THE NUTRITIVE VALUE OF WHOLE WHEAT, ENRICHED AND NON-ENRICHED FLOUR IN ADEQUATE AND INADEQUATE DIETS

by

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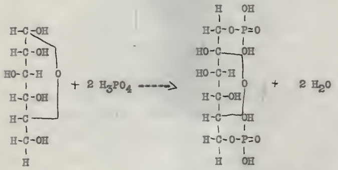
INTRODUCTION

Breads and cereals have always occupied an important place in the diet of man. Until 1880 when a method of refining flour was perfected, bread was made from whole grain cereals. In the milling of flour the germ and bran portions of the wheat grain are almost completely removed. The vitamins and minerals which occur almost wholly in the bran and in the germ portions of the wheat berry, are lost in the milling process. Patent flour, 70 per cent extraction of the wheat berry, contains 75.9 per cent carbohydrate and 10.8 per cent protein. For best health 50 to 60 per cent of the total energy supply of the body should come from carbohydrates. Flour and bread are good sources of carbohydrates but in order for the carbohydrates to be utilized by the body, B-complex vitamins must be present. These vitamins are necessary for the formation of the enzymes which aid in carbohydrate oxidation.

Food, to be utilized in the body, must first be digested. During the process of digestion, carbohydrates are hydrolyzed by the digestive enzymes to hexoses, namely; glucose, fructose, and galactose. The sugars are water soluble and are absorbed directly into the blood stream from the digestive tract. The blood carries these through the portal vein to the liver and the liver cells convert the hexoses to glucose. The only sugar found in the blood is glucose which is carried by the blood to all body cells where the carbohydrates are oxidized for energy.

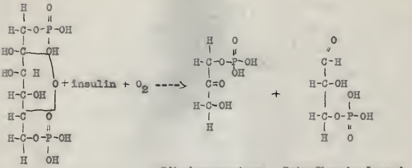
The first step in the oxidation of glucose is the combining of two molecules of phosphoric acid with a molecule of glucose. This is illustrated by the following equation.



Glucose　　　　　　　　　　　　Fructose diphosphate

As shown by the equation a hexose diphosphate results in which the sugar appears to be fructose rather than glucose.

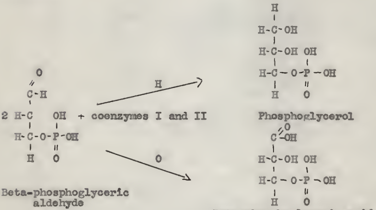
The second step in carbohydrate oxidation, as illustrated below, requires the action of the hormone insulin which is secreted by the pancreatic cells and is carried by the blood to all the cells in the body where oxidative reactions are taking place.



Fructose diphosphate — Dihydroxyacetone phosphate — Beta-Phosphoglyceric aldehyde

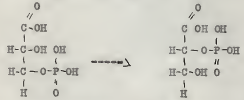
The hormone insulin aids in the breakdown of fructose diphosphate to triose monophosphates called respectively dihydroxyacetone phosphate and beta-phosphoglyceric aldehyde.

Coenzymes I and II are essential for the oxidation-reduction reaction in which two molecules of beta-phosphoglyceric aldehyde forms one molecule of beta-phosphoglyceric acid and one molecule of phosphoglycerol as shown in the following equation.



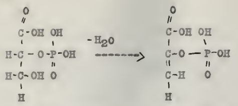
Beta-phosphoglyceric aldehyde — Phosphoglycerol — Beta-phosphoglyceric acid

Coenzyme I contains one molecule of nicotinic acid amide, one molecule adenine, two molecules of a pentose (ribose), and two molecules of phosphoric acid. Coenzyme II differs from coenzyme I only in having a third phosphoric acid radical in the molecule. Coenzymes I and II, both of which contain niacin, are important in the reversible oxidation-reduction activity, or they have the ability to give up or take up oxygen or hydrogen. They also aid in transporting oxygen across the cell wall. Niacin is also necessary in the diet because it aids in promoting the metabolism of heavy metals such as iron and copper. It aids in the transferring of oxygen from the blood to the cells. A rearrangement occurs in which the phosphoric acid of the beta-phosphoglyceric acid shifts from the beta to the alpha form.



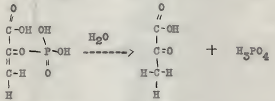
Beta-phosphoglyceric acid — Alpha-phosphoglyceric acid

The alpha-phosphoglyceric acid loses a molecule of water, forming the phosphate of pyruvic acid.



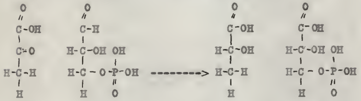
Alpha-phosphoglyceric acid — Phosphopyruvic acid

Phosphopyruvic acid is then hydrolyzed to form pyruvic acid and phosphoric acid is released.



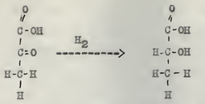
Phosphopyruvic acid — Pyruvic acid

Pyruvic acid reacts with phosphoglyceric aldehyde to form lactic acid and beta-phosphoglyceric acid.



Pyruvic acid — Phosphoglyceric aldehyde — Lactic acid — Beta-phosphoglyceric acid

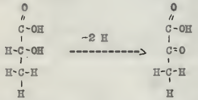
In the muscles pyruvic acid is reduced and lactic acid is formed.



Pyruvic acid Lactic acid

In this reaction an enzyme containing riboflavin acts as the hydrogen carrier. Most of the lactic acid is changed into muscle glycogen, but that which goes into the blood is carried to the liver, where the lactic acid is converted into liver glycogen. Some is excreted in the urine. About 20 per cent of the lactic acid is oxidized to carbon dioxide, and water. As a result of this reaction energy is released.

The steps in the oxidation of lactic acid are illustrated below. Two hydrogen atoms are removed from lactic acid to form pyruvic acid.



Lactic acid Pyruvic acid

For the oxidation of pyruvic acid the enzyme cocarboxylase must be present. It is now known that cocarboxylase is formed by the union of one molecule of thiamine and two molecules of phosphoric acid. This compound is called thiamine-diphosphate. The oxidation of pyruvic acid is shown in the following equation.

Pyruvic acid Acetaldehyde

Pyruvic acid is a natural product of carbohydrate metabolism, but when there is a thiamine deficiency in the diet this enzyme is not produced and pyruvic acid accumulates in the blood and around the nerve tissues. When this acid occurs in large amount it injures the nervous system. Since the nerves control the motility of the stomach, the beating of the heart, and the contraction of the muscles, a lack of thiamine leads to poor appetite and constipation. This causes fatigue, nervous irritability, poor appetite, and lack of energy.

From the preceeding discussion it is evident that the B-complex vitamins play an important role in the utilization of carbohydrates. Therefore, it was deemed advisable to study the nutritive value of whole wheat, enriched, and non-enriched flour in adequate and inadequate diets as sources of the B-complex vitamins.

REVIEW OF LITERATURE

Since milled cereals make up such a large percentage of the total caloric intake of the people, scientists have become more aware of the need for enriching these products with the vitamins and minerals removed in the milling process. In a report of the Council on Foods and Nutrition (1941) it was stated that wheat in its various forms contributes 25 per cent or more of the average caloric intake of the people in the United States. Patent flour represents from 60 to 70 per cent of the wheat berry and contains only 10 per cent or less of the original thiamine. The average American diet of today provides about the same number of calories in the form of sugar and white flour as were provided in the form of less refined flour in the average diet of the past. The less refined flour was a good source of thiamine and contained important amounts of other vitamins as well as minerals. Despite the greater consumption of fresh fruits and vegetables and other so-called protective foods, it has not been possible to make up the loss of thiamine which results from the substitution of sugar and white flour for the old time stone-ground flour.

Although whole grain cereals are nutritionally preferred foods, the National Nutrition Council for Defense (1941) recognized that the present day peoples' preference for white flour cannot be altogether ignored. This preference is based in part on the relatively better keeping qualities of white flour as compared with whole wheat flour and in part to the fact that the baking qualities of the best grades of white flour have been developed by manufacturers of these products. Because these products provide dietary essentials for a large portion of the population, the Council believed that it was in the interest of public health and welfare to encourage the wider distribution of enriched products along with the greater use of whole wheat products.

Taylor (1941), in discussing the enrichment of cereals which had lost some of their nutrients by processing, gave six suggestions for increasing the nutritive value of flour. 1. The revival of the old-fashioned graham flour, despite its instability, dark color, bitter taste, and inadaptability to many commercial and household uses. 2. The development of a new-fashioned graham flour, lighter in color with less bitterness and roughage, and with better keeping qualities. 3. The development of a high-extration flour. 4. The addition of synthetic vitamins to patent flour. 5. Restoration by supplementation with natural vitamins, which may be accomplished by the addition of dry milk solids to bread, or by the use of high vitamin yeast. 6. The retention of vitamins in other foods by more careful handling and cooking, or by the inclusion of more of the protective foods in the diet.

There are those, of course, who do not believe in the enrichment of cereals. Luck (1941) looked at both sides of the question and gave several arguments in favor of and against fortification. His arguments in favor of fortification were essentially these: 1. Any given food stuff, such as milk, varies greatly from season to season in vitamin content. 2. The incidence of malnutrition, especially of subclinical vitamin deficiency, is high, usually those people in the low income groups are the greatest suffers but in many cases even the well-to-do are afflicted because of bad dietary habits. 3. The use of highly processed refined foodstuffs, like white flour, sucrose, and margarine deprive us of valuable food factors present in crude or raw products. His arguments advanced against the fortification of foodstuffs were: 1. Fortification with pure vitamins is necessarily expensive. 2. The removal of vitamins during the processing of foods and their subsequent restoration to the same or even to other foodstuffs is a practice repugnant to one's feeling for the fitness of things; it does not make good sense. 3. Also, enrichment with pure vitamins fails to give recognition to the fact that there are almost certainly additional accessory food factors as yet undiscovered.

Staple foods, such as cereals, of low thiamine content may nevertheless contribute a major fraction of the total supply of thiamine to the diet according to Lane, Johnson, and Williams (1942). These authors also indicate that cereals supply about one-fourth the total supply of thiamine to the diet. If white bread were replaced by whole wheat bread or enriched white bread containing the recommended minimum of 1.1 mg thiamine per pound, then the thiamine in the cereals in a 2,500 calorie diet, would be increased from 0.78 to about 1.28 mg and the cereal contribution of thiamine would be over 50 per cent of the total. Cheldelin and Williams (1943) made a study of the American diet in relation to its riboflavin, nicotinic acid, and pantothenic acid content. They found that if white bread in the diet were enriched to 0.7 mg per pound, of riboflavin, the total supply of riboflavin in the diet would be 1.61 mg per 2,500 calories. Since pantothenic acid is quite evenly distributed among the various classes of foods comprising the average American diet, and since the loss of pantothenic acid in flour does not appear to be due in large measure to milling losses, restoration by enrichment of bread with pantothenic acid would therefore result in only a slight increase in the daily supply.

Winters and Leslie (1943), in a study of 308 separate diets collected from 24 women of low-income groups, found, when compared to the allowances for the sedentary women recommended by the Committee on Food and Nutrition of the National Research Council, that the caloric intake was from one-half to three-fourths the allowance, the average intake of thiamine, niacin, and riboflavin slightly more than one-third, and protein, calcium, and phosphorus approximately one-half the amounts recommended as adequate. The pantothentic acid intake was about one-fourth the amount suggested as adequate. Seasonal variations and differences were found to be slight.

Free (1940) found that when white bread baked with high vitamin B_1 yeast was ingested by 17 young college women in place of bread ordinarily included in the diet over a five week period an improved state of thiamine nutrition was indicated. This improvement was shown by the fact that the urinary thiamine excretion before the period of eating the special bread averaged 106 ug per 24 hours, whereas at the end of the five week period the excretion of thiamine averaged

206 ug per 24 hours. It is indicated by Frey, Schultz, and Atkins (1940) that the use of high-vitamin yeast will produce a white loaf of bread having approximately the thiamine content of a whole wheat loaf. No change in flavor or palatability of the bread is produced in its use. Schultz, Atkins, and Frey (1939) also suggested that when a high vitamin yeast has been employed a white bread may contain as much thiamine as whole wheat bread.

Fairbanks (1938) found that the addition of milk solids to a water bread formula increased the nutritive value of the bread when fed to rats. Fairbanks (1939) indicated that there was evidence that the nutritive value of bread containing 12 per cent milk solids is of a higher order than bread containing six per cent milk solids. Rats receiving breads containing milk solids showed significantly better growth than those on bread made without milk solids. Mitchell, Hamilton, and Schields (1943) stated that the incorporation of non-fat milk solids in white bread at six per cent of the flour improved the growth promoting and bone-forming values of bread much more than enrichment with thiamine, nicotinic acid, and iron. Light and Frey (1943) found that for the growth of young rats, white bread made with six per cent dry skim milk, permitted good growth and apparent good health. They concluded that it was equal to whole wheat for promotion of growth.

Murlin, Marshall, and Kochakian (1941) stated that whole wheat bread gave lower true digestibility values for protein than white bread but that it produced higher biological values than did white bread. They also suggested that making bread with high vitamin yeast is of some importance from the standpoint of biological value of protein; also that eating extra B-complex vitamins improved biological values. Sealock, Basinski, and Murlin (1941) stated that the higher "indigestable residue" that the whole wheat produced does not interfere with the digestion and absorption of the carbohydrate and fat. Macrae, Hutchinson, Irwin, Bacon, and McDougall (1942) found better digestibility of white bread and stated that the fineness of grinding of whole meal made no significant difference in the digestibility. The larger loss from wheat meal is accounted for by the undigested woody fibre in the bran.

Chick (1940) found that the nutritive value of straight run white flour, 73 per cent extration, was inferior for the growth of young rats to that of whole meal flour, even when the defects of the former in protein, minerals, and vitamin B_1 had been corrected. It was concluded that the inferiority must be attributed to the lack of the B_2 vitamins. Sealock and Livermore (1943) found the values of fresh bread made of peeled wheat to be for thiamine, riboflavin, niacin, pantothenic acid, and inositol 3.0, 2.5, 35, 5.2, and 644 ug per pound, respectively. The advantages of using high vitamin yeast in baking the bread were evident in values of thiamine 4.6 ug and niacin 44 ug as in contrast to bread made with regular yeast.

Williams, Mason, and Wilder (1943) stated that restorative enrichment of white flour with thiamine to whole wheat levels helps greatly whereas comparable enrichment with riboflavin to whole wheat levels will not correct the deficiency of the average diet in riboflavin. Higgins, Williams, Mason, and Gatz (1943) found that patent white flour supplemented with thiamine, riboflavin, and niacin while improving the growth rate of the rats were not adequate to secure weights attained by the animals eating the diet that contained whole wheat flour. Higgins, Williams, and Mason (1943) stated that the addition of thiamine to the flour to the extent which doubled the thiamine for each gram of food consumed did not induce any significant change in the growth curve of the rats. The addition of thiamine and riboflavin to the flour of the basal diet did increase the growth significantly. Such additions of thiamine and riboflavin to the basal diet induced weight increases which were statistically equal to those attained by rats eating the diet in which the bread was made of whole wheat flour.

Guerrant and Fardig (1947) found that flour enriched in accordance with the present formula is definitely superior to non-enriched flour with respect to thiamine and riboflavin and is somewhat superior to whole wheat with respect to these vitamins. While the amount of thiamine contributed by ground whole wheat and by enriched flour, when the flours composed 30 per cent of the diet, was only slightly less than that required for optimal growth in young rats, the amount of riboflavin contributed is definitely insufficient. However, the enriched flour was found to contain more riboflavin than the original wheat. Westerman and Bayfield (1945) found that whole wheat was a better source of the B-complex vitamins than either Morris type flour or patent flour enriched at the old levels which contained thiamine, niacin, and iron, when these materials made up 30 to 50 per cent of the diet. At a 30 per cent level the whole wheat was slightly better than patent flour, which had been enriched at the new levels to contain thiamine, riboflavin, niacin, and iron. Whole wheat and enriched flour promoted the same amount of growth when fed at a 40 per cent level, while at a 50 per cent level the new enriched flour was better as a source of the B-complex vitamins than whole wheat.

There are some indications that other members of the B-complex vitamins should be added to flour. Teply, Strong, and Elvehjem (1942) found that patent flour contained only one-sixth the amount of niacin and one-half the amount of pantothenic acid and pyridoxine as whole wheat. Westerman and Hall (1947) found that the addition of 1 ug of riboflavin and 1 ug thiamine to enriched flour stimulated even greater growth of the rats than enriched flour only. The addition of 10.3 ug calcium pantothenate and 3.5 ug pyridoxine per gram of enriched flour was beneficial, but a still greater growth resulted when 20.5 ug calcium pantothenate and 7 ug pyridoxine per gram were added to the enriched flour.

Very little work has been found in the literature in which natural foods have been used in the diet as sources of the B-complex vitamins. In the experiments reported here an attempt has been made to study the effect of the use of whole wheat, enriched, and non-enriched flour in diets which might be consumed by human beings. Diets of people with low incomes were of particular interest. Cereals are the cheapest source of energy and are consumed in large quantities by those people with low incomes.

EXPERIMENTAL PROCEDURE

A search of the literature provided only a small amount of information concerning the diets of low income groups. While Stiebling, Monroe, Coons, Phipard, and Clark (1941) have made studies of the diets of people in different sections of the United States, practically all their information showed that the diets were fairly adequate. Studies by Moser (1945) of the food consumed by the people of Pickins County, South Carolina showed a high consumption of cereals. These studies were used as a basis for the experiments reported here. The amount of food consumed was divided into two groups, the less adequate amount was reported as low values, while the more nearly adequate amount was reported as high values, as shown by the data summarized in Table 1. The less adequate values were chosen for this study because the larger per cent of cereals in the diet would show the relative effect of the growth promoting properties of the B-complex vitamins contained in whole wheat, enriched, and non-enriched flour. Moser gave the amount of food consumed in pounds and gallons for a year, for experimental use these amounts were changed to grams per day as shown in Table 1.

In order to facilitate the preparation of the food under laboratory conditions, it was necessary to make some modifications in the diet. Carrots and green vegetables were used to represent the two groups of vegetables; i.e., leafy, green, yellow vegetables and other vegetables. In making the diets green beans, spinach, cabbage, and broccoli were used alternately, therefore an average of the nutritive values of these vegetables was used to calculate the nutritive value of the green vegetable. In order to get a fair representation of meat used in an average diet, one-half beef and one-half pork were used in making the diet. It was desirable, because of the smaller volume, to use dry milk, the amount of liquid milk was calculated on a dry basis. Liquid milk contains 12.4 per cent solids. Since one cup of milk weighs 240 gm, 30 gm of dry milk would be equivalent to one cup of liquid milk. Navy beans were used for legumes while apples were used to represent tomatoes, citrus fruit, and other fruit. Whole wheat, enriched, and non-enriched flour, and cornstarch were used to represent all cereals and grain products consumed. The food for the diets was cooked, finely divided in the Waring blendor and mixed to a homogeneous mass so that the rats could not pick out various foods and eat those alone. The diets were prepared once a week and kept frozen until used.

Young albino rats weighing 45 to 60 gm were used for the tests. They were distributed in groups according to weight, sex, and litter mates. Each animal was housed in an individual wire cage with a raised wire screen to prevent consumption of the feces. The animals were given food and water ad libitum and were weighed once a week. The average weights are shown in the weight charts, Tables 13, 14, and 15, while the average growth curves are shown in Fig. 1 and 2.

Seven to 12 days before starting the experiment, the young rats were fed a vitamin B-complex free diet to partially deplete them of their stores of these vitamins. The vitamin B free diet contained the following ingredients by weight:

	Per cent
Vitamin free casein	20
Cornstarch	60
Fat	12
Salt mixture	5
Cod-liver oil	3

The vitamin free casein furnished a sufficient amount of complete protein for growth and the cornstarch, a pure carbohydrate, supplied food for energy. The fat supplied the "essential" fatty acids and additional energy food while the salt mixture supplied the minerals necessary for growth. Vitamins A and D were supplied in sufficient quantity by the cod-liver oil. Since the rat does not need vitamins C and K for growth, the only nutrients known to be essential for growth which were lacking were the B-complex vitamins.

A total of 53 rats was used in these experiments. Three different experiments were conducted using approximately 62, 40, and 33 per cent of the total calories as cereals in the diets of experiments I, II, and III, respectively. Tables 3 through 12 show the composition of the various diets used. Table 2, which gives the nutritive value of 100 gm portions of selected foods, was used to calculate the amount of the various nutrients in the different diets. Values for Table 2 were obtained from Chemistry of Food and Nutrition, Sherman (1946) and Handbook of Diet Therapy, Turner (1946). The data from these two sources were averaged in order to obtain composite values upon which to base the calculations of the nutritive value of the diets.

In experiment I, 24 rats were divided into four groups of six animals each. Diet 1 contained enough finely ground whole wheat to contribute 62 per cent of the total calories of the diet. Diet 2 contained the same amount of enriched flour while diet 3 included non-enriched flour at the same level. Diet 4 contained the same amount of cornstarch by weight but it provided 65 per cent of the total calories of the diet. A large per cent of cereals was used in this experiment because it would show more readily than a smaller amount whether or not enriched flour was superior to non-enriched flour for the growth of young rats. Cornstarch was used as the cereal in one diet because it is a purified carbohydrate and contains none of the B-complex vitamins which are necessary for carbohydrate metabolism. It was therefore possible to determine whether or not the foods in the diet, other than the cereals, furnished sufficient quantities of the B-complex vitamins for growth and reproduction.

Stiebling, Monroe, Coons, Phipard, and Clark (1941) showed that families living in the Southeast obtain 38 per cent of their calories from grain products and Cummings (1940) found that the working man received 39 per cent of his calories from bread and cereals. On this basis experiment II was set up. Forty per cent of the total calories were contributed by cereals. In this experiment 11 rats were divided into three groups of four, four, and three animals. Diet 1, diet 2, and diet 3 included enriched flour, non-enriched flour, and cornstarch, respectively. Vitamin free casein was added to the cornstarch diet to bring the protein content up to the same level as in the other diets of the experiment. This was done in order that the protein content of the diet would not be a limiting factor in the growth of the rats. The sugar was increased because sugar is a pure carbohydrate and requires the presence of the B-complex vitamins to be utilized by the body. Since the metabolism of fatty acids does not require B-complex vitamins, fat has a sparing action on these vitamins. With this in view the fat in the diets of the second experiment was decreased from 59 gm to 30 gm per day. The South Carolina study was based upon the food consumption of farm families. It is doubtful if the milk consumption of low income urban families would be as large as the rural families, therefore the amount of milk was decreased to the equivalent of one pint a day. The amount of potatoes was increased since potatoes are a cheap energy food and are used in large quantities by low income families. The amounts of fruits and vegetables were left very nearly the same. With these modifications the experiment was conducted in the same manner as experiment I.

In the previous experiments the amount of calories from cereals was relatively high, therefore it was decided to attempt a third experiment using cereals at the level consumed by the average American. Westerman and Bayfield (1945) stated that the average American derived 30 per cent of his calories from cereals and cereal products. Eighteen rats were divided into three groups of six animals each for the third experiment. Diet 1 contained sufficient quantity of enriched flour to furnish 33 per cent of the total calories of the diet. Diet 2 contained the same amount of non-enriched flour, while diet 3 included cornstarch at the same level. A few changes were made in the quantities of foods included in the diet. The amount of navy beans was decreased from 45 gm to 28 gm a day for it seemed doubtful that 45 gm of dry beans would be eaten by an individual every day. The amount of sugar was increased from 36 to 100 gm to raise the total calories to a more nearly normal amount, also sugar is a pure carbohydrate and requires the presence of the B-complex vitamins to be utilized by the body. The potatoes were increased to two average servings a day because they are a low cost energy food. Vitamin free casein was added to the cornstarch diet to bring the protein content to the level of the enriched flour and the non-enriched flour diets. This experiment, with these modifications, was conducted in the same manner as experiments I and II.

RESULTS AND DISCUSSION

First Experiment: Flour Furnished 62 Per Cent of the Total Calories

The average weight gains of the rats on experiment I are shown in Table 13 and by growth curves in Fig. 1. Those animals with cornstarch in the diet had made the least average weight gain at the end of nine weeks. They had gained 73 gm which was 65 gm less than the rats on non-enriched flour which had gained 138 gm. The rats on diet 2, containing enriched flour, made an average gain of 155 gm or 17 gm more than the rats on the non-enriched flour diet. The rats eating the diet with finely ground whole wheat made the largest average gain by the end of the nine week period, they gained 161 gm or 6 gm more than the rats on the enriched flour diet. These growth differences are shown in the photographs in Plate I. These show typical rats on the various diets.

The differences in the average growth curves of the rats on the various diets are in all probability due to the differences in the nutritive value of the diets. These differences can be attributed to the difference in the nutritive value of ground whole wheat, enriched flour, non-enriched flour, and cornstarch, since all other constituents of the diet are identical. It may be noted from Tables 3, 4, 5, and 6 that the protein content of the diets varied from 44.9 gm in the cornstarch diet to 126.7 gm in the whole wheat diet. The diet containing enriched and non-enriched flour had 117.8 gm of protein each. The recommended allowance for the average adult is 65 gm protein. The calcium varied from 0.933 gm in the cornstarch diet to 1.257 gm in the whole wheat diet, while the enriched and non-enriched flour diets each contained 1.108 gm. Since 0.8 gm is the recommended amount of calcium for an average adult, the calcium should not have been a limiting factor in the growth and reproduction of the rats.

The amount of iron contained in the diets varied from 10 mg in the cornstarch diet to 35.64 mg in the whole wheat diet. The diet with non-enriched flour had 14.73 mg while the diet containing enriched flour had 29.58 mg of iron. The recommended allowance of iron for an average adult is 12 mg. The diet with cornstarch is the only diet of which the iron content was low enough so that it might be a limiting factor in the diet.

The thiamine content of the diets varied from 1.11 mg in the cornstarch diet to 4.89 mg in the diet containing ground whole wheat. The enriched flour diet furnished 4.13 mg of thiamine while the non-enriched flour diet contributed 1.63 mg of thiamine. The cornstarch diet is the only diet in which the thiamine content is below the recommended dietary allowances of the Food and Nutrition Board, National Research Council, for a moderately active adult, which is 1.4 mg per day. The riboflavin content of the diets varied from 1.67 mg in the cornstarch diet to 3.46 mg in the enriched flour diet. The whole wheat diet contained 2.47 mg of riboflavin while the non-enriched flour diet contained 1.69 mg. The riboflavin in both the cornstarch and the non-enriched diets was slightly below the recommended allowance of 1.8 mg per day.

The amount of niacin in the diet varied from 5.2 mg in the cornstarch diet to 42.8 mg in the whole wheat diet. The diet including enriched flour contained 28.8 mg while the diet with non-enriched flour contained 5.7 mg of niacin. The recommended daily allowance for niacin is 14 mg for the average adult. It is doubtful that the amount of niacin in the diet was a limiting factor in the growth of the rats since rats do not seem to be sensitive to an inadequate supply of niacin in the diet.

Although the diet with the enriched flour included the recommended amount or more of all the nutrients, the rats on this diet did not grow as rapidly as the rats on the whole wheat diet which had a larger supply of these nutrients. The non-enriched flour diet was deficient in niacin but it had the recommended allowances of thiamine and riboflavin. There was considerable difference in some of the nutrients in the diets. The whole wheat furnished 126.7 gm protein while the enriched and non-enriched flour diets had 117.8 gm. The whole wheat diet had 35.46 mg iron as compared to 29.58 mg in the enriched flour diet. These differences may account for the slight increase in the average weight gain, 6 gm, made by the rats on the whole wheat diet over those on the enriched flour diet.

The differences in the average weight gains, 17 gm, made by the animals on the enriched flour diet over the gains made by the animals on the non-enriched flour diet may in part be attributed to differences in the vitamin and iron content of the diet. The enriched flour diet contained 2.5 times as much thiamine, 1.4 times as much riboflavin, and 2.0 times as much iron as the non-enriched flour diet. These findings agree with the results obtained by Westerman and Hall (1947) that enriched flour, when supplemented with additional thiamine and riboflavin, stimulated better growth than enriched flour alone. These findings were confirmed by the results obtained by Guerrant and Fardig (1947) who stated that the amount of thiamine, when enriched flour or ground whole wheat composed 30 per cent of the diet, is only slightly less than that required for optimal growth in young rats, while the amount of riboflavin contributed is definitely insufficient.

At the end of nine weeks the males and females on the same diets were placed together for breeding purposes. Only the animals on the ground whole wheat diet produced normal litters. Each female on this diet had an average of six normal young that grew to maturity. The rats on the enriched and non-enriched diets produced no live young. The rats on the cornstarch diet showed no weight increase which always proceeds reproduction.

To make certain that the lack of vitamin E was not the limiting factor in reproduction, vitamin E was added to the diets at the end of 14 weeks. Goettsch and Pappenheimer (1941) found that 2.5 mg vitamin E added to a vitamin E low diet fed to female rats made normal reproduction possible. Three mg of vitamin E a day was added to the diets. The animals on diets containing enriched and non-enriched flour produced no live litters. The rats on the cornstarch diet showed no signs of reproduction and at the end of 18 weeks they were discarded. It was concluded that vitamin E was not the limiting factor in reproduction but it was possibly the lack of some of the B-complex vitamins.

When the young on the ground whole wheat diet were 28 days old their average weight was 36 gm. One male and one female were selected from each litter and were fed the test diet to determine if the growth of the second generation of rats would equal that of the first generation. Growth curves were made as shown in Fig. 1. The second generation seemed normal in every way except that they were smaller in size than the first generation as shown in Table 13 and Fig. 1. At nine weeks their average weight gain was 104 gm or 57 gm less than the first generation that had gained 161 gm by the same age. Nine weeks after weaning, the second generation of rats on the ground whole wheat diet were placed together for breeding purposes. Normal litters were produced. The females averaged 10 normal young and only one died. This group of animals was kept only until the young were 28 days old. At 21 days of age the third generation had an average weight of 30 gm, while at 28 days they averaged 38 gm which compares favorably with the weight of the young of the second generation.

The reproduction of the second mating of the rats on the whole wheat diet was not as good as the first mating. Only one female raised three young. They averaged 32 gm at 21 days old and 44 gm at 28 days old. Poorer reproduction was in all probability due to the depletion of the mothers' bodies after raising a normal litter.

Westerman and Hall (1947) found that the addition of 10.3 ug per gram of flour of calcium pantothenate improved the reproduction record of the rats on a diet containing 40 per cent enriched flour. In view of this fact it was decided to add the same amount of calcium pantothenate to the enriched flour used in these diets to determine if the lack of calcium pantothenate could be the limiting factor in reproduction. The rats were placed together for breeding purposes. One female produced and raised two young. At 21 days of age their weights averaged 23 gm, while at 28 days of age they averaged 28 gm. This weight is 10 gm less than the second generation rats on the diet containing whole wheat. Nine weeks after they had been removed from their mother at 28 days of age, the rats had an average weight gain of 113 gm which is 42 gm less than the first generation who gained 155 gm during the same period. These young rats had very sparse hair, later they grew a good coat of hair but it had a soft texture possibly indicating that they had not matured properly. When they were discarded at the end of nine weeks their eyes were red-rimmed and puffed. There is no adequate explanation for this, since these conditions were not found in the first generation of the rats on the same diet.

The calcium pantothenate was increased to 40 ug per gm of flour and the animals were mated. Three young were raised by one female on the diet. They weighed 34 gm at 21 days of age and 41 gm at 28 days of age which is 10 gm more than the rats that were born when the mother was eating the diet containing 10.3 ug calcium pantothenate per gm of flour. These results gave evidence that calcium pantothenate improved the reproduction of rats eating a natural diet in which 62 per cent of the calories came from enriched flour. It also seems probable that the larger amount (40 ug per gm of flour) was more effective than the smaller amount (10.3 ug per gm of flour).

The rats on the diet containing non-enriched flour produced no young, possibly because the diet was deficient in some nutrient necessary for reproduction. To determine whether or not this was the reason or whether there was an organic disorder of the reproduction organs, the rats were placed on a stock diet and mated. On this adequate diet each female averaged seven normal young. These results gave evidence that the lack of reproduction was caused by a deficiency in the diet. This deficiency was in all probability the B-complex vitamins, since all other nutrients were supplied in a sufficient amount.

The rats on the cornstarch diet were small and thin. The hair was sparse, two of the rats were almost nude when they were discarded. The rats were sensitive to touch and no reproduction occurred. These deficiencies can possibly be attributed to the lack of the B-complex vitamins in the diet.

Second Experiment: Flour Furnished 40 Per Cent of the Total Calories

The average weight gains of the rats on experiment II are shown in Table 14 and by the growth curves in Fig. 2. At the end of nine weeks the rats eating diet 1, containing 40 per cent enriched flour, had gained an average of 152 gm or 10 gm more than the animals on the non-enriched flour diet that had gained an average of 142 gm during the same period of time. The animals eating the cornstarch diet gained an average of 117 gm or 25 gm less than the animals on the non-enriched flour diet during the nine week period. These growth differences are shown in the photographs of typical rats from each diet in Plate II.

The nutritive values of diets 1, 2, and 3 are shown in Tables 7, 8, and 9, respectively. The smaller difference in the average weight gains between the rats on the cornstarch and the non-enriched flour diet could possibly be attributed to the addition of vitamin free casein to the cornstarch diet of experiment II. This brought the protein value of the diet to approximately the same level as the enriched and non-enriched flour diets. The amount of iron varied from 10.8 mg in the cornstarch diet to 20.6 mg in the enriched flour diet while the non-enriched flour diet contained 13.2 mg of iron. The iron value of the cornstarch diet was a little below the recommended allowances of 12 mg per day but the other two diets were adequate.

The thiamine values varied from a low of 1.09 mg in the cornstarch diet to a high of 2.61 mg in the enriched flour diet. The non-enriched flour diet contained 1.36 mg of thiamine. The amount was adequate in the enriched flour diet but not in the non-enriched flour or in the cornstarch diet, since the recommended allowance is 1.4 mg per day. The amount of niacin was deficient in both the non-enriched flour and in the cornstarch diet with values of 9.5 mg and 6.8 mg, respectively. The enriched flour diet was adequate with 18.6 mg of niacin. The cornstarch diet was low in riboflavin. It contained 1.57 mg while the enriched flour and non-enriched flour diets contained 2.48 mg and 1.71 mg of riboflavin. The recommended allowances of niacin and riboflavin are 14 mg and 1.8 mg per day.

There was considerable differences in the nutrients in the enriched and non-enriched flour diets. The differences of 10 gm gain in weight made by the animals on the enriched flour diet over the gain made by the animals on the non-enriched flour diet may in part be attributed to the differences in the vitamin and iron content of the diet. The enriched flour contained 1.9 times as much thiamine, 1.4 times as much riboflavin, and 1.6 times as much iron as the non-enriched flour diet.

At the end of nine weeks the males and females on the same diet were placed together for breeding purposes. Vitamin E was added to the diets at this time, each rat was given 3 mg a day. There was no successful reproduction, one female on each of the enriched and non-enriched flour diet produced a litter of dead young. At the end of 17 weeks the rats on experiment II were placed on a stock diet, to determine if there were organic disorders of the reproductive system. On this adequate diet the females on the enriched flour diet produced an average of seven normal young. The females on the non-enriched diet produced an average of six normal young, while the females on the cornstarch diet produced an average of two normal young. This gave evidence that the diets were deficient for reproduction, probably due to the small amount of the B-complex vitamins in the diet.

Third Experiment: Flour Furnished 33 Per Cent of the Total Calories

The average weight gains of the rats on experiment III are shown in the weight chart in Table 15 and by the growth curves in Fig. 2. By the end of nine weeks, the rats eating the diet which contained enriched flour had gained 214 gm. This was 3 gm less gain than that made by the animals on the diets which included non-enriched flour and cornstarch. These had gained 217 gm each. The small variation in the growth rate of the rats on the different diets in this experiment could possibly be attributed to the smaller per cent of calories from cereals, therefore a greater per cent of the calories came from the protective foods; i.e., meat, milk, eggs, fruit, and vegetables. The meat in experiment III furnished 5.2 per cent of the total calories, while the meat furnished 3.6 per cent and 3.8 per cent of the total calories in experiments I and II. In the third experiment 13.7 per cent of the total calories were furnished by the milk while in the first and second experiment the milk furnished 9.5 and 9.9 per cent of the calories. The eggs in experiment II furnished 2.6 per cent of the calories while the eggs in experiments I and III furnished 0.6 per cent and 0.9 per cent of the calories. The fruits and vegetables contributed a total of 5.3 per cent of the calories in experiment III while the fruits and vegetables furnished a total of 3.6 and 4.4 per cent of the calories in experiments I and II. Members of the B-complex, other than riboflavin, thiamine, and niacin, evidently are furnished by the protective foods to a larger extent than by the refined cereals or by enriched flour. This apparently affords better growth for young rats. Even though the diets that contained non-enriched flour and cornstarch did not have the recommended amount of all the B-complex vitamins that were calculated, the rats on these diets grew at approximately the same rate as the animals eating the diet which contained enriched flour.

Tables 10, 11, and 12 show the nutritive value of diets 1, 2, and 3 of this experiment. The diet which contained enriched flour had 2.32 mg of thiamine while the diets that contained non-enriched flour and cornstarch had 1.29 mg and 1.19 mg of thiamine. The recommended amount of thiamine is 1.4 mg, therefore, neither the non-enriched nor the cornstarch diet had the recommended amount of thiamine. The recommended allowance of riboflavin is 1.8 mg per day. Only the enriched flour diet met this requirement with 2.36 mg. The enriched flour diet contained 1.78 mg of riboflavin while the cornstarch diet contained 1.68 mg, these amounts were both very nearly adequate. Diet 1, with enriched flour, contained 16.6 mg or 2.6 mg more than the recommended daily allowance of niacin which is 14 mg. Diet 2, with non-enriched flour, included 9.8 mg of niacin while diet 3, with cornstarch, had 7.8 mg of niacin. These amounts are lower than the recommended amount.

The males and females on the same diet were placed together for breeding purposes at the end of seven weeks. Living young were produced by the females on all diets. The female rats on the diet which contained enriched flour had an average of two to three young. The females eating the non-enriched flour had an average of four young while the females on the cornstarch diet had an average of five young. At 21 days of age the young on the diets that contained non-enriched flour and cornstarch weighed an average of 17 gm while the young of the animals on the enriched flour diet weighed 24 gm by 21 days. At 28 days of age the young on the diet containing cornstarch weighed 29 gm, the young with non-enriched flour in the diet weighed 26 gm, while the young on the diet containing enriched flour weighed 41 gm. The young on the diets containing non-enriched flour and cornstarch had sparse hair while the young on the diet with enriched flour had normal hair. These animals were smaller than normal young for the same age which weighed approximately 45 gm at 28 days. All of the diets approached the lower limits of adequacy, which allowed reproduction to take place. Even though cornstarch and non-enriched flour were included in the diet at the same level as the enriched flour; i.e., 33 per cent, the amounts of the thiamine, riboflavin, and iron were not low enough in these diets to make any real difference in reproduction between the animals on the different diets.

General Discussion of the Three Experiments

The animals in the three experiments using whole wheat, enriched flour, non-enriched flour, and cornstarch as 62, 40, and 33 per cent of the total calories in the diet showed considerable differences in growth rates. The greatest weight gains were made by the rats eating the diets that contained 33 per cent cereals. In diets where 62, 40, and 33 per cent of the total calories were supplied by enriched flour, the animals gained 155, 152, and 214 gm, respectively. The rats with diets containing 62 and 40 per cent of the calories from enriched flour varied only 3 gm in their average weight gains while the rats on the diet containing 33 per cent gained 59 gm more during the test period than those on the 62 per cent diet.

Even though the calculated nutritive value of the 62 per cent enriched flour diet was higher, as can be seen in Tables

4, 7, and 10, the rats did not grow as rapidly as did the animals on the 33 per cent diet. The diet with 62 per cent enriched flour supplied 117.3 gm protein, the diet with 40 per cent contained 99.7 gm protein while the 33 per cent enriched flour diet was fairly adequate with 67.1 gm. All the diets were adequate in calcium with 1.108, .363, and .926 gm calcium for the diets containing 62, 40, and 33 per cent enriched flour, respectively.

The iron supplied by the diets containing enriched flour was adequate at all levels. They contained 29.58, 20.60, and 16.90 mg in the diets supplying 62, 40, and 33 per cent of the calories from enriched flour. While the thiamine content of the diets was adequate at the three cereal levels, the amount of thiamine supplied by the diet containing 62 per cent enriched flour was 4.13 mg. The diets with 40 and 33 per cent cereals had a thiamine content of 2.61 and 2.32 mg with the 33 per cent diet having the smaller amount.

The riboflavin content of the diets was sufficient in all diets containing enriched flour. The diet with 62 per cent calories from enriched flour contained 3.46 mg of riboflavin while the diets containing 40 and 33 per cent of calories from enriched flour supplied 2.48 mg and 2.36 mg of riboflavin. The diet with 62 per cent of the calories supplied by the enriched flour contained the largest amount of niacin, 28.8 mg, while the other diets were more than adequate with 18.6 mg and 16.6 mg in the diets with 40 and 33 per cent of the calories from enriched flour. These results were to be expected since these four nutrients; i.e., iron, thiamine, riboflavin, and niacin, are added to the flour when it is enriched. When a large per cent of cereals is used in diets, such as ones eaten by people on low incomes, the enriched flour is of some value in supplying iron, thiamine, riboflavin, and niacin. This is shown by the average weight gains of the animals on non-enriched flour which gained at the 62 per cent level an average of 138 gm in the test period which is 17 gm less than those on enriched flour. Those on the 40 per cent and 33 per cent levels of non-enriched flour gained 142 gm and 217 gm, respectively. The animals on the 33 per cent diet gained 62 gm more than the animals on the 62 per cent cereal diet while the animals consuming 40 per cent non-enriched flour diet gained 13 gm more than the rats eating the 62 per cent non-enriched flour diet. The protein content of the non-enriched flour diets were identical with the enriched flour diet on the same experiment as is shown by the nutritive value in Tables 5, 8, and 11. Therefore, the growth differences were due to the difference in the B-complex value of the diet and not to the protein value.

The iron supplied by these diets is adequate except that the diet containing 33 per cent of the calories from non-enriched flour was not quite adequate with 11.40 mg of iron. The 62 and 40 per cent diet contained a plentiful supply of iron with 14.73 mg and 13.2 mg. The thiamine content was adequate only in the 62 per cent diet with 1.63 mg supplied. The 40 per cent and the 33 per cent diets were just below the recommended amount with 1.36 mg and 1.29 mg of riboflavin supplied. The amount of riboflavin is just under the amount recommended in the diets containing non-enriched flour. The 62 per cent diet contained 1.69 mg while the 40 and 33 per cent diets contained 1.71 mg and 1.73 mg. The amount of niacin is also inadequate in the three diets containing non-enriched flour. The diet containing 33 per cent non-enriched flour has the largest amount, 9.8 mg, while the 40 per cent diet has 9.5 mg. The 62 per cent diet has 9.5 mg. The 62 per cent diet is quite inadequate with 5.8 mg of niacin. There is evidence, however, that rats are not sensitive to a niacin deficiency in the diet.

The animals on the cornstarch diet gained 73, 117, and 217 gm on experiments containing 62, 40, and 33 per cent of the total calories from cereals in the diets. There is a wide range in the weight gains of the rats on the cornstarch diets. The rats on 33 per cent cornstarch diet gained 217 gm or 100 gm more than the rats eating the diet with 40 per cent cornstarch. The animals with 62 per cent cornstarch in the diet gained 73 gm or 44 gm less than the animals eating the diet with 40 per cent cornstarch.

Only the rats eating 33 per cent cornstarch diet reproduced. With a larger per cent of purified cereal a sufficient amount of nutrients are not present for reproductive activity.

The nutritive value of the cornstarch diets was shown in Tables 6, 9, and 12. The protein content of the diets containing 40 and 33 per cent cornstarch was the same as the protein content of the other diets of their respective experiments, while the protein content of the cornstarch diet containing 62 per cent cornstarch contained 44.9 gm of protein or 40 gm less than the other diets on the same experiment. This deficiency of protein is possibly responsible for part of the low weight gains of this group of animals. The diets containing cornstarch were all deficient in iron, thiamine, riboflavin, and niacin. The supply of iron was fairly high. The 40 per cent cornstarch diet contained 10.80 mg while the 62 per cent and 33 per cent diet contained 10.00 mg and 9.60 mg of iron. The 33 per cent cornstarch diet had the largest supply of riboflavin with 1.19 mg while the 62 per cent and the 40 per cent cornstarch diets had 1.11 mg and 1.09 mg. The 33 per cent cornstarch diet had the largest supply of riboflavin with 1.68 mg while the 62 per cent and the 40 per cent diet had 1.67 mg and 1.57 mg each. The amount of niacin was quite inadequate in the cornstarch diets. The 33 per cent diet had 7.8 mg while the 62 per cent and the 40 per cent diet contained 5.2 mg and 6.8 mg.

The diets with 33 per cent of the calories from cereal were lower in nutrients than the equivalent diets on the other experiments except in the diets that included cornstarch. The animals on this experiment, however, grew at a much greater rate than did the animals on the diets that were more nearly adequate by calculations. This can be accounted for only by factors, other than those calculated, that were supplied more abundantly by the larger per cent of protective foods in the diet with 33 per cent of the total calories from cereals.

SUMMARY

Three experiments, using the albino rat as the experimental animal, have been carried out to compare the nutritive value of whole wheat, enriched flour, non-enriched flour, and cornstarch when included in the diet in amounts to provide approximately 62, 40, and 33 per cent of the total calories of the diet. The diets consisted of natural foods in amounts consumed in the human dietary. Consideration was given to diets which have been consumed by the low income groups. These diets were high in cereal content.

Calculations of the nutritive value of the different diets were made and comparisons of the adequacy of the dietaries were included in the report. Tables showing the weekly weight gain of the rats and growth curves illustrating the differences in growth rates are also given.

The results showed that better growth and reproduction were obtained when 33 per cent of the calories came from cereals rather than when 40 or 62 per cent of the calories were from this source. This was because the larger quantities of protective foods; i.e., meat, milk, eggs, fruits, and vegetables, in the diet provided a more equal distribution of all the food essentials in the diet.

Results showed that better growth and reproduction resulted when enriched flour provided 40 or 62 per cent of the calories of the diet than when non-enriched flour furnished calories at the same level. This can be attributed to the larger quantities of iron, thiamine, riboflavin, and niacin, which were added to the flour when it was enriched.

Since vitamin E was added to the diets it would not appear to be a limiting factor in any of the diets.

Under the conditions of these experiments, it appears that the limiting factor in the diets using enriched flour as a source of calories is the lack of the B-complex vitamins other than thiamine, riboflavin, and niacin, which are added to flour when it is enriched.

Slightly better growth was obtained when non-enriched flour provided 40 per cent of the calories than when 62 per cent of the calories were from non-enriched flour. However, growth of the rats eating the diet containing 62 per cent enriched flour was a little better than the growth of the rats eating the diet that contained 40 per cent enriched flour.

Table 1. Food supply of rural families in Pickens County, South Carolina. Low values[1].

Type of food	Food consumed per year	Lbs. per year	Lbs. per day	Gm per day
Milk	60 gal.	480	1.32	597.96
Fats	47 lbs.	47	.13	58.89
Meat	45 lbs.	45	.12	54.36
Eggs	9 doz.			14.79
Potatoes	138 lbs.	138	.38	172.14
Legumes	11 lbs.	11	.03	13.68
Leafy, green, yellow vegetables	68 lbs.	68	.19	86.07
Tomatoes and citrus fruit	46 lbs.	46	.12	54.36
Other vegetables	43 lbs.	43	.11	49.83
Other fruits	86 lbs.	86	.23	104.19
Cornmeal and grits	114 lbs.	114	.31	140.43
Wheat flour	141 lbs.	141	.39	176.67
All cereal products	282 lbs.	282	.79	357.87
Sugar	30 lbs.	30	.08	36.24

[1]Moser (1945)

Table 2. Nutritive value of 100 gm edible portions of selected foods[1].

Food	Cal	Prot	Fat	CHO	Ca	Fe	Vit A	Vit B_1	Ribo	Niacin	Vit C
		gm				mg	I U	mg			
Apples	64	0.3	0.4	14.9	.007	0.3	80	.04	0.02	0.2	6
Beans, dried	350	22.0	1.5	62.1	.148	10.3		.59	0.31	2.2	1
Green vegetables[2]	33	2.4	0.2	5.4	.083	1.5	3845	.09	0.15	0.6	60
Carrots	45	1.2	0.3	9.3	.041	0.8	9750	.07	0.07	0.5	6
Eggs	158	12.8	11.5	0.7	.056	2.9	1320	.12	0.35	0.1	
Butter	733	0.6	81.0	0.4	.016	0.2	3350		0.01	0.1	
Non-enriched flour	355	10.8	0.9	75.9	.017	0.7		.08	0.04	0.8	
Enriched flour	355	10.8	0.9	75.9	.017	2.9		.45	0.27	3.5	
Whole wheat	361	12.1	1.9	73.9	.048	4.8	22	.54	0.12	5.6	
Meat[3]	284	16.8	24.0		.011	2.6	30	.58	0.19	4.7	
Dried whole milk	496	25.3	26.7	38.0	.949	0.6	1400	.30	1.46	0.7	7
Potatoes	85	2.0	0.1	19.1	.011	0.7	20	.11	0.04	1.2	16
Sugar	398			99.5		0.1					

[1] Average of figures given in Chemistry of Food and Nutrition, Sherman and Handbook of Diet Therapy, Turner.

[2] Green vegetables - the figures for cabbage, green beans, spinach, and broccoli were averaged.

[3] Meat - these figures are calculated on basis of ½ beef (stew meat) and ½ pork (roast), per serving.

Table 3. Nutritive value of Diet 1 used in Experiment I, whole wheat furnished 62 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B1 mg	Ribo mg	Niacin mg	Vit C mg
Whole wheat flour	675	50.6	2437	62.4	81.7	13.5	498.8	.324	25.65		3.78	.81	37.8	
Sugar	36	2.7	143	3.7			35.8		0.03					
Margarine	59	4.4	432	11.1	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	3.7	142	3.6	8.4	12.0		.006	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	5.6	372	9.5	19.0	20.0	28.5	.712	0.45	1050	0.23	1.10	0.5	5
Eggs	15	1.1	24	0.6	1.9	1.9	0.1	.008	0.40	198	0.02	0.50		
Beans, dried	45	3.4	158	4.0	9.9	0.7	27.9	.067	4.60		0.27	0.14	0.9	
Potatoes	72	5.4	58	1.5	1.4	0.1	13.8	.008	0.50	14	0.08	0.03	0.1	12
Carrots	100	7.5	45	1.2	1.2	0.3	9.3	.041	0.80	9750	0.07	0.07	0.5	6
Apples	100	7.5	64	1.6	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	7.5	33	0.8	2.4	0.2	5.4	.083	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.5												
Total	1334	99.9	3908	100	127	96.9	635	1.257	35.64	16919	4.89	2.47	42.8	89

Table 4. Nutritive value of Diet 2 used in Experiment I, enriched flour furnished 62 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	675	50.6	2396	62.0	72.9	0.6	512.0	.115	19.58		3.04	1.80	23.6	
Sugar	36	2.7	143	3.7			35.8		0.03					
Margarine	59	4.4	432	11.2	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	3.7	142	3.7	8.4	12.0		.006	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	5.6	372	9.6	19	20.0	28.5	.712	0.45	1050	0.23	1.10	0.5	5
Eggs	15	1.1	24	0.6	1.9	1.9	0.1	.008	0.40	198	0.02	0.05		
Beans, dried	45	3.4	158	4.1	9.9	0.7	27.9	.067	4.60		0.27	0.14	0.9	
Potatoes	72	5.4	58	1.3	1.4	0.1	13.8	.008	0.50	14	0.08	0.03	0.1	12
Carrots	100	7.5	45	1.2	1.2	0.3	9.3	.041	0.80	9750	0.07	0.07	0.5	6
Apples	100	7.5	64	1.7	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	7.5	33	0.9	2.4	0.2	5.4	.083	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.5												
Total	1334	99.9	3867	100	118	84	648	1.108	29.58	16919	4.13	3.46	28.8	89

Table 5. Nutritive value of Diet 3 used in Experiment I, non-enriched flour furnished 62 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	675	50.6	2396	62.0	72.9	0.6	512.0	.115	4.73		0.54	0.03	0.5	
Sugar	38	2.7	143	3.7			35.8		0.03					
Margarine	59	4.4	432	11.2	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	3.7	142	3.7	8.4	12.0		.066	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	5.6	372	9.6	19.0	20	28.5	.712	0.45	1050	0.23	1.10	0.8	5
Eggs	15	1.1	24	0.6	1.9	1.9	0.1	.008	0.40	198	0.02	0.05		
Beans, dried	45	3.4	158	4.1	9.9	0.7	27.9	.067	4.60		0.27	0.14	0.9	
Potatoes	72	5.4	58	1.3	1.4	0.1	13.8	.008	0.50	14	0.08	0.03	0.1	12
Carrots	100	7.5	45	1.2	1.2	0.3	9.3	.041	0.80	9750	0.07	0.07	0.5	6
Apples	100	7.5	64	1.7	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	7.5	33	0.9	2.4	0.2	5.4	.083	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.5												
Total	1334	99.9	3867	100	178	84	648	1.108	14.73	16919	1.63	1.69	5.7	89

Table 6. Nutritive value of Diet 4 used in Experiment I, cornstarch furnished 65 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Corn-starch	675	50.6	2700	64.7			675.0							
Sugar	36	2.7	143	3.4			35.8		0.03					
Margarine	59	4.4	432	10.4	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	3.7	142	3.4	8.4	12.0		.006	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	5.6	372	8.9	19.0	20.0	28.5	.712	0.45	1050	0.23	1.10	0.5	5
Eggs	15	1.1	24	0.6	1.9	1.9	0.1	.008	0.40	198	0.02	0.05		
Beans, dried	45	3.4	158	3.8	9.9	0.7	27.9	.067	4.60		0.27	0.14	0.9	
Potatoes	72	5.4	58	1.4	1.4	0.1	13.8	.008	0.50	19	0.09	0.04	0.1	12
Carrots	100	7.5	45	1.1	1.2	0.3	9.3	.041	0.80	9750	0.08	0.07	0.5	6
Apples	100	7.5	64	1.5	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	7.5	33	0.8	2.4	0.2	5.4	.083	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.2												
Total	1334	99.9	4171	100	44.9	83.4	810.9	.933	10.00	16919	1.11	1.67	5.2	93

Table 7. Nutritive value of Diet 1 used in Experiment II, enriched flour furnished 40 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	338	28.4	1200	40.0	36.5	3.0	256.5	.057	9.8		1.52	0.91	11.8	
Sugar	166	14.0	661	22.0			165.2		0.2					
Margarine	30	2.5	220	7.3	0.2	24.3	0.1	.005		1005		0.03	0.3	
Meat	40	3.4	114	3.8	6.7	9.6		.004	1.0	12	0.23	0.08	1.9	
Milk, dried whole	60	5.0	298	9.9	15.5	16.0	22.8	.569	0.4	840	0.18	0.88	0.4	4
Eggs	50	4.2	79	2.6	6.4	5.8	0.4	.028	1.5	660	0.06	0.17	0.1	
Beans, dried	40	3.4	140	4.7	8.8	0.6	24.8	.059	4.1		0.24	0.12	0.8	
Potatoes	176	14.8	150	5.0	3.5	0.2	33.6	.019	1.2	35	0.19	0.07	2.1	28
Carrots	89	7.5	40	1.3	1.2	0.3	8.3	.036	0.7	8678	0.06	0.06	0.4	5
Apples	98	8.2	63	2.1	0.3	0.4	14.6	.007	0.3	78	0.04	0.02	0.2	6
Green vegetables	95	8.0	31	1.0	2.3	0.2	5.1	.079	1.4	3653	0.09	0.14	0.6	57
Salt	7	0.6												
Total	1189	100	2996	99.7	81.4	60.4	531.4	.863	20.6	14961	2.61	2.48	18.6	100

Table 8. Nutritive value of Diet 2 used in Experiment II, non-enriched flour furnished 40 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot	Fat	CHO	Ca	Fe mg	Vit A I U	Vit B_1	Ribo	Niacin	Vit C
					gm						mg			
Non-enriched flour	338	28.4	1200	40.0	36.5	3.0	256.5	.057	2.4		0.27	0.14	2.7	
Sugar	166	14.0	661	22.0			165.2		0.2					
Margarine	30	2.5	220	7.3	0.2	24.3	0.1	.005		1005		0.03	0.3	
Meat	40	3.4	114	3.8	6.7	9.6		.004	1.0	12	0.23	0.08	1.9	
Milk, dried whole	60	5.0	298	9.9	15.5	16.0	22.8	.569	0.4	840	0.18	0.88	0.4	4
Eggs	50	4.2	79	2.6	6.4	5.8	0.4	.028	1.5	660	0.06	0.17	0.1	
Beans, dried	40	3.4	14o	4.7	8.8	0.6	24.8	.059	4.1		0.24	0.12	0.8	
Potatoes	176	14.8	150	5.0	3.5	0.2	33.6	.019	1.2	35	0.19	0.07	2.1	28
Carrots	89	7.5	40	1.3	1.2	0.3	8.3	.036	0.7	8678	0.06	0.06	0.4	5
Apples	98	8.2	63	2.1	0.3	0.4	14.6	.007	0.3	78	0.04	0.02	0.2	6
Green vegetables	95	8.0	31	1.0	2.3	0.2	5.1	.079	1.4	3653	0.09	0.14	0.6	57
Salt	7	0.6												
Total	1189	100	2996	99.7	81.4	60.4	531.4	.863	13.2	14961	1.36	1.71	9.5	100

Table 9. Nutritive value of Diet 3 used in Experiment II, cornstarch furnished 40 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Corn-starch	298	25.0	1192	37.9			298.0							
Sugar	166	14.0	661	21.0			165.2		0.2					
Margarine	30	2.5	220	7.0	0.2	24.3	0.1	.005		1005		0.03	0.3	
Meat	40	3.4	114	3.6	6.7	9.6		.004	1.0	12	0.23	0.08	1.9	
Milk, dried whole	60	5.0	298	9.5	15.5	16.0	22.8	.569	0.4	840	0.18	0.88	0.4	4
Eggs	50	4.2	79	2.5	6.4	5.8	0.4	.028	1.5	660	0.06	0.17	0.1	
Beans, dried	40	3.4	140	4.4	8.8	0.6	24.8	.059	4.1		0.24	0.12	0.9	
Potatoes	176	14.8	150	4.8	3.5	0.2	33.6	.019	1.2	35	0.19	0.07	2 .1	28
Carrots	89	7.5	40	1.3	1.2	0.3	8.3	.036	0.7	8678	0.06	0.06	0.4	5
Apples	98	8.2	63	2.0	0.3	0.4	14.6	.007	0.3	78	0.04	0.02	0.2	6
Green vegetables	95	8.0	31	1.0	2.3	0.2	5.1	.079	1.4	3653	0.09	0.14	0.6	57
Vitamin free casein	40	3.4	160	5.1	40.0									
Salt	7	0.6												
Total	1189	100	3148	100.1	85	57.4	572.9	.806	10.8	14961	1.09	1.57	6.8	100

Table 10. Nutritive value of Diet 1 used in Experiment III, enriched flour furnished 33 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	250	22.0	888	32.8	27.0	2.3	189.8	.043	7.30		1.13	0.68	8.8	
Sugar	100	8.8	398	14.7			99.5		0.10					
Margarine	59	5.2	432	15.9	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	4.4	142	5.2	8.4	12.0		.006	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	6.6	372	13.7	19.0	20.0	28.5	.712	0.45	1050	0.23	1.10	0.5	5
Eggs	15	1.3	24	0.9	1.9	1.9	0.1	.008	0.40	198	0.02	0.05		
Beans, dried	28	2.5	98	3.6	6.0	0.4	17.4	.041	2.88		0.17	0.09	0.6	
Potatoes	250	22.0	213	7.8	0.5	0.3	47.8	.028	1.75	50	0.28	0.10	3.0	40
Carrots	100	8.8	45	1.7	1.2	0.3	9.3	.041	0.80	9750	0.07	0.07	0.5	6
Apples	100	8.8	64	2.4	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	8.8	33	1.2	2.4	0.2	5.4	.082	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.6												
Total	1134	99.8	2709	99.9	67.1	85.6	412.9	.969	16.90	16965	2.32	2.36	16.6	117

Table 11. Nutritive value of Diet 2 used in Experiment III, non-enriched flour furnished 33 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	250	22.0	888	32.8	27.0	2.3	189.8	.043	1.80		0.10	0.10	2.0	
Sugar	100	8.8	398	14.7			99.5		0.10					
Margarine	59	5.2	432	15.9	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	4.4	142	5.2	8.4	12.0		.006	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	6.6	372	13.7	19.0	20.0	28.5	.712	0.45	1050	0.23	1.10	0.5	5
Eggs	15	1.3	24	0.9	1.9	1.9	0.1	.008	0.40	198	0.02	0.05		
Beans, dried	28	2.5	98	3.6	6.0	0.4	17.4	.041	2.88		0.17	0.09	0.6	
Potatoes	250	22.0	213	7.8	0.5	0.3	47.8	.028	1.75	50	0.28	0.10	3.0	40
Carrots	100	8.8	45	1.7	1.2	0.3	9.3	.041	0.30	9750	0.07	0.07	0.5	6
Apples	100	8.8	64	2.4	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	8.8	33	1.2	2.4	0.2	5.4	.082	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.6												
Total	1134	99.8	2709	99.9	67.1	85.6	412.9	.969	11.40	16965	1.29	1.78	9.8	117

Table 12. Nutritive value of Diet 3 used in Experiment III, cornstarch furnished 33 per cent of the total calories.

Food	Wt gm	% wt	Cal	% cal	Prot gm	Fat gm	CHO gm	Ca gm	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Corn-starch	225	20.3	900	33.0			225.0							
Sugar	73	6.6	291	10.7			99.5		0.10					
Margarine	59	5.3	432	15.9	0.4	47.8	0.2	.001	0.12	1977				
Meat	50	4.5	142	5.2	8.4	12.0		.006	1.30	15	0.29	0.10	2.4	
Milk, dried whole	75	6.8	372	13.7	19.0	20.0	28.5	.712	0.45	1050	0.23	1.10	0.5	5
Eggs	15	1.4	24	0.9	1.9	1.9	0.1	.008	0.40	198	0.02	0.05		
Beans, dried	28	2.5	98	3.6	6.0	0.4	17.4	.041	2.88		0.17	0.09	0.6	
Potatoes	250	22.5	213	7.8	0.5	0.3	47.8	.028	1.75	50	0.28	0.10	3.0	40
Carrots	100	9.0	45	1.7	1.2	0.3	9.3	.041	0.80	9750	0.07	0.07	0.5	6
Apples	100	9.0	64	2.4	0.3	0.4	14.9	.007	0.30	80	0.04	0.02	0.2	6
Green vegetables	100	9.0	33	1.2	2.4	0.2	5.4	.082	1.50	3845	0.09	0.15	0.6	60
Salt	7	0.6												
Vitamin free casein	27	2.4	108	4.0	27.0									
Total	1109	99.9	2722	100.1	67	83.3	448.1	.926	9.60	16965	1.19	1.68	7.8	117

Table 13. Average weights of rats on Experiment I.

Diet	Weeks										Total
	0	1	2	3	4	5	6	7	8	9	gain
					First generation						
1. Whole wheat	48	85	113	136	157	167	177	189	198	209	161
2. Enriched flour	48	84	118	131	146	157	167	176	191	203	155
3. Non-enriched flour	49	79	102	117	129	139	159	165	180	187	138
4. Cornstarch	51	71	85	91	96	101	112	117	119	124	73
					Second generation						
1. Whole wheat	36	56	71	84	91	105	115	122	128	140	104
2. Enriched flour	21	28	34	47	55	69	88	102	127	134	113

Table 14. Average weights of rats on Experiment II.

Diet	Weeks										Total gain
	0	1	2	3	4	5	6	7	8	9	
1. Enriched flour	52	90	116	126	146	160	169	182	197	204	152
2. Non-enriched flour	53	89	110	126	139	155	164	171	185	195	142
3. Cornstarch	53	79	89	111	127	140	145	156	160	170	117

Table 15. Average weights of rats on Experiment III.

Diet	Weeks										Total gain
	0	1	2	3	4	5	6	7	8	9	
1. Enriched flour	55	105	143	164	191	209	229	238	258	269	214
2. Non-enriched flour	56	101	140	164	188	206	217	235	255	273	217
3. Cornstarch	58	100	143	169	188	209	228	237	261	275	217

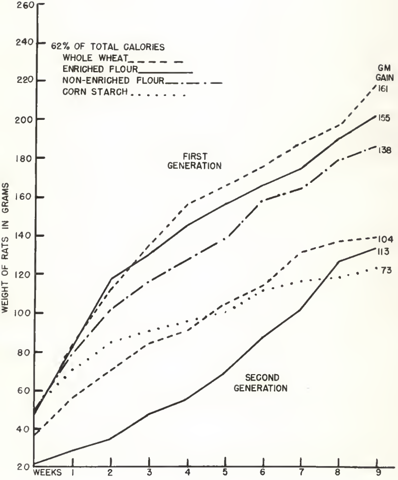

260
240
220
200
180
160
140
120
100
80
60
40
20
62% OF TOTAL CALORIES
WHOLE WHEAT
ENRICHED FLOUR
NON-ENRICHED FLOUR
CORN STARCH
GM GAIN
161
155
138
104
113
73
FIRST GENERATION
SECOND GENERATION
WEIGHT OF RATS IN GRAMS
WEEKS 1 2 3 4 5 6 7 8 9

FIGURE 1.

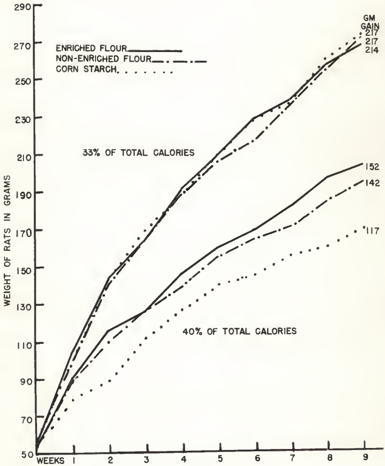

GM
GAIN
217
217
214
ENRICHED FLOUR
NON-ENRICHED FLOUR
CORN STARCH
33% OF TOTAL CALORIES
40% OF TOTAL CALORIES
152
142
117
WEIGHT OF RATS IN GRAMS
290
270
250
230
210
190
170
150
130
110
90
70
50
WEEKS
1
2
3
4
5
6
7
8
9

FIGURE 2.

EXPLANATION OF PLATE I

Female rats on Experiment I.

3285 Diet 1 containing whole wheat.

3283 Diet 2 containing enriched flour.

3299 Diet 3 containing non-enriched flour.

3298 Diet 4 containing cornstarch.


3283
1A5799
3283
1A5798
3299
1A5801
3298
1A5800

EXPLANATION OF PLATE II

Female rats on Experiment II.

3308 Diet 1 containing enriched flour.

3310 Diet 2 containing non-enriched flour.

3311 Diet 3 containing cornstarch.

PLATE II

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