# THE FORMULATION OF A LOW-COST FOOD MIXTURE WHICH WOULD CORRECT AMERICAN DIETARY DEFICIENCIES

by

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Signature of the author

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Signature of the Professor in charge of thesis

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181 Glenway Street
Dorchester, Mass.
May 10, 1940

Mr. George W. Swett
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Sir:

In accordance with the regulations of the faculty, I hereby submit my thesis entitled, The Formulation of a Low-Cost Food Mixture Which Would Correct American Dietary Deficiencies, in partial fulfillment of the requirements for the degree of Bachelor of Science from the Massachusetts Institute of Technology.

Respectfully submitted,

Herbert B. King

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his most sincere gratitude to
Professor Robert S. Harris in
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suggestions and guidance and
inspiration throughout this
thesis
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INTRODUCTION.

The history of man on this earth has been so intimately dependent upon the availability of a sufficient supply of food that it can almost justifiably be said that food is the one most important factor in human progress and civilization. Until only yesterday in the history of man there has been recorded a narrative of the struggle against hunger and starvation. In all the many thousands of years in which man has recorded his existence on earth, his first real progress began only about two hundred and fifty years ago, when for the first time in his history man began to provide a supply of food adequate enough to allow himself to think of other pursuits beside seeking something to eat.

It is difficult for Americans and most Europeans to conceive of living in a world where large parts of the population died from hunger and famines which were as much a part of the pattern of life as were the seasons of the year. But such was the case until improvements in agriculture and food technology made it possible under a government allowing free enterprise for there to be sufficient food available for all and at all times.

We often do not realize what a really great influence food in its varying periods of abundance and shortage has had on the history of the race. The food of our ancestors, and even of ourselves, is closely associated with social and cultural habits. Early man progressed from a barbaric existence to that of the nomadic pastoral being, living off his herds. Then there was a long period which lasted until only about two hundred and fifty years ago, in which civilization was centered around agriculture, with grain as the chief crop, and bread being the universal food, at that time truly the "staff of life". Men are now living in a rapidly progressing industrial age in which one quarter of the population is engaged in an agriculture which feeds the other three quarters of the population so that they may produce materials to enrich life, and to develope art and culture. It is people who are no longer hungry who are able to divert their time from seeking food to contriving ways of lifting life above the plane of mere existence.

Today in the United States a high stage of civilization has been reached; the average man can enjoy luxuries which no amount of money could have secured for a prince a few hundred years ago. This great nation produces more foodstuffs than any other country on earth has ever been able to produce. There is no need for any person in the United States to die of starvation, since this is a nation so wealthy and so rich in natural resources that large portions of the population can, and are being, fed and supported by more fortunate members of the society.

But as science progresses, each day new ideas bring additional light where light was formerly thought to already dwell. For centuries men felt that if enough bread were supplied, the diet would be complete and that suffering from hunger could not exist. In those days most people thought of vegetables as being unfit for human consumption, except in times of emergency, and milk was regarded as a dangerous source of disease, due to its lack of sanitation. During those same Dark Ages even meat was not a very important part of the diet since game was scarce and there was not enough feed to nourish domestic animals aside from those which were used as draw animals.

The discovery of America was greatly significant to the nutrition of the European nations. Here it was that potatoes were discovered both by the Spanish and the English explorers. The popularity of the potato was slow in developing since in those days people thought of food in terms of bread, and the bread which could be made from potatoes was inferior to that made from grain. But because of the ease with which they could be grown, and because of their excellent hunger-satisfying qualities, potatoes became one of the most important items in the diet.

The success of the potato led agriculturists to divert some of their grain crops to animal feeding, thus improving their meat supplies, as well as increasing the use of milk and other dairy products. Furthermore, it stimulated interest in agriculture, and in experimentation with other crops such as fruits and vegetables. At this time

(17th century) new foods such as coffee, tea, and chocolate began to take their place in the diet, and increasing interest in the inclusion of a variety of foods in the diet as well as interest in the preparation of foods was shown by the publication of a number of cook books.

It seemed that at last hunger and starvation were to be displaced when machinery was introduced into the production and processing of foods. But it remained for the science of Nutrition, at that time as yet unborn, to point the way to the true banishment of hunger.

The only function of food seemed to be the allaying of the pangs of hunger, and one food was thought to be as good in this function as another. How recently such concepts of Nutrition were held is shown by the following quotation from a popular textbook in 1813, Richerand's <u>Elements of Physiology</u> : "By aliment is meant whatever substance affords nutrition, or whatever is capable of being acted upon by the organs of digestion...However various our aliments may be, the action of our organs always separates from them the same nutritious principles; in fact, whether we live exclusively on animal or vegetable substances, the internal composition of our organs does not change...There is but one food, but there exist several forms of food." The same idea was expressed by William Beaumont in 1833: "The ultimate principles of nutriment are probably always the same, whether obtained from animal or vegetable diet."

It remained for the rapid development of biochemistry to finally demonstrate the existence of a multiplicity of factors in Nutrition, rather than a single food principle. Only a year after Beaumont's publication William Prout declared that foods were composed of three distinct principles: oily, saccharine, and albuminous. He identified the saccharine principle chiefly with plant tissues, and the albuminous principle chiefly with animal tissues. He stated that, "A diet to be complete must contain more or less of all the three staminal principles."

To give a detailed resume of subsequent discoveries in the field of Nutrition is not the purpose of the present paper, but we must all be aware of the tremendous amount of work which has been compiled on the chemistry and Physiology of Nutrition.

From the time of Prout's publication to the present, there has been a change in the attitude of workers in the field of Nutrition toward the problem of hunger in relation to the population. We in the United States no longer have high death rates from starvation; hunger in this twentieth-century democracy has taken on a new and more important meaning. To look at it from a purely economic point of view, where formerly the people would starve to death because there was not enough food to keep them alive, we now have people on nutritionally inadequate diets who may not hunger in the usual sense, but who cannot realize their natural capabilities and are inefficient and hence liabilities from a social and an economic point of view. In fact, it is difficult to conceive of the great price of inadequate nutrition until we realize that robust health and vitality is being robbed from the greatest part of our population because they are not receiving the proper types of food. The great pity of it all is that by eating the proper foods, indications are that this evil could be remedied either with slight or no increase at all in the food expenditures of the nation.

Since the beginnings of scientific nutritional research, it has become increasingly evident to workers that there do exist certain very definite dietary deficiencies in the population which are endemic in a large portion of the population. Even though we may not have had means of detecting required amounts of certain dietary elements, it was observed that persons receiving a larger, and apparently more nearly optimal share of certain dietary elements, exhibit certain characteristics of more perfect health.

From the point of view of calories, it is true that in this country no one need go hungry, but we can no longer close our eyes to the fact that twenty million Americans show serious signs of malnourishment. The very fact that this great number of obvious deficiency conditions can be recognized indicates that there must be many times this number of sub-clinical dietary deficiencies which rob individuals of their lives, and make the remaining years less productive and less enjoyable. Statistics show that ninety-six percent of the population are sufficiently malnourished to have poor teeth. These are in a large part people who would normally be considered to be healthy. It is obvious that in the future there must be a new definition for the word health. "Health" does not mean mere absence of pain. It means both physical and mental well-being, with a joy of living.

Medicine and Public Health have done much through sanitation, education, and therapy toward giving the American Public a place in which to live which is free from the germs of infectious diseases, but comparatively little has been accomplished in the elimination of conditions due to inadequate dietary, except in cases of extreme deficiency. In other words, it is time to take some of the emphasis from helping the weak to survive to helping to make the strong stronger and happier.

Much work has been done by the United States Department of Agriculture and similar agencies in the compilation of sample diets and other educational work in the proper selection of foods. But unfortunately it is impossible for a large portion of our population to afford the diets necessary under this plan to give an adequate balance of nutrients. Even if it were possible, American agriculture does not produce the foods suggested in the amounts which would be required, and it would take years under our system of agriculture for an adjustment to meet the necessary changes.

There is increasing evidence to show that as knowledge of proper nutrition was increasing, people were busy inventing new methods of refining their foods, which resulted in the greater reduction of the food-value of their already inadequate diets. Dietary deficiencies are present in the population today which were not present fifty years ago when we understood these deficiencies very poorly, due to the fact that today we eat enormous quantities of white sugar and refined cereals in place of such highly nutritious foods as eggs, milk, fresh fruits and vegetables, and whole-grain cereals.

More recently food manufacturers have, in many instances, taken to the practice of replacing some of the nutritional values in their product after processing, and in many cases adding more of certain factors than were naturally present. This practice has been vigorously condemned by certain groups who have contended that dietaries should be improved only by the use of the proper natural foods. But there seems to be no doubt that the nutritional level of the country could be raised by the production of foods so rich in nutritive value that it would hardly be possible to suffer from nutritional deficiencies provided that an adequate bulk or caloric portion of food is taken. This means of raising the nutritional level of a nation becomes practical when these foods can be produced at a cost within the budget of even the most limited income groups.

Quite possibly there will be a time when with comparatively little trouble the exact requirement of each nutrient factor may be prescribed for each individual, according to his needs, and a mixture of pure chemicals may be compounded to supply the correct stimulus for complete health of mind and body, so far as it can be supplied by Nutrition alone. But it is certainly not wise to wait for that day before an attempt is made to improve the dietary of the nation, for while it is doubtlessly true that there are many missing answers to questions about the functions and biochemistry of many of the nutrients, enough is now known about them to prescribe what amounts will in most normal cases result in optimal nutrition.

In the ideal case which was mentioned, each person is studied to determine what the exact optimal requirements of nutrients are for him individually. Obviously, with present means of determining requirements, such a scheme is entirely impractical. Even so, it can be predicted with great accuracy what the amounts of the different vitamins, minerals, etc. will be for a normal man, woman, or child, for example, but the compounding of a diet of pure vitamins and amino acids is impossible since many have not yet been isolated in pure form or synthesized, and when they have been they are usually too expensive for such a scheme.

A more practical suggestion, perhaps, embodying the basic reasoning of a purely chemical diet, would be the formulation of a food mixture composed of food ingredients which are known to be rich in the nutritional values desired, even though there might be included a good deal of extraneous matter. While this would be a satisfactory solution, provided, of course, that a compound could be made to furnish the necessary nutrients, and, from a practical point of view, if it were sufficiently inexpensive, there is a social objection to the use of such a food. The dietary habits of man are the accumulated habits of his ancestors. To suddenly change the diet of a people from one of three meals a day composed of a fair variety of dishes to perhaps one or two meals of a somewhat peculiar-tasting mixture with small bulk, is a task which all the combined efforts of the nutritionists of the world could probably not solve, even if the people could be shown how much their health could be improved, for there is no doubt that eating, although one of the most commonplace of all indulgences, is nevertheless one of man's greatest pleasures.

However, it would probably not be difficult to convince the people that they ought to add to their regular diet or perhaps replace some one small item with an extremely inexpensive food mixture which can be demonstrated to have great nutritional value. It is on the strength of this idea that this present paper has been undertaken: the formulation of a low-cost food mixture to correct the deficiencies of the American dietary.

## FOOD EXPENDITURES AND DIETS IN THE UNITED STATES

To formulate a food which is to correct the dietary deficiencies of the American dietary, it is obviously necessary to determine what the deficient factors are, and to what degree they are deficient. This suggests the following method of procedure: an average incomplete diet is to be selected and analyzed for its nutritional value. This diet should be so selected that it represents a worse diet than the vast majority of all American diets. By subtracting these values from the optimal values, a formula for a combination of nutrients should be obtained which when added to the vast majority of diets will raise those diets to or above the optimal nutritional level. The first problem is,therefore, the determination of the nature of the incomplete diet upon which the study is to be based. In order to do this, it is necessary first to study the distribution of family incomes in the United States.

The percent of the income spent on food varies greatly with varying conditions. From one point of view, the population may be considered under three classes, farming communities, villages and small cities, and metropolises. The reason for this classification is evident when it is realized that those in the first group may raise practically all of their own food, thus spending a negligible amount of money on the diet, while urban families must buy all of their food. From a nutritional standpoint

TABLE I*- Average Expenditures of American Families for Certain Catagories of Consumption, by Income Level

(1935-36)

| Income level | All items | Food ($) | Food % total | Housing | Medical Care | Clothing |
|---|---|---|---|---|---|---|
| under $500 | $466 | $203 | 43.6% | $90 | $22 | $35 |
| 500-750 | 707 | 310 | 43.8 | 125 | 29 | 56 |
| 750-1,000 | 914 | 380 | 41.5 | 161 | 38 | 78 |
| 1,000-1,250 | 1,127 | 433 | 38.4 | 203 | 47 | 100 |
| 1,250-1,500 | 1,316 | 487 | 36.9 | 230 | 57 | 123 |
| 1,500-1,750 | 1,512 | 527 | 34.9 | 267 | 71 | 147 |
| 1,750-2,000 | 1,684 | 558 | 33.1 | 302 | 79 | 164 |
| 2,000-2,500 | 1,968 | 617 | 31.4 | 349 | 91 | 207 |
| 2,500-3,000 | 2,302 | 690 | 30.0 | 404 | 109 | 255 |
| 3,000-4,000 | 2,729 | 770 | 28.2 | 485 | 132 | 316 |
| 4,000-5,000 | 3,276 | 852 | 26.0 | 571 | 158 | 408 |
| 5,000-10,000 | 4,454 | 1,038 | 23.3 | 784 | 248 | 557 |
| 10-15,000 | 6,097 | 1,214 | 19.9 | 1,204 | 227 | 829 |
| 15-20,000 | 9,134 | 1,785 | 19.6 | 1,490 | 416 | 1,265 |
| over $20,000 | 14,822 | 2,261 | 15.3 | 2,721 | 837 | 2,177 |
| all levels | $1,389 | $467 | 33.6% | $248 | $64 | $141 |

*Adapted from National Resources Committee (1939)

The figures in the columns marked "food" represent actual outlays for food in the home and restaurant, as well as imputed values for food consumed on the farm.

any of these groups is liable to suffer from an inadequate diet, since the farm family may be limited to a diet of the few items produced on the farm, while the urban family is the victim of the limitations of his pocketbook and the grocer's shelf.

Not only is the type of community important in such a consideration , but the section of the country must also be considered. It is obvious that certain foods will vary in price and availability in different parts of the country. In fact, this price and availability factor is a very important cause of dietary deficiencies in many parts of the country.

The National Resources Committee (1939) has made a number of studies of incomes and expenditures in the United States. Table I shows a summary of their findings (adapted). from this table it can be seen that the largest single catagory of expense at every income level below $20,000 is food. At the $20,000 income level, housing takes first place. In the lowest income class shown - under $500 - 43.6% of the current income is spent on food. However, it is found that in this income group purchasing power is augmented by past savings and by borrowing, so that the actual amount spent on food is an average of $302.

Food declines in relative importance more rapidly with advancing income than does any other catagory of consumption. Yet it is significant to note the marked increase in dollar outlays at successive income levels. Food outlays in the $500 income class are less than one tenth of those in the $20,000 class. This wide range in expenditures reflects, of course, differences in the palatability and in the variety of the food consumed, as well as differences in the nutritive value of the diet.

With rising income there is a demonstrable increase in the use of foods such as milk, eggs, fresh fruits and vegetables, and other foods which are associated with a decreased death rate, better growth in children, greater adult stature, and much improved general health. The explanation of this lies in the fact that these foods are richest in essential minerals, vitamins, and good protein.

During the period of the National Resources Committee study, the thirteen million families and single individuals in the lower third income group (under $780) paid out, on the average, more than half their incomes for food, yet the average value of food consumed by them was only $236, as contrasted with $404 for those in the middle third ($780-$1,450) and $642 for those in the upper third.

In terms of per capita expenditure, the lower third spent about $82 for food during the year, or $1.60 per week; the middle third averaged about $125 for the year, or $2.40 per week, while the upper third averaged $186 per capita per year, or $3.60 per week.In a study by Stiebeling and Phipard (1939), the weekly per capita food expenditure was analyzed in finer expenditure catagories, and was distributed by color and geographic region.

TABLE II* - Percentage Distribution for Food per Capita

by Level of Expenditure.

| Color of Family and Region | Percentage of Records in which Weekly Food Expenditure per Capita Was: | | | | | | |
|---|---|---|---|---|---|---|---|
| | under $.63 | $.63-1.24 | $1.25-1.87 | $1.88-2.49 | $2.50-3.12 | $3.13-3.74 | $3.75 & over |
| White | % | % | % | % | % | % | % |
| New England | 0 | 0.5 | 12.5 | 25.8 | 27.2 | 17.3 | 16.7 |
| Middle Atlantic | 0 | 0.8 | 10.1 | 27.4 | 23.3 | 17.6 | 20.8 |
| E. N. Central | 0 | 1.7 | 14.5 | 26.4 | 26.8 | 14.9 | 15.7 |
| W. N. Central | 0 | 0.5 | 12.1 | 23.3 | 24.7 | 18.7 | 20.7 |
| South Atlantic | 0 | 1.5 | 18.4 | 29.1 | 26.1 | 13.4 | 11.5 |
| E. S. Central | 0.5 | 7.7 | 31.2 | 29.6 | 16.7 | 8.2 | 6.1 |
| W. S. Central | 0 | 2.2 | 24.2 | 34.0 | 16.5 | 12.1 | 11.0 |
| Mountain | 0 | 3.0 | 14.3 | 35.1 | 26.2 | 10.1 | 11.3 |
| Pacific | 0.1 | 0.6 | 8.0 | 26.0 | 27.0 | 16.9 | 21.4 |
| Negro | | | | | | | |
| Middle Atlantic | 0 | 5.2 | 23.7 | 24.7 | 13.4 | 9.3 | 23.7 |
| South | 0.6 | 34.1 | 33.4 | 15.8 | 9.0 | 4.8 | 2.3 |

*Adapted from Stiebeling and Phipard (1939)

One of the conditions under which a study such as this must be made is that the people in the sample population studied must have some regular source of income. Relief cases cannot be considered since theoretically they have no income at all, and hence could not afford any diet, no matter how inexpensive. The sample population studied in the Department of Agriculture Report summarized in Table II consisted only of wage earners, with no relief families included. Dr. Stiebeling estimates that about 99% of the nonrelief families in this country have food valued at 63¢ or more per person a week, and about 94% of the families have food valued at $1.25 or more per person per week.

It is obvious that the worse the diet which is supplemented and brought up to a satisfactory level, the greater will be the percentage of the total diets in the country which will also be brought to an optimal level. Table II shows that the most frequent amount spent by employed wage earners for food is $1.88-$2.49 weekly per capita. However, to select the poorest diet eaten by persons expending this amount for food would leave the diets of almost twenty-five percent of the population below the optimal level. On the other hand, selecting the poorest diet obtained in the expenditure class $1.25 to $1.87, the diets of all but the lowest six percent of the population are included.

Why not include diets in the expenditure class $.63

to $1.24? Since this unit represents only about six percent of the population, it has such an incomplete diet that any supplement to such a diet would almost have to be a complete food, and would be relatively more expensive. However, it must be remembered that it is the diets of those in the lower income groups which are most in need of improvement, and hence it is these diets which are the main concern here. In answer to this, the selection of the $1.25-$1.87 expenditure group for the typical nutritionally inadequate diet which is to be improved to an optimal level, will include 94% of all diets and bring them to an optimal level. Furthermore, since the optimal "requirements" include added factors of safety, the same supplementary values which bring the 94% of the diets to an optimal level will doubtlessly bring the remaining six percent to a nearly satisfactory level, or at least improve them considerably.

The next step is to examine the diets which are obtained by persons on the $1.25 to $1.87 diet, and to select what may be considered an average poorest diet. In the study by Stiebeling and Phipard the diets of the sample populations which were analyzed by the amount of money expended upon them, were also analyzed for their nutritional factors. Table III represents a summary of the average amounts of dietary elements consumed by each expenditure unit.

Since no figures were given for vitamin D, this value was figured on the basis of eggs alone since this is the only common food source of the vitamin. Negroes were found to have

Table III* - Average Amounts of Various Dietary Elements Obtained per Day in the Food-Expenditure Unit $1.25-1.87

| Color & Region | protein (gms) | Ca (gm) | P (gm) | Fe (gm) | Vitamins A (IU) | Vitamins $B_1$ (IU) | Vitamins C (IU) | Vitamins G (IU) |
|---|---|---|---|---|---|---|---|---|
| White | | | | | | | | |
| N.Atlantic | 63 | .58 | 1.01 | 9.8 | 2000 | 290 | 760 | 440 |
| E.N. Central | 63 | .56 | 1.01 | 10.3 | 2500 | 350 | 840 | 450 |
| W.N. Central | 63 | .56 | 1.00 | 10.5 | 2400 | 360 | 850 | 510 |
| S. Atlantic | 60 | .57 | 1.10 | 11.0 | 2600 | 370 | 900 | 430 |
| E.S. Central | 64 | .73 | 1.27 | 12.4 | 3400 | 420 | 920 | 460 |
| W.S. Central | 61 | .63 | 1.00 | 10.0 | 2000 | 290 | 540 | 420 |
| Mountain | 59 | .66 | 1.03 | 9.3 | 3400 | 290 | 1190 | 480 |
| Pacific | 52 | .63 | 1.08 | 11.2 | 3100 | 380 | 1250 | 520 |
| Negro | | | | | | | | |
| South | 70 | .68 | 1.35 | 14.7 | 6400 | 440 | 1090 | 500 |

*Stiebeling and Phipard (1939)

the lowest egg consumption, averageing about 11.1 dozen per year. Assuming fifty-six units of vitamin D per egg, the value of twenty-five units per day was arrived at as the average minimum amount of vitamin D consumed in the food-expenditure unit $1.25 to $1.87.

Table III shows a summary of the average amounts of various dietary factors found in the diets of sample populations in various regions of the country. The lowest average amount is the lowest figure in each column. Subtracting this lowest figure from the figure for the optimal amount will give the amount of that nutritional factor which will bring 94% of American diets to an optimal level.

Before selecting the amounts of each of the dietary factors which shall be considered to be optimal, it is first necessary to decide what the basis for this selection shall be. Infants usually require much higher proportions of certain vitamins and minerals than adults. The proportion for males may be higher than that for females. Since the mixture which is to be prepared would be unsuitable for infants, anyway, the best procedure seems to be to select the greatest optimal requirements for any person of either sex, and after infancy. Table IV shows these amounts, together with the minimum amounts of each of the nutritional elements selected from Table III.

Table IIII- Calculation of the Necessary Amounts of Nutritional Factors to Supplement Average Poor Diet

| Factor | Lowest Average Amount in Diet | Theoretical Optimal Requirement | Amount Necessary in Supplement |
|---|---|---|---|
| Protein | 59 gms | 75 gms | 16 gms |
| Calcium | .56 gms | 1 gm | .44 gms |
| Phosphorus | 1.0 gms | 1.32 gms | .32 gms |
| iron | 9.3 mg | 15 mg | 5.7 mg |
| Vitamin A | 2000 IU | 6000 IU | 4000 IU |
| Vitamin $B_1$ | 290 IU | 600 IU | 310 IU |
| Vitamin C | 540 IU | 1800 IU | 1260 IU |
| Riboflavin | 420 SU | 600 SU | 180 SU |
| Vitamin D | 25 IU | 500 IU | 475 IU |

The theoretical optimal requirement of protein is estimated to be 1.5 grams per kilogram of body weight. The figure of 75 grams given here is for an adult of average size.

Any food mixture supplying the factors in the amounts listed in the last column of Table IV should bring 94% of the diets in the United States to an optimal nutritional level and definitely improve the remaining 6%. In order that the mixture can be available to this 6% however, the ingredients must be so selected that the product will be as inexpensive as possible.

Since the figures which have been given are based on non-relief diets, the question might be raised, "What about the diets of those on relief?". No large scale study has been undertaken that makes it possible to compare food expenditures of families on relief with those of non-relief groups, but expenditures for food by families on relief differ widely from place to place because of varying relief policies. In a study made in Washington D. C. by the Department of Agriculture (as yet unpublished) it was found that 70% of the relief families had food valued at $1.25 or more per week (per person) and 96% had food valued at $.63 or more per person per week. This would indicate that a food mixture containing the nutrients computed above would be suitable for most people on relief. Furthermore, it is logical that since people on relief generally have food distributed free to them by various agencies, an inexpensive food mixture such as this should take the place of some more expensive but less nutritious food, thus leaving more money for other foods.

SELECTION OF THE COMPONENTS OF THE FOOD MIXTURE

The use of natural foods would be a very desirable procedure because these foods are less expensive than processed foods and they are as a rule more easily available. But reference to table V will show what large quantities of substances must be taken to supply the necessary vitamins. It is evident that sources which are quite concentrated in vitamins will have to be used. The most logical scheme of procedure seems to be to select the protein source first, and then to add whatever vitamins and minerals are missing.

According to the calculations, sixteen grams of protein are required. But proteins vary in their nutritional value according to the kinds and amounts of amino-acids they contain. Furthermore, while a person on the average poorest diet may be getting fifty-nine grams of protein a day, this is most likely not an ideal combination of the proper amino acids. By adding a factor of safety of 25% and by giving a protein ~~and by giving a protein~~ which contains the best balance of amino acids according to present knowledge, the protein requirement should be well cared for.

In 1897 Rubner proposed the idea that the human being required a minimum amount of protein, and that he should obtain all kinds of protein to meet this requirement. It is now known that the difference in the values of proteins is due to the difference in their amino-acid makeup. Various workers have found that of the known amino acids, at least ten are

Table V* - Mineral and Vitamin Analyses of Certain Food Substances.

| Substance | Ca | P | Fe | Cu | Mn | Cl | Vitamin A | Vitamin $B_1$ | Vitamin C | Riboflavin |
|---|---|---|---|---|---|---|---|---|---|---|
| | mg per 100 gms | | | | | | I.U. per 1oo grams | | | mg. per 100 gm |
| Wheat (whole) | 53 | 374 | 5.0 | 0.72 | 3.4 | 68 | 0-20 | 75-250 | | .06 |
| " (germ) | 71 | 1050 | | | | 70 | 400 | 400-2000 | | .033 |
| Oatmeal (whole) | 63 | 422 | 3.8 | 0.5 | 2.8 | 69 | 0-25 | 325 | 0;11 | |
| Cornmeal (yellow) | 16 | 152 | 1.3 | 0.2 | 0.28 | 146 | 350-1000 | 70 | | .02 |
| Alfalfa leaf meal | 1130 | 238 | 3.5 | | | | 17,000 | | 5.7-160 | .7 |
| Soybean meal | 230 | 649 | 7.0 | | | | 200-500 | 200-400 | | |
| Rice (brown) | 84 | 290 | 2.0 | 0.4 | 1.70 | | | 50-100 | | |
| Rice polishing | 73 | 200 | 1.0 | 0.2 | 0.62 | | $34\gamma$ carotene | 300-760 | | |
| Peanut meal | 71 | 399 | 2.3 | 1.0 | 1.57 | 56 | | 220-325 | | |
| molasses (blackstrap) | 258 | 30 | 8.0 | 1.9 | 0.04 | 317 | | | | |
| Yeast (Brewer's) | | | | | | | | 1200-6000 | | 1.8-3.0 |
| Barley (whole) | 51 | 400 | 4.7 | 0.4 | 1.59 | | | 50-100 | | .01 |

*Adapted from "Nutritional Abstracts" and "Newer Knowledge of Nutrition" by McCollum, etc.

essential for the normal repair of tissues and for other protein functions, but which cannot be synthesized in the body in sufficient amounts for its needs.

As yet no worker has been able to prove that he has determined the exact combination of amino acids which are necessary for man, but this is no valid reason for not including a protein which is as nearly the ideal combination as possible.

When a protein is ingested into the human body those amino acids which are needed are removed and used. Those which are in excess are deaminized, and they raise the body nitrogen-level in proportion with the amount in which they are present in excess. A perfect protein would be used in its entirety and when ingested in amounts equal to or less than the output of nitrogen during a period of nitrogen starvation, would show absolutely no rise in nitrogen output.

Many various means have been tried to find which proteins are best, and which of the amino acids are absent from various proteins. By feeding animals one particular protein exclusively, and noting the deficiency syndrome which arises, and then by adding, one by one, various pure amino acids to the diet, those amino acids which are deficient in the protein may be discovered. By this means, Osborne and Mendel found that zein, one of the proteins of corn, is deficient in lysine and tryptophane.

Various means of calculating the biological values of proteins have been devised. The so-called "body-weight method" was devised by Osborne, Mendel and Ferry. This method gave the biological value of proteins at various dietary levels as the ratio of the gain in weight of rats to the protein intake. The "nitrogen balance method" of Mitchell and Boas Fixen gives the biological value as the ratio of the body nitrogen spared to the food nitrogen absorbed, times one hundred.

All methods have shown that certain definite statements may be made. Animal proteins are as a class better than vegetable proteins. Of all the proteins tested, whole egg is the most nearly complete, with whole milk second. Table VI gives a list of certain biological biological values computed by the nitrogen-balance method.

Table VI*- Biological Values of Proteins

| Source | B. V. |
|---|---|
| Whole egg | 94 |
| Liquid skim milk | 90# |
| dry milk solids | 89# |
| whole milk | 85 |
| egg white | 83 |
| beef liver | 77 |
| whole wheat | 67 |
| potato | 67 |

#Fairbanks and Mitchell (1935)
*Adapted from Mitchell and Hamilton (1929)

The results obtained with similar experiments varies from one worker to another, due to variation in samples and in technique, but in all experiments, egg protein has been shown to be the most nearly perfect. Since the value of a protein has been shown to depend entirely upon the amino acids which are available in it, it follows that a mixture of proteins should be able, if properly selected, to make up for the amino acid deficiencies of one-another, thus forming a complete protein from the combination of inferior proteins. That this does happen when two supplementary proteins are combined has been shown in numerous experiments. (see Mitchell and Carman,(1924), (1926); Markuze,(1934), etc.)

In comparatively few cases have proteins been completely analyzed for their amino-acid makeup. Egg proteins are among those which have been most completely analyzed. Table VII shows the percentage analyses of the more important proteins of certain food substances. In this study, a large number of additional substances, such as peanut meal and meat meal,have been reviewed also, but these were found unsuitable for the present work either because of the poor quality of the protein, as in the former, or because of the high price, as in the latter, and hence they have been omitted from the table.

In order to put these proteins on a fair basis for comparison, the percentage amino acid in each protein

Table VII - Amino Acid Content of Certain Proteins

| Amino Acid* | Ovalbumin[1] | Ovovitellin[2] | Livetin[3] | Leucosin[4] | Gliadin[4] |
|---|---|---|---|---|---|
| Glycine | 1.7 | | | .94 | .5 |
| Alanine | 2.2 | .75 | | 4.45 | 2.0 |
| VALINE | 2.5 | 1.87 | | .18 | 3.34 |
| LEUCINE & ISOLEUCINE | 10.7 | 9.87 | | 11.34 | 6.62 |
| PHENYLALANINE | 5.1 | 2.54 | | 3.83 | 2.35 |
| Tyrosine | 4.3 | 3.37 | 5.2 | 3.34 | 3.3 |
| Serine | | | | | .2 |
| Cystine | 1.3 | 1.19 | 3.9 | | 2.1 |
| Proline | 4.2 | 4.18 | | 3.18 | 10.3 |
| Hydroxyproline | | | | | |
| Aspartic acid | 6.1 | 2.13 | | 3.35 | .81 |
| Glutamic acid | 14. | 12.95 | | 6.73 | 43.66 |
| TRYPTOPHANE | 1.3 | 2.42 | 2.1 | | 1.1 |
| ARGININE | 5.2 | 7.77 | | 5.94 | 2.9 |
| LYSINE | 6.4 | 5.38 | | 2.74 | .6 |
| HISTIDINE | 1.4 | 1.90 | | 2.83 | 1.5 |
| Ammonia | 1.4 | 1.25 | | 1.41 | 4.1 |
| METHIONINE | 4.6 | | | | 2.0 |
| Hydroxyglutamic acid | | | | | |
| TOTAL % | 72.4% | 44.57% | 11.2% | 50.27% | 94.4% |

*Essential amino acids are capitalized

Blank spaces indicate either no information or no value

Table VII - Continued

| Amino Acid | Glutenin[4] | Glutelin[4] | Zein[4] | Glycinin[5] | Lactalbumin[6] | Casein[6] |
|---|---|---|---|---|---|---|
| Glycine | .89 | .25 | | 1.0 | | |
| Alanine | 4.65 | | 9.8 | | 2.5 | 1.5 |
| VALINE | .24 | | 1.9 | .7 | .9 | 7.2 |
| LEUCINE & ISOLEUCINE | 5.95 | 6.22 | 25.0 | 8.5 | 19.4 | 9.4 |
| PHENYLALANINE | 1.97 | 1.74 | 5.0 | 3.9 | 2.4 | 3.2 |
| Tyrosine | 4.25 | 3.48 | 5.9 | 1.9 | .9 | 4.5 |
| Serine | .74 | | 1.0 | | | .5 |
| Cystine | 1.8 | | .9 | 1.1 | | |
| Proline | 4.23 | 4.99 | 8.4 | 3.8 | 4.0 | 8.0 |
| Hydroxyproline | | | .8 | | | .3 |
| Aspartic acid | 2.0 | .63 | 1.8 | 9.4 | 1.0 | 4.1 |
| Glutamic acid | 25.7 | 12.72 | 31.3 | 19.5 | 10.1 | 21.6 |
| TRYPTOPHANE | 1.6 | | .2 | 1.7 | | 1.7 |
| ARGININE | 4.72 | 7.06 | 1.6 | 8.1 | 3.2 | 3.8 |
| LYSINE | 1.92 | 2.93 | | 9.1 | 9.2 | 6.0 |
| HISTIDINE | 1.76 | 3.0 | .8 | 1.4 | 2.1 | 2.5 |
| Ammonia | 4.01 | | | | 1.3 | 1.6 |
| METHIONINE | | | 2.2 | | | 1.4 |
| Hydroxyglutamic acid | | | 2.5 | 5.5 | | 10.5 |
| TOTAL % | 66.8% | 45.14% | 102% | 75.6% | 57% | 87.8% |

Explanation and notes on Table VII.

Ovovitellin, Ovalbumin, and Livetin are egg proteins.

Leucosin, Gliadin, and Glutenin are wheat proteins.

Glutelin and Zein are corn (maize) proteins.

Glycinin is a soybean protein.

Lactalbumin and Casein are milk proteins.

The references for Table VII are as follows:
(see also Bibliography at end)

1. Schmidt (1938)
2. Sherman (1935)
3. Kay and Marschall (1928)
4. Lloyd and Shore (1938)
5. Horvath (1939)
6. McCollum, Orent-Keiles and Day (1939)

TABLE VIII - Amino-acid Content of 100 Gram Portions of the Total Protein in Foods

| Amino Acid | EGG | WHEAT | SOYBEAN | CORN | MILK SOLIDS** | OATS |
|---|---|---|---|---|---|---|
| glycine | .497 | .407 | .88 | .08 | | .9 |
| ALANINE | .914 | 2.906 | | 4.9 | 1.7 | 2.23 |
| VALINE | 1.398 | 1.447 | .615 | .95 | 5.92 | 1.62 |
| LEUCINE & ISOLEUCINE | 6.7 | 5.547 | 7.45 | 14.6 | 11.5 | 13.5 |
| PHENYALANINE | 2.4 | 1.901 | 3.43 | 3.05 | 3.05 | 2.88 |
| tyrosine | 3.16 | 3.337 | 1.67 | 1.47 | .547 | 3.98 |
| serine | | .391 | | .5 | | |
| cystine | 1.319 | 1.595 | .97 | 1.1* | | 2.69 |
| proline | 2.71 | 6.001 | 3.34 | 5.88 | 7.23 | 4.86 |
| hydroxyproline | | | | .4 | .239 | |
| aspartic acid | 2.59 | 1.278 | 8.25 | 1.11 | 3.47 | 3.6 |
| glutamic acid | 8.75 | 28.536 | 17.1 | 19.77 | 19.3 | 16.6 |
| TRYPTOPHANE | 1.526 | 1.063 | 1.49 | .1 | 1.35 | 1.66 |
| ARGININE | 4.4 | 3.348 | 7.12 | 8.7* | 3.7 | 13.9 |
| LYSINE | 3,82 | 1.141 | 8.00 | 2.3* | 6.7 | 4.11 |
| HISTIDINE | 1.o9 | 1.439 | 1.23 | 4.8* | 2.43 | 2.91 |
| ammonia | .857 | 3.38 | | 2.48 | 1.33 | 14.7 |
| methionine | 1.34 | .8 | | 1.1 | 1.113 | |
| hydroxyglutamic acid | | 3.08 | 4.84 | 1.3 | 8.37 | |

** Dried skim milk powder

* from "Biochemistry of the Amino Acids"-Mitchell & Hamilton

Blank spaces indicate either no information or a negative value.

Table IX - Amino Acid Content of 100 Gram

Portions of Various Foods

| Amino Acid | EGG | Wheat | Soybean | Corn | Skim milk* | Oats |
|---|---|---|---|---|---|---|
| Glycine | .0696 | .0468 | .29 | .009 | | .153 |
| Alanine | .1279 | .323 | | .575 | .642 | .37 |
| VALINE | .1957 | .166 | .205 | .011 | 2.23 | .276 |
| LEUCINE & ISOLEUCINE | .938 | .638 | 2.48 | 1.68 | 4.35 | 2.3 |
| PHENYLALANINE | .336 | .218 | 1.14 | .351 | 1.15 | .49 |
| Tyrosine | .4426 | .371 | .567 | .169 | .206 | .678 |
| Serine | | .045 | | .058 | | |
| Cystine | .1846 | .183 | .32 | .052 | | .457 |
| Proline | .379 | .69 | 1.11 | .676 | 2.73 | .827 |
| Hydroxyproline | | | | .046 | .09 | |
| Aspartic acid | .363 | .147 | 2.75 | .128 | 1.309 | .613 |
| Glutamic acid | 1.22 | 3.28 | 5.7 | 2.27 | 7.27 | 2.82 |
| TRYPTOPHANE | .2138 | .122 | .49 | .012 | .51 | .282 |
| ARGININE | .616 | .385 | 2.37 | .366 | 1.39 | 2.36 |
| LYSINE | .534 | .131 | 2.66 | .011 | 2.53 | .70 |
| HISTIDINE | .1525 | .166 | .41 | .156 | .916 | .495 |
| Ammonia | .1199 | .388 | | .285 | .502 | 2.5 |
| METHIONINE | .188 | .992 | | .126 | .42 | |
| Hydroxyglutamic acid | | .354 | 1.61 | .150 | 3.15 | |
| % protein in the food | 14% | 11.5% | 34% | 11.5% | 37.7% | 17% |

*dried, powdered

Blank spaces mean either no value available or neagtive value.

Capitalized amino acids are the essential amino acids

Table X - Amino Acid Values in a Combination of

50% Soybean, 25% Wheat, 25% Skim milk

Compared With an Equal Portion (100 gms) of Egg

| Amino Acid | Soybean 50 gm | Wheat 25 gm | Skimmilk 25 gm | Total 100 gm | Egg 100 gm |
|---|---|---|---|---|---|
| Glycine | .15 | .0117 | | .162 | .0696 |
| Alanine | | .081 | .161 | .241 | .1279 |
| Valine | .102 | .041 | .56 | .703 | .1957 |
| Leucine & Isoleucine | 1.24 | .16 | 1.09 | 1.49 | .938 |
| Phenylalanine | .57 | .055 | .29 | .915 | .336 |
| Tyrosine | .283 | .093 | .052 | .428 | .4426 |
| Serine | - | .011 | | .011 | |
| Cystine | .16 | .046 | | .206 | .1846 |
| Proline | .55 | .17 | .682 | 1.4 | .379 |
| Hydroxyproline | | | .02 | .02 | |
| Aspartic acid | 1.37 | .037 | .327 | 1.734 | .363 |
| Glutamic Acid | 2.8 | .82 | 1.82 | 5.44 | 1.222 |
| Tryptophane | .25 | .031 | .13 | .411 | .2138 |
| Arginine | 1.18 | .096 | .348 | 1.624 | .616 |
| Lysine | 1.33 | .033 | .631 | 1.994 | .543 |
| Histidine | .20 | .042 | .229 | .471 | .1525 |
| Ammonia | | .097 | .126 | .223 | .1199 |
| Methionine | | .248 | .11 | .358 | .188 |
| Hydroxyglutamic acid | .81 | .089 | .79 | 1.689 | |

constituent of a food was multiplied by the ratio of that protein to the total protein, and these values were added to give the total of each amino acid in 100 grams of the total protein (Table VIII). Then these values were multiplied by the percentage of protein in 100 grams of the entire food substance, to give the total amino acid content of 100 grams of the substance (Table IX).

In looking through these three tables, certain very definite shortcomings will be observed. All but one of the analyses fall short of a 100% complete analysis, many being extremely incomplete. Many values which are missing due to a lack of data are probably quite important. For example, the more recently announced amino acid, threonine, is not given for any of the proteins listed.

In spite of this, these tables are apparently of some value, if only in comparing the relative values of one protein to another. In tests on rats performed by Mitchell and Smuts (1932) it was shown that soybean protein is deficient in cystine, wheat is deficient in lysine, and corn is deficient in lysine and tryptophane. These results are borne out by the calculations when these cereal amino-acid values are compared with the values for egg.

The nutritional value of milk protein is recognized as being inferior only to that of egg, perhaps its chief weakness being its low value of cystine. Skimmilk powder is whole milk from which the fat (and hence most of the fat-soluble vitamins) have been removed, and whose protein is practically unaltered by the dehydration (spray or roller process).

Cereals as a whole are inferior to animals as a source of protein. Wheat,corn, and oats are perhaps the most widely used ceraels in this country. Evidence as to the relative values of these cereals as sources of protein varies from one worker to another; Boas Fixen (1935) claims that whole wheat and whole corn are approximately the same in nutritive value, and Mattill's results (1935) indicate approximate equality of wheat and oats, while Mitchell's results (1935) indicate slight superiority of oats over corn.

MIXTURE NUMBER ONE

A protein mixture was formulated provisionally and examined for its suitability. This mixture is tabulated in Table X, and consists of 50% soy, 25% wheat, and 25% powdered skim milk. For the moment it is not necessary to consider the physical form in which these components will be combined, except to observe that they must be in a form which is edible.

Table X was composed by multiplying the percentage of each amino acid by the proper ratio composition of the factor, and then adding across the wheat, soybean, and skimmilk columns. Comparing the fourth column, which represents the theoretical amino acid composition of this provisional protein, with the fifth column, which represents the amino acids present in 100 grams of egg, it can be seen that in most instances the composite protein is considerably richer than the egg protein, and that in only one case is it slightly weaker - the case of tyrosine. Not only does it seem to be an excellent protein, but it has eliminated the deficiency of lysine present in wheat protein and the deficiency of cystine present in soybean protein.

Certain foods are difficultly acceptable to the public because of unpleasant taste, religious and racial predjudices, and for many other reasons. In fact, this is one of the most important reasons that education is not completely efficient in improving the nutritional status of the Nation. Therefore, it would certainly be unwise to formulate a mixture which might be objectionable on any of these grounds. Of the three ingredients suggested, wheat is perhaps the least objectionable. Wheat is eaten by almost all races, and in fact is generally considered superior to all other cereals, usually being the one cereal which is permissible for such special occasions as holidays and religious ceremonials. Skim milk powder, on the other hand, is a much more recent and less familiar product. That a certain number of people do object to drinking liquid milk is evident from the high incidence of calcium deficiencies among persons whose incomes can well afford milk. The inclusion of skim milk powder in a supplementary food should be an unobjectionable method of including milk in the diet, since this powder is essentially as nutritious as whole milk, except that it is almost devoid of fat and the fat-soluble vitamins. It is an almost tasteless white powder with excellent keeping qualities, and it is low in cost.

The inclusion of a soybean product is perhaps the chief objection which would be raised to this suggested mixture, especially since it is to be used in so large quantities as 50% of the total product. Probably the four main objections to its use would be: (1) its indigestibility , (2) its high fat content, and hence its proneness to rancidify, (3) its flavor, and (4) its unfamiliarity to the public. A great deal of work has been done, both in this country and abroad, on the use of the soybean as human food, and the results of this work tend to invalidate these objections. The whole soybean has a tough cellulose hull which causes it to be almost completely indigestible to human beings, but when this hull is removed, the finer the bean is ground, the more digestible it becomes. Furthermore, the digestibility and the biological value increases with the amount of cooking. With proper heating and milling, the digestibility of edible soybean meal has been shown to be over 85%(Adolph and Wang, 1934). The digestibility of processed edible soya flour is still higher.

Hayward, Steenbock, and Bohstedt (1936) found that in meals prepared by the solvent extraction method, in which the extracted beans were heated at 98 degrees Centigrade for 15 minutes, the protein had a high biological value in tests on rats. When ground whole soybeans were autoclaved with steam at seventeen pounds pressure for 1½ hours, the protein had a high nutritional value. Raw soybeans and commercial meal prepared at low temperatures had low nutritional values. The heating process was found to raise the digestibility of the protein only three percent, but the Biological Value was raised twelve percent.

Much has been done to remove the objection to soybean on the ground that its high fat content causes rancidity.

Edible whole soybean flour can be subjected to a steaming treatment which accomplishes two purposes without destroying the protein: it eliminates the objectionable flavoring substances (chiefly methyl-n-nonyl ketone), and inactivates the enzymes which cause rancidity (lipases, oxidases, and peroxidases). Another type of soybean flour is the solvent-extracted flour, from which most of the oil is removed by chemical treatment. It has a very concentrated protein (over 45%) and is highly digestible.

The fourth objection which might be raised to the use of soybean is perhaps difficult to overcome, but since the product has no objectionable taste or appearance, and since the other components are familiar, this objection is probably not at all serious. Since soybean is not toxic, there are no grounds for not using large amounts of it.

What is the evidence that the mixture of soybean, wheat, and skim milk powder which has been proposed will actually supply as complete a protein as the amino acid calculations indicate? Hayward, Steenbock, and Bohstedt (1936) found that casein added to a ration of ground raw soybeans resulted in normal growth of rats, as shown by the nitrogen-balance method, while neither was able to do so separately. Similarly, Peragallo (1936) showed that a mixture of soy and wheat flour had 93.55% of the protein digested. Mitchell and Carman (1936) showed that a mixture of wheat flour and skim milk powder (protein ratio 2:1) gave a biological value of 71 by the Mitchell nitrogen-balance method, while the value to be expected if there were no supplementary value is 62. These and similar experiments show a high degree of supplementary action between these three protein sources.

This suggested mixture is valuable as a source of minerals, as well as a protein source. Liquid milk is perhaps the best commonly-used source of food calcium, and dry skim milk is even richer in this element, and it is well utilized.* Augmented by the calcium present in soybean and in wheat, this mixture should supply the required .44 grams of calcium in a twenty-gram portion. Soybeans, according to Forbes and Keith, have .649 grams of phosphorus per 100 grams, and skim milk powder has .979 grams per 100 grams of powder, so that the requirement of .32 grams should be supplied. Iron is found in skim milk powder in only small amounts, but wheat is rich in available iron, and whole soybeans contain 6.5 mg. of available iron per 100 grams. So that this combination is not only excellent from a protein point of view, but also will furnish most of the mineral requirement.

The vitamins, on the other hand, occur in these foods in comparatively small amounts, and vitamin concentrates must be used to supply the difference. That vitamin C deficiency is frequently serious is shown by the fact that sporadic cases of scurvy are constantly occuring, but this vitamin is very

*Ellis and Mitchell (1933) found milk calcium 92% utilized.

readily and easily destroyed by heat, oxidation, and other conditions of storage, and since no practical method of stabilizing it in a food such as the present study is considering, has been devised, it must be supplied by other materials in the diet. In preparing Table XI, the lower limits reported by McCollum, etc. (1939) were used to obtain some indication of the amounts of vitamins A, $B_1$, D, and riboflavin one would expect to find in the proposed mixture.

Table XI - Vitamin Content of Proposed Mixture.

| | Vitamin A | Vitamin $B_1$ | Riboflavin | Vitamin D |
|---|---|---|---|---|
| Soybean, 50 gms. | 150 I.U. | 125 I.U. | .1 mg | - |
| Wheat, 25 gms. | 5 | 40 | .015 | - |
| Milk solids, 25 g. | 6 | 20 | .2 | - |
| total in 100 gms. | 160 | 185 | .315 | - |
| total in 20 gms. | 40 | 46 | .063 | - |
| yet to be supplied | 3960 I.U. | 265 I.U. | .5 mg (170 S.U.) | 475 I.U. |

From this table it can be seen that the proposed mixture supplies but a fraction of the necessary vitamins, the remainder of which will be supplied by vitamin concentrates.

Some materilas are especially rich in vitamins in their natural state, or with little modification, while other products are especially processed to consist either entirely or almost entirely of one or more pure vitamins. Leaves and stems of many plants are extremely rich sources of certain vitamins. For example, Boas Fixen and Roscoe (1937), list alfalfa leaf meal as containing 17,000 International Units of vitamin A per 100 grams. Unfortunately, however, this meal is relatively indigestible to the human being, and hence, little of the vitamin is nutritionally available. Recently, concentrates prepared from certain vitamin-rich cereal grasses (Kohler, Graham, and Schnabel, 1940) have been made more available by a new process. These are possibly rich potential sources of vitamins, but at present the cost of this material is too high to be practical. Fish oils are about the only rich source (natural) of vitamin D, but such products cannot be used because of unpleasant taste and odor, and proneness to rancidify.

For the purpose of the present preparation, the vitamin products which are most suitable are those which have been prepared in such a way as to give a maximum percent of vitamin and a minimum of materials which lower the availability or have poor keeping qualities.

Brewer's yeast is washed, pasteurized,and dried, and represents a concentrated source of the B complex. One of the products reviewed (strain K, Anheuser-Busch) contained 45 International Units of vitamin $B_1$ and 20 Sherman Units of vitamin $B_2$ per gram. In order to obtain the required amount of vitamin $B_2$ (170 S.U.), eight and one-half grams must be used. This will also give 382.5 units of vitamin $B_1$. On the basis of twenty-four cents per pound, eight and one-half grams will cost \$.0045 .

However, by the use of "vitamin concentrates", which are almost pure vitamins, the proper amounts of these two vitamins can be secured at lower cost, and without the addition of so much extra bulk. While prices are extremely variable, those quoted here are the lowest current (1940) prices, and are probably higher than future prices, due to the fact that the current European war has made present prices higher than they would normally be, and that prices have been declining steadily with improved production methods and increased demand. Crystalline vitamin $B_1$ (Merk) can be secured for \$4,50 per million units, and vitamin $B_2$ can be had for \$3.50 for 400,000 units (International Vitamin Corp.). In terms of the requirements for the food mixture, a daily portion of $B_1$ would cost \$.0012 and of $B_2$, \$.0015 , or almost half the price of the same amount of vitamins supplied by the dry yeast.

Similarly, vitamin A may be secured at thirteen cents per million units and vitamin D at fifty cents per million units (Distillation Products, Inc.). In terms of the requirement for a daily portion of food mixture, this will amount to \$.00052 for 3960 units of vitamin A, and \$.00024 for 475 units of vitamin D. The total cost for the daily requirement of vitamins in this food mixture will therefore be \$.00345 .

The costs of the wheat, soybean, and skim milk also vary considerably with season, market conditions, etc. The form of the wheat and soybean must allow for the greatest digestibility, but need not be an extremely refined flour. The approximate costs for the daily requirement of these components are:

| | | |
|---|---|---|
| 25 gms. skim milk powder (Hood) | @ 7¢ per pound.. | $.00385 |
| 25 gms. whole wheat meal | @ 4¢ per pound.. | .0022 |
| 50 gms. soybean meal (solvent) | @ 2¢ per pound.. | .0022 |
| | cost for 100 grams....... | $.00825 |
| | cost for 20 grams....... | $.00165 |
| | cost of vitamins......... | $.00345 |
| | cost for 20 gms. of mixture.... | $.0051 |

From these calculations, it can be seen that by the addition to the diet of a twenty-gram serving daily of this food mixture, at a cost of about half a cent per day, the diets of 94% of the population in the United States can be brought to an optimal level in every factor except vitamin C.

While this suggested combination would seem quite satisfactory from both a nutritional and a cost standpoint, there are doubtlessly other combinations which are equally or more satisfactory, especially from a taste viewpoint.

MIXTURE NUMBER TWO

Oats would seem to be an excellent grain to use in a supplementary food mixture. It is very inexpensive, and most investigators have shown it to be very good from a nutritional standpoint. Murlin, Nasset, and Marsh (1939) showed that a precooked rolled oats product had a biological value of ninety-eight, practically a perfect protein. Mitchell and Smuts (1932) by the paired feeding method with rats showed that the protein of oats is deficient in lysine. This same report gave the protein content of oats as about 17%. These same workers in another report (1932, a) showed a gain in body weight of 2,52 grams per gram of protein ingested, a very satisfactory gain.

Unfortunately, there is probably less definite knowledge concerning the amino acid composition of oat protein than that of any other cereal grain. Table XII shows the amino acid composition of the oat protein avenin. The individual figures have come from several different sources, from different samples, and with different methods of preparing the protein, all of these facts lowering the reliability of the figures. Luers and Siegert (1924) claim that oats contain five different proteins; an albumin, a globulin soluble in cold saline, a globulin soluble in saline at 65° C, a prolamin, and a glutelin. The glutelin, avenin, is the only one of these proteins the analysis of which has been reported at all completely, but this one protein represents 85-90% of the total protein.

Table XII - Amino Acid Composition of the Oat Protein Avenin

1. From Abderhalden and Hamalainen (1907):

| | |
|---|---|
| Glycine | 1.0% |
| Alanine | 2.5 |
| Valine | 1.8 |
| Leucine & Isoleucine | 15.0 |
| Phenylalanine | 3.2 |
| Proline | 5.4 |
| Aspartic acid | 4.0 |
| Glutamic a cid | 18.4 |

2. From Csonka (1932):

| | |
|---|---|
| Tyrosine | 4.43 |
| Tryptophane | 1.85 |

3. From Csonka (1927):

| | |
|---|---|
| Cystine | 2.99 |
| Ammonia | 16.37 |

4. From Larmour (1927):

| | |
|---|---|
| Arginine | 15.48 |
| Lysine | 4.56 |
| Histidine | 3.23 |
| TOTAL | 111.22% |

Using these amino acid values, Table VIII shows the composition of the pure protein, on a basis of avenin alone, and Table IX shows the amounts of each amino acid in 100 grams of oats. Comparison of the oat analyses on both tables VIII and IX with the corresponding analyses of egg would indicate that oat protein is superior to egg protein. This indication is supported by the work mentioned above which gave the precooked rolled oats a biological value of 98. Mattil (1930) also using precooked oats found a biological value of only 82. Furthermore, the analyses for oats given in tables XII, VIII, and IX do not indicate a deficiency of lysine, as was demonstrated to be the case by Mitchell and Smuts (1932). These being the reports, the obvious conclusion must be that the amino acid analysis used is somewhat unreliable.

However, since none of these findings deny the excellence of oats as a source of protein, and because of the low cost of this cereal, it seems necessary that it receive consideration as a component of a supplementary food mixture.

While it would be going considerably beyond the accuracy of the figures which have been presented to prepare a table similar to Table X using oats as part of the mixture, we may regard the following results of Mitchell and Smuts (1932) as being a good basis for formulating a mixture: Using the Mitchell paired feeding method, and measuring the gain in body weight per gram of protein ingested, with a constant level of protein in the test diet, a gain of 1.58 grams was noted with corn alone, while corn plus .15% lysine showed a gain of 1.82 grams. Corn plus .13% tryptophane showed a gain of 1.44 grams, while corn with .15% lysine and .13% tryptophane gave an increase in weight of 2.07 grams. Wheat alone gave a gain of 1.64 grams, while wheat plus lysine gave a value of 2.05 grams, indicating that wheat is deficient in lysine. Similar studies showed that cystine improved the value of soybean and that lysine would supplement oats.

A suggested mixture using oats would be:

| Substance | Deficient in: |
|---|---|
| 35% oats (rolled) | lysine |
| 10% corn (meal) | lysine and tryptophane |
| 20% wheat (meal) | lysine |
| 20% soybean (meal) | cystine |
| 15% dry skim milk | |

Dr. Oscar Skovholt (1935) found that the addition of 6% dry skim milk to wheat flour will cause an increase of 40% in the cystine, 39.8% in the histidine, 107.1% in the lysine, and 5.1% in the tryptophane. Tables VIII and IX show that soybean is rich in lysine, and should supplement at least part of the shortages of the oats, corn and wheat. Maynard, Fronda, and Chen (1923) found that cornmeal fed alone caused a weight increase of 1.18 grams per gram of protein ingested, while cornmeal and soybeanmeal (protein ratio 2:1) gave a weight increase of 1.76 grams, indicating considerable supplementary relationship.

The price of such a mixture would be roughly as follows:

| | | | | |
|---|---|---|---|---|
| 35 grams | oats | @ 3¢ per pound... | | $.00231 |
| 10 " | corn | @ 2½¢ " " ... | | .00055 |
| 20 " | wheat | @ 4¢ " " ... | | .00176 |
| 20 " | soymeal | @ 2¢ " " ... | | .00088 |
| 15 " | skimmilk | @ 7¢ " " ... | | .00231 |
| | | Total cost of protein | | $.00781 |
| | | Cost for a 20-gm portion | | $.00156 |

The vitamin content of this mixture is approximately as given in the following table, using the lowest values in McCollum's (1939) table.

Table XIII - Vitamins in Mixture Number Two

| | Vitamin A | Vitamin $B_1$ | Vitamin $B_2$ | Vitamin D |
|---|---|---|---|---|
| 35 gms oats | - | 35 I.U. | .007 mg | - |
| 10 " corn | 50 I.U. | 6.5 | .001 | - |
| 20 " wheat | 4 | 32 | .012 | - |
| 20 " soy | 60 | 50 | .08 | - |
| 15 " skimmilk | 4 | 12 | .12 | - |
| Total in 100 gm. | 118 | 135.5 | .213 | - |
| " " 20 gm. | 23 | 27 | .042 | - |
| Deficient | 3977 I.U. | 273 I.U. | 170 S.U. | 475 I.U. |

The amount of vitamins present in this mixture is low, as in mixture nimber one, and approximately the same amounts of vitamin concentrates will hatve to be added.

The prices of the vitamins are as follows:

| | | |
|---|---|---|
| 3977 | units Vitamin A @ 13¢ per million... | $.00052 |
| 273 | " " $B_1$@ $4.50 " " ... | .00122 |
| 170 | " " $B_2$@ $3.50 " 400,000... | .0015 |
| 475 | " " D @ 50¢ per million... | .00024 |
| | Cost of vitamins per daily serving.. | $.00348 |
| | Cost of protein " " " .. | .00156 |
| | Total daily cost of mixture.. | $.00504 |

Apparently the two mixtures cost approximately the same: about half a cent per day, or about $1.80 per year.

Comparing the two mixtures, it can be seen that both are extremely inexpensive mixtures of ordinary cereals which have been compounded with the purpose of filling up definite gaps in the American dietary. The first mixture has only three components, with a high percentage of protein, a point which may be a disadvantage, although it has been shown that there is no obvious basis for objection to this use of soybean. The second mixture combines three different cereals, soybean, and skim milk powder. The important basic cereal is oats. From all available data and experience, oats appears to be an excellent source of protein, but exact information is very incomplete, tending to put the selection of the second combination on a much less firm footing than the first combination.

SUMMARY AND CONCLUSIONS

The problem of endemic nutritional disorders, and more important, of the unbelievably widespread existence of sub-clinical dietary deficiencies is of vital importance to the Public Health worker. Much has been attempted to remedy this problem, chiefly along an educational line, but while it is comparatively easy to teach the public the facts of proper nutrition, it is amazingly difficult to overcome their apathy and incompetence, and the inertia of fixed customs. Perhaps even more important, it is useless to educate people to use certain foods if they cannot afford to purchase them. To many people this has been a stumbling block, and prominent workers in nutrition have despaired of improving the dietaries of the lower income groups until their economic level can be raised.

However, to sit and wait for an improvement in the standard of living is certainly not a rational procedure. During the past several years great strides have been made in the field of nutritional research, and since work such as this is of no real value until it has been applied to the improvement of the dietary of the nation, the possibility presented itself of applying the available knowledge of nutrition to the improvement of the American dietary to an optimal level.

Since people prefer to take their nourishment in the form of food, rather than as medicine, it was decided to formulate a food mixture which would add to the poorest type of diet enough nutrients to raise that diet to an optimal nutritional level. This poorest diet was so chosen that it was worse than about 94% of all American diets. This would mean that 94% of American diets would be brought to an optimal nutritional level or above, while the other 6% would be definitely improved.

Using available data, the nutrients in the average poorest diet chosen were compared with the corresponding values in an optimal diet, and a formula for the dietary supplementing mixture was arrived at.

Again using available data, two theoretically complete proteins were formulated, using supplementary action of the amino acids as a basis. Vitamin concentrates were added to give the necessary amounts of vitamins.

Finally, formulae for two food mixtures were arrived at. According to the calculations given, either of these mixtures is able, at a cost of about half a cent per day per person, to bring almost any diet to an optimal nutritional level in all known factors but vitamin C. While no actual tests have been performed on the two mixtures which have been suggested, their validity seems assured by the constant reference to reliable literature which has been resorted to.

Can people in the lowest income gropps afford to pay half a cent per day for a supplementary food mixture? Table IV shows that for less than two dollars per year, the person on the average poorest diet will get one quarter the amount of a complete protein, four fifths as much calcium, one third as much phosphorus, more than half as much iron, twice as much vitamin A, more vitamin $B_1$, almost half as much vitamin $B_2$, and nineteen times as much vitamin D as he gets in his normal diet, which costs him about twenty cents per day, or about sixty-five dollars per year.

In conclusion, two food mixtures have been formulated which, according to available data, will, for a very small cost, bring 94% of American diets up to an optimal level and definitely improve the remaining 6%. It is the fact that diets can be so improved by an inexpensive food-mixture, rather than the specific mixtures which have been suggested here, which is of importance.

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