, only when some form of decortication or polishing of the wheat berry is resorted to. When it is recalled that the higher extractions spoil almost as quickly as whole-wheat flour, it becomes obvious that the solution of the depletion of thiamin is not to be approached in this manner. It is possible, by special selection of streams, to produce a grayish flour which has as high a thiamin content as whole-wheat; but such flour cannot be used for cake or pastry, and it is significantly less stable than patent flour, though good enough for excellent wheaten bread.

In order to appraise the portent and implication of enrichment of flour with thiamin, it is necessary to apply three yardsticks: (1) the amount of thiamin announced as daily requirement; (2) the amount of thiamin in the flour; and (3) the daily intake of the flour. Three levels of requirement have been suggested: the first is the level of 1,000 micrograms per person per day, accepted by the Food and Drug Administration of the Federal Security Agency as minimal requirement;<sup>11</sup> the second is the figure of 1,800 micrograms per day for the active adult male, proposed by the Committee on Food and Nutrition of the National Research Council; the third is the figure of 2,700 micrograms per day, suggested by Dr. Russell Wilder as requirement for the active adult male, including a factor of safety of 100 per cent of an adequate intake.

The interrelation of thiamin content and volume of ingestion of flour is well illustrated in a contrast between the United States and Canada.

Enriched flour in this country must contain at least 1,660 micrograms of thiamin per pound. In the average daily consumption of flour in the United States (6.5 ounces), the average ingestion of thiamin contained in enriched flour would be 674 micrograms. The proposed high-extraction flour of Canada is

<sup>11</sup> *Federal Register*, July 8, 1941, VI, 3305.



to contain 1,200 micrograms of thiamin per pound. In the average daily (prewar) consumption of Canada, taken as 8 ounces of flour, the daily intake of thiamin therein contained would be 600 micrograms. If we were to assume (as seems likely in view of the increase of manual work in Canada) that the intake of flour is now 9 ounces, the high-extraction flour would provide a thiamin intake of 675 micrograms per day. In other words, by using more flour with a lower content of thiamin, the Canadian may obtain daily as much thiamin in that article of the diet as would the American eating his average amount of enriched flour. It is believed that when the enriched war flour of Great Britain is averaged

to take account of the different kinds of wheat included, the thiamin content will approximate that aimed at in Canada, namely, 1,200 micrograms per pound. It seems likely that the present British daily intake of flour per person is not less than 12 ounces; this 12 ounces would contribute 900 micrograms of thiamin per pound. Thus we come to the somewhat paradoxical conclusion that a flour of lower content of thiamin in one country may not only provide the thiamin necessary for the carbohydrate of that flour, but may provide a larger absolute amount of intake of thiamin per day than is to be secured in another country with a lower consumption of flour containing a higher content of thiamin.

## V. THE PRESENT STATUS

As of October 1941, the program of "enrichment" of wheat flour in the United States had not advanced beyond tentative supplementation with thiamin, nicotinic acid, and iron. In all likelihood, final official definitions of these three enrichments will not be promulgated until riboflavin also becomes available—perhaps during 1942. That occasion will permit of technical review of the entire subject. Later, bread will need to be appraised, possibly also other commercially baked products.

The amount of enriched flour now being manufactured is not known. In the nature of the process it does not seem possible to measure commercial enrichment of flour except through the biennial census of manufactures. It is not practicable, by random sampling of households and bakers, or by voluntary census by millers, to measure any new development in the distribution of an untried article in commerce. Data from the next census of manufactures, covering production in the calendar year 1941 or in fiscal years ending in 1941, will not be available until about the end of 1942.

Believers in and supporters of enrichment of flour are not in accord in their expectations. The most optimistic of the proponents profess to expect that half the flour consumption of the country, or 50 million barrels, will be enriched by addition of synthetic vitamins; and

that the other half of the flour consumption will be enriched, if at all, by use of special yeasts, dried milk, expansion in use of whole-wheat flour, and introduction of modified processes in milling. Few seem prepared to suggest high extraction, as in the war flours of Europe and Canada, and none seem to predicate increase in consumption of bread.

The conservative proponents feel that for the first few years (apart from public subsidy) enrichment of flour with synthetic vitamins will occur largely in high-priced flours, in trademark brands of national or at least regional distribution. This expectation would imply an enrichment, in the foreseeable future, of not over 10 million barrels of patent flour. To this must be added the unestimated use of enriched flour in bakeries. At present, the minimum out-of-pocket cost per barrel of flour—of adding to each pound of flour 1.65 milligrams of thiamin, 6.5 milligrams of nicotinic acid, and 6.5 milligrams of iron—is around 29 cents per barrel. If riboflavin, when it becomes available, were to cost \$1.25 per gram, as at present, this would bring the cost of enrichment toward 50 cents per barrel of flour, depending on extent of addition. Thus future expectations depend upon prospective heavy reductions in prices of thiamin and riboflavin, with only small reductions possible in prices of nicotinic acid and salts of iron.

While it seems probable, for the time being,

that high-grade and high-priced flours can carry such expensive enrichments, according to commercial experience it does not seem warranted to expect low-priced flour, sold to bakers and households, to carry such "out-of-pocket" contribution by millers. Certainly, in the case of low-priced, and especially self-rising flours, which go mostly to consumers particularly in need of vitamins, it seems at the moment impossible to envisage widespread application other than through public subsidy. At present, low-income families are being subsidized indirectly in purchase of dairy products, meat, eggs, and fruits—protective foods in the circumstances where they are employed. Eventually, if the diet of the lowest nourished (so-called) third of our population is to be raised rapidly to a higher level, enriched flour will need to be distributed under subsidy, as a protective food, to the same classes. This is in fact already under way.

It seems proper publicly to recognize that conflicting views are held by two wings of proponents of enrichment of flour, which have not been brought into the open of the scientific forum. One is the view that enrichment of flour is a temporary device, to be replaced within a few years by changes in milling designed to turn out wheat flour with vitamins retained, but otherwise identical or comparable with current white flour. The other is the view that both public taste and milling technique are amenable to change only slowly, and perhaps not significantly; and that enrichment of flour is therefore here to stay—at least until vitamins are made freely available in other foodstuffs through enrichment or selection. Those who hold the first view seem to assume that the desired "whiteness" of the semi-whole-wheat (or pseudo-whole-wheat) flour they advocate is a mere detail of technique of processing and of easy choice by consumers. This view reveals failure adequately to comprehend the physics and chemistry of bleaching, and the nature of whiteness in flour. Indeed, most of the discussion of the so-called "bread of our fathers" is being carried on by proponents who, in their personal experience, know little of whole-wheat breads as they appear in different white

countries of the world, representing continuations of older practices in milling and baking which no longer exist in this country. In any event, it is to be recognized that the attitudes of wheat breeders and producers, of millers and bakers, and also of housewives, will be different toward a continuing program of enrichment from their attitudes toward a program of enrichment as transitional to a basic change in the milling of wheat flour.

At the National Nutrition Conference in Washington (May 26–28, 1941), proposals were made to inaugurate surveys of unprocessed and processed foodstuffs in respect of their contents of minerals and vitamins. Since, in different parts of the country and by different income classes, widely varying reliance is placed on mineral and vitamin contents of foods other than cereals, the first prerequisite to improvement in the diet is collection of dependable and comparable analytical data. It will be necessary first to standardize methods of assay, applied both to raw and to processed foodstuffs. The program of survey, inaugurated by the National Nutrition Conference, will require several years under favorable conditions, even with foodstuffs selected in the order of their assumed importance. It will be necessary also for innovations in processing to be validated in terms of retention of minerals and vitamins.

At the end, it will devolve upon teachers of home economics to indicate how losses of minerals and vitamins are to be avoided in the course of preparation for the table (including baking and toasting), since saving is as important as supplementation of vitamins. Perhaps it was the unexpressed appreciation of these incidental losses that has led proponents of higher requirements to set these figures high, to provide a factor of safety. Certainly, if 20–70 per cent of the thiamin in the several raw foods is lost before ingestion, this will have to be taken into account in one way or another.

Also, we shall need to study to what extent especially the water-soluble vitamins are not resorbed from, or are destroyed in, the alimentary tract. It is already known for thiamin, for example, that conversion into the coenzyme occurs in the alimentary tract as

well as in the tissues. It is significant that in the treatment of clinical deficiencies of thiamin, parenteral administration is much more effective than administration by mouth. So long as we are compelled to place a question mark on losses in commercial processing and in preparation for the table (losses in baking and toasting may be high but perhaps reducible), and also a question mark on resorption, we are hardly in a good position to suggest to technically uneducated housewives where and how provision for vitamins is to be made. The larger such uncertainty, the more likely is the layman to seek the practical solution by purchase of vitamins in concentrated forms.

It is not merely desirable on general grounds, but imperatively necessary on special grounds, that producers, processors, distributors, and consumers, as well as scientists, should understand the variability of vitamins in foodstuffs. Vitamins in plants are dynamic, not static, components; this holds true for animals, since their vitamin contents depend upon their intakes. Our information over the field is too scattered, and in only a few places concentrated enough to permit of statements in figures. But the effectual implication is so clear that broad statements are permissible.

The plants that furnish our food products reproduce mostly by seeding, though there is some reproduction by pruning and from cuttings of roots, stalks, or branches. There is, of course, modification by budding, by hybridization, and in other ways. When propagation is by seed, it is clear in experiment that vitamins and minerals deposited in seeds are used in the process of sprouting and, for a time, tend to make the new plant independent of soil and synthesis. Incidentally, mineral deficiencies are common in plant crops.

In the life of an annual plant, there is presumably a curve of vitamin content for root, stalk, leaf, fruit, and, finally, seed. No one has traced this rigorously; but our information on the thiamin content of buds, stalks, fruits, and seeds makes this inference reasonable. But within this picture are a number of important variabilities which cannot be disregarded—as we have already shown—between the different grains, from region to

region and from season to season, between and within types and varieties, and under different environmental influences. This is exactly what would be expected if one considers the vitamin to be, so to speak, a form of *yield* in the grain, for nothing is more familiar than the observation that yields vary from year to year, even more than from place to place. Combining these four variabilities within a crop, we have a range of content of thiamin which might be twice as much per sample in one year as in another, as already illustrated (p. 92). Under these circumstances, and with less variation, the arithmetic mean has little meaning; and it is not clear that the mode or median would have much more reliable implication.

Variability also occurs in connection with harvesting and storage. In one year the grain dries slowly, in another rapidly; in another year it is harvested wet. These factors influence other components and, presumably, influence some of the vitamins contained in the grains. Frost probably has an influence, as well as drought or excessive moisture. If the grains are stored without being properly conditioned, presumably the vitamins will suffer just as other components of the kernel suffer. Possibly there are long-term deteriorations, in the case of grain held over several years, just as it is known that there are changes in the protein and possibly in the fats, simply as the expression of the fact that a seed is a living organism and there is no reason to expect any component to remain constant over several years.

These changes in vitamin content of different types and varieties, under different environments, in different years, and in different places we expect to find occurring in all plants, whether fruits or roots, leaves or seeds. Though we do not possess comprehensive information, what we do know is in accordance with this expectation.

In the harvesting of soft crops—fruits and vegetables, which are much more exposed to decomposition and change than hard crops like seeds—the effect of harvesting and initial storage may be expected to be pronounced; and this is confirmed by the scattered information we possess. At the stage of ripeness,

the material is either protected from or exposed to desiccation; the temperature at which it is held directly after the harvest is important; protection from or exposure to light is often crucial. These and other factors are known to influence the vitamin content of some crops, and may possibly influence all crops. The importance of this post-harvest exposure is less with grains, which are harvested with a relatively low moisture content, than with fruits and vegetables (and, in agriculture, with grasses), which are harvested with a heavy proportion of moisture and a high content of native enzymes. A good illustration is the difference between a grass dried in the absence of sunshine at lowered atmospheric pressure, and a hay dried under full sun in the open air with heavy destruction of vitamins. Here we would expect perfection of storage and refrigeration to have an influence in reducing otherwise heavy deterioration.

Another factor is to be noted. In the course of the life of the plant, whether root, stalk, leaf, fruit, or seed, there are functional and structural curves not well known except for a few components. For example, the ripening of a fruit involves sweetness, flavor, vitamins, texture, and color as the most important factors. Now these do not march forward in line. It can be shown that the high point of vitamin C may occur before high points of sugar and flavor in the ripening of a fruit. Harvesting is done traditionally to secure sugar, texture, color, and flavor, not vitamin content; if done to secure the highest content of vitamin, the fruit may be regarded as otherwise inferior. If all the desiderata are to be considered, this imposes upon practical agriculture a burden of choice which even a skillful farmer is technically unprepared to assume, though it might be undertaken by a co-operative association.

In the case of foodstuffs consumed raw, the exact conditions at the time of harvest and the influence of subsequent grading, storage, and refrigeration must be expected to modify significantly the vitamin content at the time of eating. There are also pronounced differences in the parts of the plant; for example, the outer green leaves have a different composition from that of the inner white leaves.

These factors prevent us from stating the normal content of any vitamin in any fresh fruit or vegetable measured by the unit of sale.

Having thus secured some idea of variabilities in crops after harvest, as the result of harvest and storage, we come to the field of processing. Here again our knowledge is not evenly distributed; it is intensive in some places, but fragmentary in others. In general, however, we know that while processing at times may have little effect on vitamins and minerals, if it has an effect this is in the direction of deterioration. Processing involves application of heat, concentration, and dilution; addition of sugar, vinegar, or other conservers and flavors; the setting free of native enzymes and the inclusion of atmospheric oxygen. It may also involve the action of light, as in the case of drying fruits or diffusion through glass containers. Processing may involve the rejection of parts rich in vitamin; a canner may use the entire fruit or vegetable, or he may divide it in such a way as seriously to lower the vitamin content. Whenever water is used, there is diffusion of water-soluble vitamins into the fluid where they are less protected than in the native location; and, in addition, a great deal of the cooking water is thrown away. The sum total of these numerous points of variability is likely to be significant reduction in the content of some of the water-soluble vitamins and possibly also in the content of fat-soluble vitamins, especially vitamin A. One may say that the processing water should be saved and reused; but there are grave technical reasons against this in the factory, and it may also be incompatible with regulations on labelling.

It is in connection with the separation of vitamin-high from vitamin-low fractions that the heaviest losses occur. Thus, in the low-extraction flours, something like two-thirds of the weight of the wheat is converted into a short-patent flour which contains perhaps one-tenth of the thiamin of the wheat; in the so-called refining of granulated beet or cane sugar, the loss is complete; when dextrose or levulose is made from starch, there is complete loss of thiamin; when milk solids are separated from milk, vitamins are sacrificed. Thus, the tendencies in processing of these foodstuffs are toward higher concentration, in

terms of calories, with lowered concentration or elimination of vitamins and minerals. Contrasting the two fields—the cereals and sugars against the various fruits and vegetables—we become aware that, while we can measure shortage of vitamins in flours and sugars, we are not yet able to measure the vitamins in fruits and vegetables, comparably at least, in order to learn whether these are abundant enough to carry the vitamin burden for flour and sugar.

For animal products the data are still less clear, but the trends are in the direction of loss. Hogs store thiamin much more than do sheep and cattle; presumably, this holds also for nicotinic acid and riboflavin. We do not yet know whether particular breeds of swine store vitamins more than others. We do not yet know at what age or weight in swine the storage of vitamins is highest, to what extent the diet in the finishing period affects the storage in the animal, or whether slaughter and the maturing of slaughterhouse meats in cold storage affect the vitamin content. As a matter of fact, lean pork is one of the rich sources of thiamin, and it is also rich in nicotinic acid and riboflavin. We do not yet know to what extent different methods of curing meats affect the vitamin content—a subject much more important for pork than for beef or mutton. Also, we have variabilities in the case of milk, eggs, and poultry, in all of which the vitamin contents are the expression of the diet of the animal, possibly also of the methods of feeding and of previous storage in the body. We know there is wide variability in different samples of milk and eggs, as is glaringly revealed in the difference between the vitamin A contents of summer butter and winter butter in the northern states of this country. In the feeding of animals, there are opportunities to raise the vitamin content and equalize it through the twelve months by appropriate feeding; but this is a technical question for the future. We do not yet know to what extent the fat-soluble vitamins of milk are conserved in commercial butter, or the water-soluble vitamins of milk conserved in cheese or in condensed or dried milk. We do not fully know to what extent vitamins are injured in the act of pasteurization, though

there is evidence that this simple operation, if done without regard to the hydrogen potential, may be significantly destructive of thiamin. We do not know to what extent eggs in cold storage lose water-soluble and fat-soluble vitamins.

The same reasoning applies to sea food, and to fish in general. Fish constitute a very important source of vitamins A and D, also iodine, especially to the populations living close to the sea. In the past, the population of the United States has not depended on sea food for vitamins A and D to the same extent as does that of Western Europe. The shortage of sea food in Europe today is a serious factor in the shortage of vitamins A and D. That A and the pro-vitamin can be secured from plant sources is true; but nowhere, until the present war, has it occurred to anyone to adopt the practice of growing such plants as carrots and spinach to relieve shortage of sea foods. In this country most sea food is consumed fresh. For such sea foods as are processed and packed, we do not know what losses in vitamins A and D attend these procedures; the writer not long ago was surprised to find how wide were the variations in the vitamin A and D content of commercial samples of excellent grade.

Looking over the whole field, one sees variability. Obviously, with many trends in one direction, an apparently normal diet might be significantly low in vitamins, while the same diet—at another time and in another place, and purchased on the same basis of household criteria—might be competent in the same vitamins and minerals. It is this uncertainty which leads physicians particularly concerned with vitamin-deficiency diseases to insist upon a high factor of safety, representing the native instinct of playing safe in the absence of information.

Now this entire area is a field, not for conjecture or approximate appraisal, but for analyses and measurements. Years will be needed to fill in the data already indicated in a provisional manner by the fragmentary knowledge already available. Our best information deals with sugars and cereal products. It is precisely in the foods known to be protective, and so classified, that our knowledge

is least comprehensive and trustworthy. This is due largely to limitations of methods.

In what has been said above concerning need of data, reference is made particularly to thiamin, nicotinic acid, riboflavin, ascorbic acid, and vitamins A and D, but it might well be applied also to iron. To secure such data in large numbers, in different regions and over a period of time long enough to afford assurance, implies possession of methods that can be applied repeatedly in large numbers and that will check on samples. These methods we do not yet possess, with desirable assurance, for a single one of the vitamins named. Animal assays cannot be used, partly because it is impossible to carry them out in the numbers required, and for the additional reason that the plus and minus errors are too wide.

What is necessary is to have clear-cut physical or chemical methods which can be used in large numbers, in duplicate for checks, and requiring no more skill than is needed in the estimation, for example, of total nitrogen in biological material. The thiochrome method for measurement of thiamin has been standardized for cereals so that it can be applied reliably; but it is not yet standardized for all foodstuffs. The methods for analysis of nicotinic acid and riboflavin do not yet approach, in availability and reliability, the thiochrome method for the measurement of thiamin. The same thing holds in the measurements of A and D, and pro-vitamin A. It is simply necessary for all to recognize that we are in the beginning of study of procedures, of preparation of samples and methods of analyses, which can be relied upon to the extent otherwise accepted as necessary in biological work.

The importance of method extends to demand as well as supply. An estimate of requirement presupposes some idea of intake and outgo, of balance. We do not possess today a method of testing the "balance" of a vitamin which can be adapted to human beings in the numbers needed for establishment of requirement. Of a stated intake by the mouth, we do not know how much is destroyed in the alimentary tract, or evacuated. With respect to urinary elimination, we cannot relate it to intake, to metabolism, or to storage. What progress could have been expected in the

study of protein metabolism had we not possessed procedures to measure input and output of nitrogen? Some such dependable assay of balance must be secured before we can determine body requirement, since measurement of injury after it has occurred cannot be relied upon to indicate at what point of declining intake the injury was inaugurated.

It may not be out of place, in a discussion of the present status, to indulge in a certain amount of forecast on the historical basis. Few reforms can be accomplished at one strike on a blueprint. Much more often a reform takes time and is the co-product of planning and current experience, and the experience in introducing a reform may be as important as the experience which taught the necessity of that reform. If one will read, in chronological order, the collected materials of the past five years on the subject of enrichment, as suggested above on page 77 (including the hearings before the Food and Drug Administration held after the National Nutrition Conference), one will come to a vivid realization that this reform in the diet cannot be compared with a crop ready for harvest. It is rather to be compared with a crop of which the planting and acreage are still being studied for a harvest in the future.

In the broad sense, we lack perspective on vitamins in the national food supply. If we divide the food supply into cereals, potatoes, sugars, meats and fish, dairy products and eggs, fruits, vegetables, and beverages, we have eight groups of foodstuffs, seriously overlapping from the standpoint of analysis, to which might be ascribed—in ranges, if not in points—their contributions of protein, fat, carbohydrate, and of each mineral and vitamin of known importance. These foodstuffs might all be regarded as available in surplus—with price, taste, and convenience the variable external influences. Such an analysis would give confirmation, amplification, or restriction to the frequent prediction that the diet should contain, in terms of poundage, 40 per cent of protective foodstuffs, or some other figure.

In truth, we possess no such classification and tabulation of the gross food supply. Yet, over and over again, in popular discussions we contrast the vitamin content of the cereals in

the diet today with that in an earlier period, disregarding the fact that per capita daily wheat-flour consumption, for example, is 6.5 ounces, no more than half of the intake of our grandparents. Over and over again, we read discussions of the amount of vitamins present, neglecting total intake of the food in question. If such tabulations were to be made—and this could be done for raw foods in the Department of Agriculture—we would then have a global figure for each vitamin in the total diet, just as Pearl reached a global figure for protein in the national diet.<sup>12</sup> On the basis of such information we could then proceed to measure for the national diet the destructions of vitamins in harvesting, in commercial processing, and in storage. This would give us three groups of data that might be compared with cost, disappearance, consumption, and ingestion in the disposition of a crop.

If such an assembly were attempted, we should be surprised to find how uneven is our information; how much our information is on thiamin, and how little on riboflavin and nicotinic acid; how poor is our information on minerals. We might even be surprised to learn, for the topic as a whole, that cumulative destructions might approach, or even exceed in importance, the vitamin contents of raw unharvested foodstuffs.

Against some such picture of supply (always retaining the ranges of price) we could then erect data on requirements, which again would need to be ranges and not points, depending on age, sex, occupation, and components of the diet.

The present tabulations of requirements were fully recognized as tentative, and so announced. This is fortunate, for it is preferable to begin enrichment on tentative estimates of requirements, rather than defer enrichment until full knowledge is in hand. If we wish wheat flour to carry a definite responsibility for a stated share of the thiamin intake, enrichment ought to be defined in terms of final content on ingestion, which makes our method of enrichment superior to that in Great Britain. Estimates of requirements ought to be based more and more on the study of human beings,

and less on experiments on animals. In particular, we need to know why clinical symptoms of deficiencies do not arise, as much as why they do arise. For example, we need to know why some teeth do not decay throughout a long life, just as much as why other teeth decay in childhood. Such information accumulates slowly, and yet it is indispensable as a background for specific designations of requirements.

Furthermore, we need to appreciate the cost relations in a manner not now adequately appreciated. It is legally practicable now to prohibit a miller from selling decomposed flour, but not—in the same way—legally practicable to compel him to enrich flour. The optimistic predictions of enrichment, extending to half of the total flour production of the country, are based upon total disregard of cost relations. As of October 1, 1941, as already noted, the out-of-pocket cost of enriching flour with thiamin, nicotinic acid, and iron is about 29 cents a barrel. If, at present prices, riboflavin were added to the list, this cost would approach 50 cents a barrel. It is safe to say that *the practical progress of this reform depends more upon the declining price of vitamins than upon the rising education of the consuming public*. If the prices of thiamin and riboflavin can be brought down close to the prices of nicotinic acid and iron, then the out-of-pocket cost would be reduced certainly below 20 cents a barrel, possibly down to 10 cents a barrel. Since the first objective of enrichment is to reach low-income classes in order to provide a third or even a half of our population (accepting popular statements) with vitamins necessary for what might be termed dependable nutritional health (in so far as this is governed by vitamins), the cost of the reform remains the first basis of the discussion.

Finally, there must occur in the education of the public some reasonable classification of degrees of deficiency. We are not dealing with questions of choice between 100 per cent and zero. Here, as so often, reforms are relative. The pharmacologist may discuss the relative toxicities of overuse of alcohol and tobacco; but the public understands that the toxic effects of tobacco are of a different order from

<sup>12</sup> Raymond Pearl, *The Nation's Food* (Philadelphia, 1920).

the toxic effects of alcohol, in their social and industrial implications. We ought to prevent the industrial disseminations of fumes and dusts; but some are far more injurious than others. We ought to prevent the sale of spoiled foods; but some spoilage is merely revolting, while other spoilage induces diseases in consumers. Widespread occurrence of night blindness is more important than widespread occurrence of a skin lesion in itself trivial. In other words, it is necessary, in practical attempts to control deficiencies, to have a realistic approach to the day-to-day importance of the manifestations in various so-called sub-clinical deficiencies.

The term "enrichment of flour" was adopted in part for legalistic reasons, but mainly to avoid implications which might lie in the terms *retention*, *restoration*, and *fortification*. Yet it is difficult to use the term "enrichment" without falling into use of the older terms, no matter whether one defines enrichment from the standpoint of supply and demand, native content, or requirement. The figures for thiamin correspond broadly with restoration, but those proposed for riboflavin clearly involve fortification, while those for nicotinic acid and iron are considerably below those for whole wheat. At these levels, and at present prices of enriching components, less than half of the out-of-pocket burden of enrichment would represent restoration of depletion, and more than half would represent fortification.

Deliberations of the Millers' National Federation show that many millers accept a social obligation—limited, but still definite—to retain, or eventually replace, the native vitamins and minerals of the grains they process. In the wider field, processors of foodstuffs are gradually coming to accept a limited social obligation to retain the most desired native qualities of raw foodstuffs. At the same time, processors feel under no such obligation to do more than retain, or replace, the native vitamins; specifically, they feel under no obligation to make a processed foodstuff richer in vitamins than was the raw material from which it was formed.

Despite intention and desire to fulfill such limited social obligation, the history of processing of foodstuffs during the past two dec-

ades indicates that added costs entailed by improvements in quality tend to be reflected forward to consumers. The cumulation of numerous improvements has had the effect of widening the earlier spread between prices of raw foodstuffs and finished products prepared from them. In strict reasoning, we should expect that the expense of added service will be reflected either backward to raw material, or forward to finished product, or both. It will further be rejoined that when processors absorb such added cost by carrying through an improvement, this is not really an out-of-pocket contribution to consumers, because it is done in the expectation of securing consumer approval and good will, and might thus be interpreted as a form of advertising. If out-of-pocket contribution is to be interpreted in this sense, then processors might possibly be asked to enrich a processed foodstuff beyond the original native content, which they might do in the hope of securing still further good will.

Great Britain fought two years of this war without enrichment of flour. In September 1941 began general distribution of the thiamin-enriched flour announced in July 1940, but high officials will not predict when all white flour (about 76 per cent extraction) will be so enriched. The formula is merely one of addition: 0.2 gram of thiamin is to be added to the 280-pound sack of flour, wherever ground, and irrespective of native thiamin content. Unenriched flours may now come to the British market carrying all the way from 400 to 800 micrograms of thiamin per pound of flour. In Canada, 76 per cent extraction flour is being made for export and enriched by addition of a stated amount of thiamin before shipment overseas; but flour of lower or higher extraction for domestic consumption in Canada is not enriched. In Australia also, flour is being enriched only for export to Great Britain.<sup>13</sup>

The final thiamin content of enriched white flour in Great Britain may thus vary from

<sup>13</sup> In *Baker, Miller and Pastrycook*, June 1941, it is reported that native thiamin in Australian wheat flours runs from 550 to 1,150 micrograms per pound, extraction not stated; this strikes us as high for soft white wheat.



1,100 to 1,500 micrograms per pound. If per capita daily consumption be provisionally taken as at least 10 ounces, the thiamin intake in flour would be equivalent to 700–1,000 micrograms per day. Considering thiamin losses in other elements of the British war diet, especially through contraction in pork consumption, this is low compared with accepted standards in this country. So far as we are advised, the British Ministry of Food has not stated a figure for per capita daily requirement of thiamin, to be used in connection with the intake of enriched flour. In technical circles in Canada, the unofficial but accepted estimate is 1,000 micrograms—no higher than the minimum figure adopted by our Food and Drug Administration, and much lower than the figure adopted by the Food and Nutrition Committee of the National Research Council.

In Continental Europe, so far as we know, no flour is enriched with thiamin. Doubtless a case for such enrichment can hardly be made out in countries where, in the milling of wheat and rye, there is significant volume of whole-grain meal; where the extraction of flour varies from 82 to 88 per cent; and where the intake of wheat and rye flour per person per year is generally high.

Optional directions of enrichment efforts are clearly available and are being advocated by different groups in this country, as follows:

1. Revival of old-fashioned graham flour, despite its instability, dark color, bitter taste, high roughage, and inadaptability to many commercial and household uses.

2. Development of new-fashioned graham flour, with lighter color, less bitterness and roughage, and better keeping qualities.

3. Development of high-extraction flour, like the 85 per cent flours of Great Britain (wheat meal) and Continental Europe.

4. Addition of synthetic vitamins to patent flour—a restoration.

5. Restoration by supplementation with natural vitamins such as those in yeast and in milk.

6. Retention of vitamins in other foodstuffs, especially meats and other protective foodstuffs, to lighten the vitamin burden of cereal foods.

Consumers will be influenced by government policy and skill of processors, as well as by tradition, experience, and taste. Government policy will be influenced by processors' skill and by consumers' reactions. And processors' developments will be influenced by government policy and by consumers' reactions. Prices will influence all three. As service after service is applied to foodstuffs, the spread from farm price to consumers' price tends to widen. And behind the cost picture stands the group of low-income families.

*Dr. Taylor, who prepared this study at the request of the Food Research Institute, was one of its three directors from 1921 to 1936. Since becoming director emeritus of the Institute, he has been director of research, General Mills, Inc., Minneapolis.*

## ANALYTICAL INDEX

- Agriculture, condition of U.S., in relation to enrichment of foods, 78-79
- Allen, R. G. D., and Bowley, A. L., 91
- American Medical Association, Council on Foods, 86
- Animal foodstuffs: effect of processing on nutrients, 82; variability of vitamins in, 102; *see also* Butter; Milk; Pork
- Ascorbic acid, *see* Vitamin C
- Australia, enrichment of flour in, 105
- Averages, limitations of, 84-85, 92
- Beriberi, 82
- Beverages, 89, 91
- Butter, 88, 89, 102
- Calorie intake: changes in cereals and sugar in, 83; decline in, 84; difficulties in determining per capita, 85; *see also* Diet; Nutrition
- Canada, enrichment of flour in, 97-98, 105-06
- Canning, 88
- Cereals: decline in use of, 82, 83; vitamins and minerals in, 92-98
- Consumer income and expenditures, studies of, 78, 90-91
- Consumption, food, *vs.* disappearance and ingestion, 84
- Cooking, loss of nutrients in, 99-100
- Costs, of enriching components, 98-99, 104
- Depression of 1930's, 78, 90, 91
- Diet: "adequate," 78, 85; changes in U.S., 83-84; effect of low income on, 90-91; factors limiting, 79-81; impossibility of prescribing, 85, 87; rural *vs.* urban, 81; *see also* Nutrition; Protective foods
- Disappearance, food, 84
- Diseases: deficiency, 82, 85, 87, 90, 91, 102; infectious, 80, 82, 86
- Drummond, J. C., 91
- Endosperm of wheat kernel, 94-95
- Engel, Ernst, 78
- Engels, Friedrich, 90-91
- Enrichment of foodstuffs: adoption as public policy, 77-79; aspects of, 77, 88, 105; background of, 79-89; components, 86; compulsory, permissive, and commercial, 86; problems of, 86-88; status of, 77, 86, 98-106; *see also* Costs; Flour
- Famines, causes of, 81-82
- Federal Security Agency, 77, 86, 97
- Federal Surplus Commodities Corporation, 79
- Flour: cost of enriching, 98-99, 104; extraction rate and thiamin content, 96-97, 105; graham, 93, 106; methods of effecting enrichment, 98-99, 106; problem of level of enrichment, 93, 97-98, 104; *see also* Australia; Canada; Great Britain; United States
- Food, Drug, and Cosmetic Act (1939), 77, 86
- Food and Drug Act (1906), 87
- Food and Drug Administration, 77, 86, 93, 97, 103, 106
- Food supply: diversification, 84, 89-90; limitations on data of, as measure of nutrition, 84-86; *see also* Diet; Enrichment; Nutrition; Protective foods; United States
- Fortification, 77, 88, 105
- Fruits, vitamins in, 88, 101, 102
- Gamble, S. D., 91
- Geographical factors influencing: diet, 80, 90; enrichment, 87-88; protective foods, 89-90
- Germ, wheat, 94, 95, 96, 97
- Grains, *see* Cereals
- Great Britain: enrichment of flour in, 79, 83, 98, 105, 106; enrichment of margarin in, 88; role of protective foods in, 89-90
- Growth, nutrition and, 86
- Health, 82, 91; *see also* Nutrition
- Hopkins, F. G., 89
- Hunger, "hollow" *vs.* "hidden," 81, 91
- Income and diet, 78, 81, 82, 84, 90-91
- Industrial Revolution, 80, 82
- Ingestion, *vs.* consumption and resorption, 84-85
- Institute of Nutrition, 77
- International Labour Office, 91
- Iodine in table salt, 87, 88, 90
- Iron: as enriching component, 86, 98, 105; in wheat, 92, 93, 94
- Kernel of wheat, described, 94-95
- League of Nations, 91
- Life expectancy, 80, 81
- Lime, 86
- McCollum, E. V., 89
- Margarin, 88
- Maynard, L. A., 86
- Milbank Memorial Fund, 77
- Milk, 84, 85, 89, 91, 102
- Milling, flour, effect of, on vitamins, 83, 96-97
- Minerals: availability of, in drug form, 88; difficulty of maintaining intake, 87; lack of information on, in foodstuffs, 85, 92; losses in cooking, 99, 101; *see also* Iron
- Morgan, Agnes F., 77
- National income, *see* Income
- National Nutrition Conference for Defense, 77, 99
- National Research Council, Food and Nutrition Committee, 97, 106
- National Resources Board, 83, 90
- National Resources Committee, 90
- Nelson, E. M., 77
- Nicotinic acid: as enriching component, 86, 90, 98, 105; in grains, 92, 93, 94; in pork, 102
- Nutrition: background of problem, 79-82; difficulties in measuring, 85-86; education in, 87, 104; expansion of field, 86-87; increase of knowledge of, since 1920, 78; limitations in using food supply as measure of, 84-85; and present war, 77-79, 89; requirements for optimum, 97-98; state of, in children, 85-86; studies of mass, 90-91; *see also* Diet; Protective foods
- Orr, Sir John, 91
- Pearl, Raymond, 104
- Pellagra, 82, 90
- Plague, 82
- Population: decline in proportion living on farms, 83; effect of Industrial Revolution on European, 80; effect of lack of mobility on, 82; relation of primitive, to resources, 79
- Pork: declining use in U.S., 83-84; effect of processing on thiamin content, 89, 102
- Preservation of foods, 82, 84, 90, 101
- Preventive medicine, extension of concept of, to nutrition, 86-87
- Processing, effect of refinement of food, on nutritional elements, 82, 83, 88, 89, 93-94, 96-97, 101-02
- Protective foods: concept of, 89; cost of, 89, 91; distribution of, in U.S., 77, 79, 99; influence of geography on, 89-90; knowledge of, 81, 91, 102-03; role of, in Great Britain, 89-90
- Proteins, in wheat and flour, 92, 93
- Refrigeration, 82, 84, 90, 101
- Resorption, 85
- Restoration, 77, 88, 89, 93, 97, 105, 106
- Retention, 77, 82, 88, 89, 93, 105, 106
- Riboflavin (vitamin B<sub>2</sub>): cost of, 98; as enriching component, 86, 105; in grains, 92, 93, 94; in pork, 102
- Rickets, 86, 90
- Roberts, Lydia J., 77
- Rowntree, Seebohm, 91

School lunches, 88, 91  
 Scurvy, 82, 90  
 Sea food, 81, 89, 102  
 Sebrell, W. H., 77  
 Standard and plane of living:  
   effect of Industrial Revolution  
   on, 80; effect of low income on,  
   90-91  
 Statistics, misleading character  
   of available food, 84-85, 104  
 Stiebeling, Hazel K., 91  
 Sugar, 83, 84, 89, 90, 101, 102  
 Taylor, A. E., 77, 106  
 Thiamin (vitamin B<sub>1</sub>): effect of  
   milling on, in wheat, 96-97; as  
   enriching component, 86, 97-  
   98, 105; location of, in wheat,  
   94; in pork, 89, 102; in U.S.  
   diets, 84; variations in content  
   of grains, 92-93, 94

United States: appraisal of food  
 supply, 83-85; approach to en-  
 richment, 82-89; Department  
 of Agriculture, Bureau of Home  
 Economics, 90; Department of  
 Labor, Bureau of Labor Statis-  
 tics, 90; locale of deficiency dis-  
 eases in, 90; present program  
 for flour enrichment, 79, 86, 97,  
 98, 104

Vitamin A, 86, 88, 89, 101, 102,  
 103

Vitamin B, *see* Nicotinic acid;  
 Riboflavin; Thiamin

Vitamin C (ascorbic acid), 86, 88,  
 89, 101

Vitamin D, 86, 89, 90, 102, 103

Vitamins: in cereals, 92-98; diffi-  
 culties in measuring, 103-04;  
 difficulty of maintaining intake,

87; effect of processing on, 83,  
 88-89; lack of information  
 on, 85, 95; losses in cooking,  
 99-100; present "requirements"  
 tentative, 104-05; sale of, in  
 drug form, 78, 88; in sea food,  
 81, 102; variability of, in food-  
 stuffs, 100-02; *see also* Nico-  
 tinic acid; Riboflavin; Thiamin

War: bearing of present, on en-  
 richment movement, 77-79, 89;  
 relation of, to famine, 82

Ward, Medora M., 91

Wheat, *see* Cereals; Flour; Germ;  
 Kernel; Thiamin; Vitamins  
 Wilder, R. M., 77 n., 97

Works Progress Administration,  
 90

Xerosis conjunctivae, 86

# WHEAT STUDIES *of the* FOOD RESEARCH INSTITUTE

## VOLUME XVII

No.		PRICE
1.	<i>World Wheat Survey and Outlook, September 1940.</i> Helen C. Farnsworth and V. P. Timoshenko. September 1940, pp. 1-37 . . . . .	\$ .75
2.	<i>Wheat Subsidization and Exports: The Experience of 1938-39.</i> V. P. Timoshenko. October 1940, pp. 39-99 . . . . .	1.00
3.	<i>Price Relations of Liverpool Wheat Futures, with Special Reference to the December-March Spread.</i> Sidney Hoos and Holbrook Working. November 1940, pp. 101-43 . . . . .	1.00
4.	<i>The World Wheat Situation, 1939-40: A Review of the Crop Year.</i> J. S. Davis. December 1940, pp. 145-220 . . . . .	1.25
5.	<i>World Wheat Survey and Outlook, January 1941.</i> Helen C. Farnsworth and B. M. Jensen. January 1941, pp. 221-60 . . . . .	.75
6.	<i>Rice and Wheat in World Agriculture and Consumption.</i> V. D. Wickizer. March 1941, pp. 261-314 . . . . .	1.00
7.	<i>Wheat in the Post-Surplus Period 1900-09 with Recent Analogies and Contrasts.</i> Helen C. Farnsworth. April 1941, pp. 315-86 . . . . .	1.00
8.	<i>World Wheat Survey and Outlook, May 1941.</i> Helen C. Farnsworth. May 1941, pp. 387-420 . . . . .	.75

## VOLUME XVIII

1.	<i>World Wheat Survey and Outlook, September 1941.</i> Helen C. Farnsworth and B. M. Jensen. September 1941, pp. 1-36 . . . . .	.75
2.	<i>Wheat in National Diets.</i> M. K. Bennett. October 1941, pp. 37-76 . . . . .	1.00
3.	<i>Why Enrichment of Flour?</i> A. E. Taylor. November 1941, pp. 77-108 . . . . .	.75
4.	<i>The World Wheat Situation, 1940-41; A Review of the Crop Year.</i> Helen C. Farnsworth. December 1941 . . . . .	1.00
5.	<i>World Wheat Survey and Outlook, January 1942.</i> Helen C. Farnsworth and B. M. Jensen. January 1942 . . . . .	.75

## RECENT CONTRIBUTIONS *from the* FOOD RESEARCH INSTITUTE

(Numbered reprints available free on request)

No.	
103.	"Food as a Political Instrument in Europe." Karl Brandt. <i>Foreign Affairs</i> , April 1941
104.	"The Conference Process." Hobart Young. <i>American Journal of Sociology</i> , March 1941
105.	"How Europe Is Fighting Famine." Karl Brandt. <i>Foreign Affairs</i> , July 1941
106.	"International Contrasts in Food Consumption." M. K. Bennett. <i>Geographical Review</i> , July 1941
107.	"Consumption Level; Consumption Standard; Plane of Living; Standard of Living." J. S. Davis. <i>Journal of Marketing</i> , October 1941
108.	"The Economic Situation of Agriculture, Industry, and Commerce in the Light of Present World Conditions." Karl Brandt. Address before Appraisal Division, California Real Estate Association, October 1941
109.	"Governmental Price Control as It Pertains to Agriculture." J. S. Davis. Address before Agricultural Section, Sixteenth Annual Statewide Meeting, California State Chamber of Commerce, October 1941

# FOOD RESEARCH INSTITUTE

STANFORD UNIVERSITY, CALIFORNIA

A research department of Stanford University, established in 1921 jointly by Carnegie Corporation of New York and the Board of Trustees of the Leland Stanford Junior University, for research in the production, distribution, and consumption of food.

DIRECTOR	ECONOMISTS	ASSOCIATE ECONOMIST
JOSEPH S. DAVIS	MERRILL K. BENNETT	HELEN C. FARNSWORTH
DIRECTOR EMERITUS	KARL BRANDT	
ALONZO E. TAYLOR	VLADIMIR P. TIMOSHENKO	JUNIOR STATISTICIAN
Minneapolis, Minnesota	VERNON D. WICKIZER	ROSAMOND H. PEIRCE
	HOLBROOK WORKING	

## PUBLICATIONS

### WHEAT STUDIES

Published monthly from September through May except in February. Annual subscription, \$6.00. The volume includes a comprehensive annual review of *The World Wheat Situation*, three *Survey and Outlook* issues at four-month intervals, and four special studies. Bound Volumes I–XVII, \$7.50 each.

Recent issues listed on inside back cover.

### GRAIN ECONOMICS SERIES

Books, wider in scope or of greater length than issues of WHEAT STUDIES.

No. 2. N. Jasny, *Competition among Grains*. January 1940. 606 pp. \$4.00.

No. 3. V. D. Wickizer and M. K. Bennett, *The Rice Economy of Monsoon Asia*. November 1941. 360 pp. \$3.50.

### FATS AND OILS STUDIES

Books on 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. 7. Karl Brandt, *Whale Oil: An Economic Analysis*. June 1940. 264 pp. \$3.00.

### MISCELLANEOUS PUBLICATIONS

Books embodying the results of research in fields other than those covered by the series listed above, or more comprehensive in character.

No. 9. J. S. Davis, *On Agricultural Policy, 1926–1938*. January 1939. 494 pp. \$3.00.

## CONTRIBUTIONS

Chiefly reprints of papers by members of the Food Research Institute. Free on request.

*List of publications and contributions available on request. Address orders and inquiries to*

FOOD RESEARCH INSTITUTE

STANFORD UNIVERSITY, CALIFORNIA