A COMPARISON OF THE NUTRITIVE VALUE OF ENRICHED AND NON-ENRICHED FLOUR IN DIETS SIMILAR TO THOSE CONSUMED BY CERTAIN LOW INCOME GROUPS IN MISSISSIPPI

by

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B. S., University of Illinois, 1946

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1949

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INTRODUCTION

Wheat has been cultivated since the earliest ages. It was the main crop in Egypt, Rome, and Greece. The wheat grown in Egypt, according to Jacob (1944), was not like the wheat grown today, but rather an emmer wheat. Later, the Romans perfected this wheat. The Chinese cultivated wheat in 2700 B.C. The first wheat in the United States was planted in New England in 1602.

Wheat has become the most important cereal crop in the world. Nearly six hundred million people use it as food in the form of bread. The Egyptians were the first to discover that leavened breads could be made by setting aside their doughs until they raised. Their yeast was derived from air-borne yeast spores. The flour milled by the Egyptians was not very refined, for they pounded their grains between stones and some of the chaff and bran were removed with the aid of air currents. The Romans progressed from mortar and pestle grinding to circular mills or querns and they were able to produce several grades of flour by sieving or bolting the meal.

The conical querns of the Romans were gradually replaced by large flattened millstones which continued to be used in Europe and America until 1870. Water power and later steam power were used for turning these millstones. With the discovery of the steam engine and the harnessing of electric power, the millstones were replaced by revolving pairs of steel rollers and this is the method of milling in use today. Instead of one crushing operation, there is a gradual breaking of the grains, and with the aid of the middlings purifier, the bran and germ are removed in between breakings. A very highly refined flour is produced, because all that is left is the endosperm which is mostly starch. The important vitamins and much of the protein have been removed with the separation of the bran and germ.

Millers designate flour by a certain percentage extraction which is based upon the weight of the total flour secured after all the bran and germ have been removed. Low extraction flours contain less bran and germ than high extraction flours. Normally millers use 72 percent extraction, but occasionally higher extractions must be used. During World War II, Great Britain milled all their flour at 85 to 90 percent extraction so that the people would benefit from a higher vitamin and mineral content of the flour. After the war many European countries encountered starvation, and the United States was called upon to alleviate this situation by shipping grain and flour as well as other nonperishable foods. For greater flour yields and in order to conserve wheat, millers were asked to mill 80 percent extraction flour instead of 72 percent extraction flour. The 80 percent extraction flour was used in this country for only one year.

For a long time people did not realize that important nutrients were present in the coarser sections of the wheat grain. Beginning with the twentieth century, chemists and nutritionists recognized the existence of nutrient substances whose functions were different from those constituents in foods needed for energy and building supplies. They found that many diseases, such as pellagra, beri-beri, and rickets could be prevented by including foods in the diet which contained certain nutrients which Funk in 1912 called "vitamins." The whole grain was especially high in the B-complex vitamins and therefore, people were urged to eat more whole wheat flour and bread.

In spite of this new knowledge of nutrition, preference for fine white flour has persisted, and now 98 percent of the flour milled in this country is white flour. This is not surprising, because a soft, light, finely-textured loaf of bread can be made from white flour. A heavy, solid loaf of bread results when the whole grain is included.

With the outbreak of World War II, nutritionists were confronted with the fact that millions of people were not getting enough of the vitamins and minerals to maintain health and vigor. The need for better national nutrition was emphasized by numerous dietary surveys. Coco et al. (1943) evaluated the diets of grade and high school students in Louisiana and found that 11 percent of the white and 3 percent of the Negro children received a diet adequate in all essential food factors. The diets were fair among 60 percent of the white and 35 percent of the Negro students, and poor among 29 percent of the white and 62 percent of the Negro students. Youmans et al. (1943) in their compilation of diet records in a rural community in Tennessee found that 69 percent of the children were not receiving the National Research Council's recommended amount of calories. Sixty-one percent of the children did not receive an adequate amount of protein, 77 percent did not receive enough calcium, 70 percent did not obtain enough iron, and 45 percent did not obtain a sufficient amount of vitamin A. Seventy-nine percent of the children did not procure the recommended amount of thiamine, 55 percent did not receive enough riboflavin, and 67 percent were low in vitamin C. Kelly and Sheppard (1942) found that 26 percent of the hospital patients in the upper income groups in Philadelphia were ingesting less than 50 percent of the recommended levels for riboflavin, and 13 percent less than half the recommended allowances for thiamine and calcium.

Since cereals, as stated by Tobey (1942), still contribute 25 percent of the total calories in the average American diet, scientists began to consider enriching white flour with some of the vitamins and minerals present in the whole wheat berry. Nutritional benefits would result without disturbance of long established food habits and preferences, and without drastic changes in manufacturing and purchasing. This was not a new idea since the fortification of foods, such as milk with vitamin D, table salt with iodine, and margarine with vitamin A, had already been approved by the American Medical Association's Council on Foods and Nutrition (1939).

The first step in launching the movement to enrich flour and bread was the public hearing held in September 1940 by the Food and Drug Administration to consider a standard identity for flour. The millers felt prepared for the addition of only thiamine to flour, whereas nutritionists held that the prevalence of pellagra and the increasing evidence of arbiflavinosis called for the addition of niacin and riboflavin as well. The testimony also stressed the prevalence of anemia due to a deficiency of iron. Most of the groups favored the addition of larger quantities of thiamine, niacin, and iron, and also riboflavin when it could be made available.

In May 1941, the Food and Nutrition Board of the National Research Council, which advocated the enrichment program, obtained the approval of the Federal Food and Drug Administration for the enrichment of flour. Immediately following this the National Nutrition Conference for Defense was organized, and it urged the use of the term "enriched" rather than "restored" for the improved flour. The National Research Council had favored the use of the term "restored", which indicated that vitamins and minerals would be added to white flour to the same levels present in whole wheat.

The first standard for enriched flour required that 1.66 mg of thiamine, 6 mg of niacin, and 6 mg of iron be added to each pound of flour. When riboflavin became available in 1943, the standard was changed to include this vitamin and the amounts of the other vitamins and iron were increased in order to secure further nutritional benefits. The new minimum and maximum standards were as follows for each pound of flour: 2.0 to 2.5 mg of thiamine, 1.2 to 1.5 mg of riboflavin, 16.0 to 20.0 mg of niacin, and 13.0 to 16.5 mg of iron. Enriched bread would carry the proportion of enrichment ingredients that would be carried by bread made with enriched flour. In January 1943, the enrichment program was aided by War Food Order No. 1 of the Federal Security Administration which made it compulsory to enrich all white flour and bread sold in the United States. This order remained in force until 1946. However, there has been little decline in enrichment of bread and flour since its termination, for 21 states and Puerto Rico and Hawaii have passed compulsory legislation for enrichment of bread and flour. If all states would require enrichment, it would presumably benefit low-income groups, particularly if a business recession should occur. At such a time millers and bakers would be in strong competition, and in their efforts to cut costs, enrichment might be hampered.

The nutritional effect of the enrichment program should be considered. Lane, Johnson, and Williams (1942) estimated that if enriched bread replaced the conventional white bread in a diet containing 2500 calories, the average intakes of thiamine would be raised from 0.8 to 1.6 mg; of riboflavin, 1.4 to 1.8 mg; and of niacin, 11 to 17 mg. For a 2500 calorie diet, the National Research Council recommends 1.5 mg of thiamine, 1.8 mg of riboflavin, and 15 mg of niacin respectively. Thus with enriched bread in the diet, the requirements for these vitamins would be met.

The three vitamins, thiamine, niacin, and riboflavin, in which diets are most often deficient, have been added to enriched flour. All are members of the B-complex, and they all are connected with the coenzyme systems in the body. The coenzymes formed by these three vitamins are thiamine diphosphate or co-carboxylase, riboflavin adenine dinucleotide, and diphosphopyridine-mucleotide which contains nicotinic acid. Thiamine, riboflavin, and nicotinic acid must be present in the diet for the synthesis of these coenzymes. The need for these vitamins would be further increased when the diet consisted of a high percentage of carbohydrates, for these coenzymes are involved in the oxidative reactions that occur in intermediary carbohydrate metabolism. The diphosphopyridine-mucleotide accepts hydrogen from the metabolite or product of digestion. The hydrogen is then transferred to a dehydrogenase, riboflavin adenine dinucleotide, and finally a system is reached whereby the hydrogen is accepted by molecular oxygen. Along with these oxidative reactions, phosphorylation also occurs. In the breakdown of carbohydrates, organic acids are produced, and these are acted upon by the co-carboxylase to yield carbon dioxide.

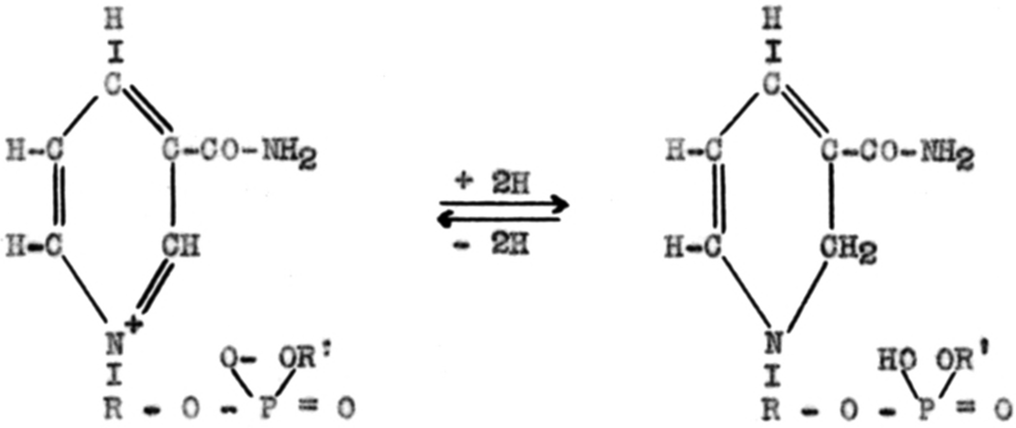
According to Kleiner (1948) the phosphopyridine-mucleotides (Coenzyme I and II) can be represented as follows:

Nicotinic acid-amide-d-ribose

Phosphoric acid (2 or 3 molecules)

Adenine-d-ribose

The important hydrogen carrier part of this molecule is the nicotinic acid amide. It may be shown in the following way:



Oxidized nicotinic acid amide

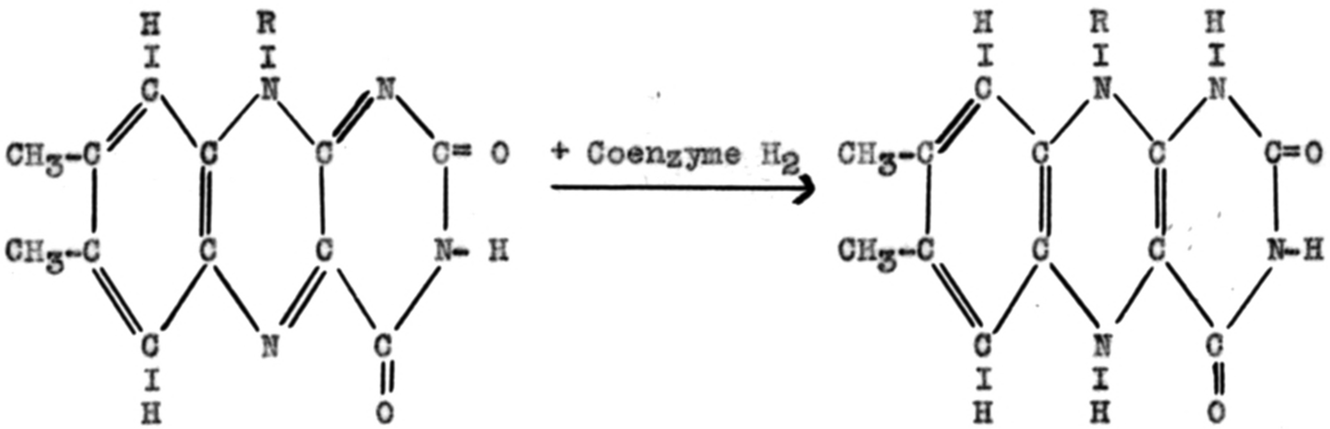
Reduced nicotinic acid amide

Coenzyme I and II cannot act independently, for they require the presence of protein enzymes or dehydrogenases, such as riboflavin adenine dinucleotide. After the coenzyme accepts hydrogen from the tissue metabolite, it is transferred to the dehydrogenase.

The dehydrogenase, riboflavin adenine dinucleotide is represented by Kleiner (1948) as follows:

Isoalloxazine-D-ribose-phosphate-phosphate-D-ribose-adenine
(Riboflavin)

The transfer of the hydrogen from the coenzyme to the dehydrogenase is represented thus:



Oxidized dehydrogenase

Reduced dehydrogenase

For regeneration of the reduced dehydrogenase molecular, oxygen is necessary.

As has been shown, the two vitamins which play an important part in this coenzyme dehydrogenase system are nicotinic acid amide and riboflavin. Both Coenzyme I and the dehydrogenase or yellow enzyme take part in the reactions involved in muscle glycogenolysis. These reactions may be represented as follows:

H_3PO_4
Glycogen ⇌ Glucose-1-phosphate
Phosphorylase
Mg^{++} Mn^{+} or Ca^{++}

Glucose-1-phosphate ⇌ Glucose-6-phosphate
Phosphoglucomutase

Glucose-6-phosphate ⇌ Fructose-6-phosphate
Phosphohexisomerase

Mg^{++} + Adenosine Triphosphate
Fructose-6-phosphate ⇌ Fructose-1,6-diphosphate
Phosphatase

Fructose-1.6-diphosphate ⇌ 3 Phosphoglyceraldehyde
Aldolase
↑↓
Dihydroxyacetone phosphate

H_3PO_4
3 Phosphoglyceraldehyde ⇌ (1,3-Diphosphoglyceraldehyde)

Coenzyme I (Diphosphopyridine-nucleotide)
(1,3-Diphosphoglyceraldehyde) ⇌ 1,3-Diphosphoglyceric acid
Dehydrogenase (Riboflavin adenine dinucleotide)

$$\text{1,3-Diphosphoglyceric acid} \xrightleftharpoons{\text{Adenosine Diphosphate}} \text{3 Phosphoglyceric acid} + H_3PO_4 + \text{Energy}$$

$$\text{3 Phosphoglyceric acid} \xrightleftharpoons[\text{Phosphoglyceromutase}]{} \text{2 Phosphoglyceric acid}$$

$$\text{2 Phosphoglyceric acid} \xrightleftharpoons[\text{Enolase} + H_2O]{} \text{(Enol) -Phosphopyruvic acid}$$

$$\text{(Enol)-Phosphopyruvic acid} \xrightleftharpoons[Mg^{++}]{\text{Adenosine Diphosphate}} \text{Pyruvic acid} + H_3PO_4 + \text{Energy}$$

$$\text{Pyruvic acid} \xrightleftharpoons[\text{Lactic dehydrogenase}]{\text{Coenzyme I (Diphosphopyridine-nucleotide)}} \text{Lactic acid}$$

In normal muscle contraction there are two phases. One, the contractile phase, in which the lactic acid produced, as in the above reaction, is reconverted to glycogen; and the other, the recovery phase, in which pyruvic acid or lactic acid is oxidized to carbon dioxide and acetaldehyde. The latter reaction requires the presence of the enzymes cocarboxylase, which is thiamine diphosphate, and riboflavin adenine dinucleotide. This reaction may be represented as follows:

```
CH3
 l           Cocarboxylase                    //O
C = O       ----------------->          H - C          + CO2
 l          Riboflavin adenine-              l
CO-OH         dinucleotide                  CH3

Pyruvic acid                            Acetylaldehyde
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The above reaction occurs in all body tissues carrying on the oxidation of carbohydrates. If not enough thiamine is present in the diet, the enzyme cocarboxylase cannot be synthesized in sufficient quantities. Therefore, the oxidation of pyruvic acid does not proceed at a normal rate, and it accumulates in the blood surrounding these tissues. Since oxidation proceeds at a very fast rate in the nervous tissue, this is the first place to be affected by a lack of thiamine in the diet. The first symptoms usually noticed are fatigue and irritability, and these are followed by a lack of muscle coordination.

The vitamins used to enrich flour; namely, thiamine, riboflavin, and niacin, have been shown to be constituents of the coenzymes which are important in the intermediary metabolism of carbohydrates. An increased intake of these vitamins is particularly important in the diet of people with low incomes, because they consume large amounts of carbohydrates in the form of refined cereals. This study was undertaken to see if low-income diets could be further improved by the use of enriched flour.

REVIEW OF LITERATURE

When cereal chemists first started to analyze wheat, the starch and protein constituents were considered of primary importance. Starch and protein are the two largest components of flour, because they are both contained in the endosperm fraction of the wheat berry. Also the starch and protein help to determine the baking characteristics of the flour.

The approximate composition of wheat as stated by Kent-Jones (1939) is as follows:

	Percent
Moisture	8-17
Starch	63-71
Protein	8-15
Cellulose	2- 3
Fat	1.5- 2
Sugars	2- 3
Mineral matter	1.5- 2

Starch, according to Swanson (1941), occurs in the wheat endosperm as a sphero-crystal granule with a layered structure, and each granule has an outer coating of cellulose or insoluble starch. Bice, MacMasters, and Hilbert (1945) found that the first starch granules in the growing wheat grain are small, smooth, and transparent, and devoid of many substances found in the mature grain. With increasing maturity of the wheat, the granules become somewhat less transparent and show lamellation and surface irregularities, because of the increase in starch content.

Two forms of starch develop in the endosperm, amylose, water soluble, and amylopectin, water insoluble. Amylose consists of a straight chain molecule of glucose units, with a molecular weight of 300. Amylopectin is a branched chain of glucose units with a molecular weight well over 1000. Phosphoric acid and fatty acids are often found as part of the molecule of amylopectin. Amylopectin always predominates in wheat, as it is laid down more rapidly in the early stages of growth.

Osborne and Mendel (1907) are noted for their work on wheat proteins. Through their efforts, the proteins of the wheat kernel were divided into: gliadin, soluble in 70 percent alcohol;

glutenin, soluble in dilute acid and alkaline solutions; leucosin, an albumin-like protein, freely soluble in pure water; and a globulin plus a protease, both present in small quantities. Chief constituents of gluten are gliadin and glutenin, which together make up over 80 percent of the total protein in the seed. Kent-Jones (1939) stated that the proteins of wheat are not evenly distributed throughout the grain, for the bran and germ are higher in protein content than the endosperm.

About two-thirds of the total fat is in the germ area. Wheat oil consists mostly of unsaturated fatty acids. When these unsaturated acids become oxidized, very drastic effects on baking action result. The sugars in wheat are sucrose, dextrins and maltose, all of which are present in small quantities. The amount of diastatic enzymes which convert the starch to sugar are more important than the amount of fermentable sugars. The mineral matter remains behind as a white ash when flour is heated to a high temperature. The principal minerals in wheat are phosphorus, potassium, calcium, magnesium, sulfur, and iron.

There are many commercial grades of flour, as flour is made from many blends of wheat. The following, according to Kent-Jones (1939), is just an approximate analysis:

	Percent
Water	13-15.5
Starch	65-70
Protein	8-14
Cellulose and fat	1- 1.5
Sugar	1.5- 2
Mineral matter	0.3- 0.6

The process of milling according to Copping (1930) has only a slight effect on the protein and carbohydrate content, but by the removal of the germ, the fat content of flour is about one-half that present in whole wheat. Also the ash content is one-sixth the amount present in whole wheat because of the removal of bran. White flour which contains no germ or bran has about one-half the calcium present in whole wheat, one-fourth the potassium, one-fifth the phosphorus, and one-fifth the iron.

Of equal importance are the amount and location of the B-vitamins in the grain and their retention in flour. As stated by Sherwood, Nordgren, and Andrews (1941) the vitamins of wheat are not uniformly distributed throughout the kernel, but are concentrated in certain tissues. Of the total thiamine in the wheat kernel, the endosperm contains about 24 percent, the embryo 15 percent, and the outer layers of the kernel about 61 percent. Bell and Mendel (1922) and Andrews (1943) found that the germ contributes about one-third the total thiamine content of wheat, and the non-germ tissues contribute about two-thirds of the total. Jackson and Doherty (1943) and Moran (1945) by dissection experiments, found the thiamine to be largely concentrated in the scutellum portion of the germ. The scutellum contained 44 ug of thiamine per g and carried 59 percent of the total thiamine of wheat. Somers, Cooledge, and Hamner (1945) determined the location of the thiamine by treating the cut surfaces of grains with potassium ferricyanide. The thiamine present is oxidized to thiochrome, and this compound fluoresces when illuminated with a mercury vapor lamp. These investigators found that the thiamine was located principally in the aleurone layer, endosperm cells adjoining aleurone cells at the base of crease, scutellum of embryo, and the endosperm adjoining the scutellum.

According to Moran (1945) and Jackson and Doherty (1943) the riboflavin was more uniformly distributed throughout the grain, although the highest concentration was in the germ. Andrews, Boyd, and Terry (1942) didn't find the riboflavin distribution so uniform, as two-thirds of the total riboflavin was contained in the red dog, shorts, and bran. Somers, Cooledge, and Hamner (1945) found that the aleurone layer contained considerable amounts of riboflavin, and that the bran coats contained some. The inner cells of the endosperm appeared to contain little riboflavin.

Andrews, Boyd, and Gortner (1942), Jackson and Doherty (1943), and Moran (1945) found that the niacin content of wheat is concentrated in the bran. Teply, Strong, and Elvehjem (1942) found the pyridoxine concentrated in the germ portion of the wheat, but not the niacin or the pantothenic acid.

Conner and Straub (1941) found the thiamine content of hard wheat to range from 3.65-6.90 ug per g with an average of 5.03 ug per g. Schultz, Atkin, and Frey (1941) found a wider range, 4.2-7.3 ug per g with an average of 5.6 ug per g. Andrews (1943) found the average thiamine value of all types of wheat to be 1.4-3.5 mg per pound with soft wheats lowest and spring wheats highest. Sherwood, Andrews, Nordgren (1941) and Hoffman and

Schweitzer (1940) found a relationship between thiamine and ash contents of flours. Morris, Alexander, and Pascoe (1945), by means of a microdissection technique, found the lowest concentration of ash in cheek endosperm fractions, and that the center endosperm fractions were 0.05 percent higher. Lowest concentrations of protein were found in the center endosperm and the cheek fractions were somewhat higher. Nordgren and Andrews (1941) found no relationship between protein and thiamine content of wheat, but Conner and Straub (1941) did.

Conner and Straub (1941) reported no significant differences in the riboflavin range of hard and soft wheats, which were found to be 0.89-1.91 ug per g and 0.81-1.48 ug per g respectively. Boyd and Terry (1942) reported average riboflavin values of 1.20, 1.17-1.22, and 1.17 ug per g for hard spring, hard winter, and soft wheats respectively. Teply, Strong, and Elvehjem (1942) found all samples of wheat to average in ug per g, 52-74 for niacin, 10.2-15.0 for pantothenic acid, and 4.1-4.7 for pyridoxine.

Conner and Straub (1941) and Andrews (1943) found the thiamine values of wheat affected by locality, environment, and variety. Conner and Straub (1941) reported the riboflavin values to be affected by locality. Andrews, Boyd, and Terry (1942) reported negligible effects of environment, but some differences in variety. Later Andrews (1943) stated that riboflavin was not influenced by variety or environment. Teply, Strong, and Elvehjem (1942) stated that in the case of dark, hard winter wheats, neither varietal nor environmental differences have any effect on pantothenic acid or pyridoxine. Niacin content is dependent upon variety and environment.

Schultz, Atkin, and Frey (1942) assayed the mill streams of two old American flour mills and found that the best white flours of a century ago contained concentrations of thiamine comparable to the whole grains from which they were made. The high thiamine content in stone milled flours was attributed to the presence of a large portion of the aleurone layer of the wheat berry. With the modern method of wheat milling, Schultz, Atkin, and Frey (1939) found the distribution of thiamine to be 82.5 percent in feed, 18 percent in straight flour, and 6.7 percent in patent flour. Straight flours averaged 1.5 ug per g, and short patent flour 0.7 ug per g of thiamine. Patent flour as stated by Nordgren and Andrews (1941) generally contains about one-seventh of the thiamine of whole wheat, and as stated by Andrews, Boyd, and Terry (1942), one-third of the riboflavin. Teply, Strong, and Elvehjem (1942) and Andrews (1943) agree that patent flour contains one-sixth as much niacin as whole wheat and one-half as much pantothenic acid and pyridoxine.

Andrews (1943) and Jackson and Doherty (1943) both agree on the distribution of the vitamins in the different mill streams. The shorts and the red dog contain more of the total thiamine of the wheat than any other fraction. As milling extraction is extended, thiamine first shows a rapid rise, and then tapers off as the bran portions are included. Inclusion of the bran portions only causes a linear increase in the riboflavin content. Again the shorts contain more of the total riboflavin than any single fraction, but the total combined flours contained 40 percent of the riboflavin as compared to 25 percent of the thiamine. Niacin failed to increase appreciably until a large portion of the bran was included.

The vitamin and iron values of whole wheat and white flour are compared to the enrichment levels of white patent flour as follows:

	Whole wheat flour mg/lb.	White flour mg/lb.	Enriched flour mg/lb.
Thiamine	2.53	0.30	2.0
Riboflavin	0.56	0.15	1.2
Niacin	25.30	3.50	16.0
Iron	17.3	3.0	13.0
Pantothenic acid	6.03	2.59	
Pyridoxine	2.09	0.99	

The value for thiamine, riboflavin, niacin, and iron were taken from Tables of Food Composition (1945), those for pantothenic acid and pyridoxine from Teply, Strong, and Elvehjem (1942), and the values for enriched flour from Williams and Wilder (1944).

Since consumers eat more white bread than they do whole wheat bread, it should be of value to consider how these compare in vitamin and mineral content, their importance in diets, their ease of digestibility, and the biological value of their proteins.

Schultz, Atkin, and Frey (1941) in tests on 31 samples of whole wheat flours and bread reported the thiamine in the flour ranged from 1.90-2.53 mg per pound, and the breads averaged 1.35 mg per pound or about 60 percent of the thiamine present in flour. Andrews, Boyd, and Terry (1942) found that fresh whole wheat bread averaged 1.6 to 2.09 ug per g of riboflavin, depending upon the proportions of nonfat milk solids used. Whole wheat bread has been reported by Teply, Strong, and Elvehjem (1942) as having 13.08 mg niacin per pound, but Thomas, Bina and Brown (1942) reported only 4.08-5.25 mg per pound. Studies on the iron content of whole wheat breads by Hoffman, Schweitzer, and Dalby (1940) and Free and Bing (1940) have shown variations from 4.4 to 22.1 mg per pound. Tobey and Cathcart (1941) stated that most whole wheat breads contained 9-15 mg of iron per pound.

Tobey and Cathcart (1941) reported that non-enriched white bread, made with 6 percent nonfat milk solids, usually has from 0.30-0.45 mg of thiamine per pound, 3.0-5.7 mg niacin per pound, 0.6 mg riboflavin per pound, at least 4.0 mg iron per pound, and from 0.3-0.4 g calcium per pound. Maynard and Nelson (1948) stated that with the addition of 6 percent nonfat milk solids to enriched bread, the thiamine content was approximately three times as large as that of ordinary bread, the iron content was increased four times, and the niacin content three times. Tobey (1942) reported that dry skim milk solids average in ug per g 22 of riboflavin, 3 of thiamine, 18 of niacin, and also some pantothenic acid and pyridoxine. Therefore, an increase or decrease above or below the 6 percent milk solids as commonly used in white bread would cause a corresponding increase or decrease in the vitamin content of the bread.

The values reported by Tobey for whole wheat (1942) and non-enriched white bread (1941) when compared to the present standards for enriched bread listed by Williams and Wilder (1944) are as follows:

	Whole wheat bread mg/lb.		White bread 6% milk solids mg/lb.		Enriched bread mg/lb.	
	Min.	Max.	Min.	Max.	Min.	Max.
Thiamine	0.66	2.64	0.30	0.45	1.1	1.8
Riboflavin	0.27	0.40	0.60		0.7	1.6
Niacin	6.00	15.00	3.00	5.70	10.0	15.0
Iron	9.00	15.00	4.00		8.0	12.5

Free (1940) made a study on 17 young women who substituted a special high vitamin B_1 bread for ordinary bread in their regular diets for a period of five weeks. The bread contributed about 16 percent of the total caloric value and about 34.1 percent of the total thiamine intake. Results showed no significant change in the red blood cell counts or the hemoglobin content, but the urinary excretions of thiamine nearly doubled. Of the 17 women, 15 reported they liked the bread, and six reported an increase in appetite.

Chick (1940) tested the nutritive value of straight-run white flour (73 percent extraction) in comparison with wholemeal flour on white rats. Salt mixture, casein, and pure Vitamin B_1 were added to the white flour to bring the diet up to optimum for the growing rat. The average weekly weight gains on the wholemeal flour were superior, and this was attributed to the lack of the B_2 vitamins in the white flour.

Higgins, Williams, and Mason (1943) reported results on feeding rats a thiamine-low diet. The diet used was similar to that consumed by large portions of our population. Diets differed only in the flour from which the breads were made. The addition of thiamine to patent white flour, at a level approximately equal to whole wheat, did not produce any significant difference in the weights of the rats in comparison with those receiving white flour. But the addition of both thiamine and riboflavin to white flour at the levels present in whole wheat produced growth gains in rats equal to those obtained on the whole wheat flour diet. Rats receiving the wholewheat diet or the white flour diet fortified with thiamine and riboflavin had similar red blood cell counts and hemoglobin levels.

Higgins, Williams, Mason, and Gatz (1943) found the whole wheat bread as a component of the same diet used in their previous experiment, gave a much better growth rate than bread made with white flour. When thiamine, riboflavin, and niacin were included in white flour at whole wheat or enrichment levels, the growth rate was still higher with whole wheat bread. Normal blood values were obtained by both the whole wheat and the flour fortified with thiamine, riboflavin, and niacin. The concentration of the thiamine in the liver, skeletal muscle, kidney, and testes was lowered in a striking manner when the diet contained non-enriched white flour. A similar picture was observed for riboflavin in the liver and kidney only. Hepatic tissue changes and body growth were benefitted by the enrichment of flour with the B-vitamins, but not to the extent obtained with whole wheat bread.

Williams, Mason, and Wilder (1943) studied the nutritive contribution of whole wheat, enriched, and non-enriched flour by giving seven women a diet composed of foods which commonly appear on the American table. Flour contributed 30 percent of the calories. The subjects receiving non-enriched flour developed a moderate chronic thiamine deficiency. Those receiving enriched white flour, with 6 percent milk solids, developed no symptoms of nutritional deficiency, but two subjects had low excretions of thiamine and riboflavin and abnormal elevations of pyruvic acid after the administration of dextrose. Those receiving whole wheat had the same symptoms as well as weakness and loss of appetite. Thus the physical status of the subjects on the enriched flour diet with 6 percent milk solids was just as good as those on the whole wheat diet.

Westerman and Bayfield (1945) reported the value of enriched, Morris type, and whole wheat flour as sources of the B-vitamins. The above flours were incorporated into purified diets at 30, 40, and 50 percent levels, and fed to rats. The flour was the only source of the B-vitamins. At the 30 and 40 percent levels, the animals fed whole wheat and white flour enriched with thiamine, riboflavin, and niacin gained an equal amount of weight, and they made greater gains than those receiving white flour enriched with only thiamine and niacin. At the 50 percent level, the animals receiving white flour enriched with all three vitamins gained more weight than those fed whole wheat or the white flour enriched with thiamine and niacin. None of the animals grew as well as those on the stock ration.

Westerman and Hall (1947) studied the effect of supplementing enriched flour with other B-complex vitamins. The diets contained 40 percent enriched flour in which the added vitamins were incorporated. Greatest gains were made by the rats receiving 7 ug of pyridoxine and 20.5 ug of calcium pantothenate per g of enriched flour. Differences in average weight gains were slight between those receiving 20.5 ug calcium pantothenate in the enriched flour, and those receiving 3.5 ug pyridoxine in the enriched flour. When pyridoxine was added to enriched flour, the animals made greater growth gains than when calcium pantothenate was added to enriched flour, but both together gave better results. It was also noted in this experiment that the addition of both riboflavin and thiamine to enriched flour stimulated greater growth than that obtained by the addition of either vitamin alone.

Westerman and Templeton (1948) made further studies on the effect of supplementing enriched flour with more of the B-complex vitamins. It was found that the animals with additional riboflavin or calcium pantothenate in the diet lived longer and showed fewer deficiency symptoms than those animals on the diet with just choline and pyridoxine added to the enriched flour. Reproduction and length of life were also better when enriched flour contained more of the B-complex vitamins. On the 40 percent and 60 percent levels, the rats on enriched flour made better weight gains than those on whole wheat and whole wheat plus added thiamine.

Guerrant and Fardig (1947) compared the thiamine and riboflavin content of whole wheat, non-enriched and enriched flour and breads. These flours and breads were incorporated in the purified diets at the 30 percent level. The results showed that ground whole wheat furnished sufficient thiamine and riboflavin to sustain life and to support a slow rate of growth. The addition of a thiamine-niacin supplement was less effective than the riboflavin-niacin supplement to the whole wheat diet. When diets containing 30 percent of non-enriched flour were supplemented with thiamine, riboflavin, and niacin, an immediate and continued growth response resulted. With just a riboflavin-niacin supplement, deficiency symptoms seemed to be accentuated, and the animals died off faster than those not receiving any supplements. With 30 percent of enriched flour, favorable growth was obtained with and without vitamin supplements. As with whole wheat, the riboflavin-niacin supplement was more effective than the thiamine-niacin supplement. Results with 30 percent bread instead of flour gave similar results in all cases except for slightly better growth being obtained by the animals on all the bread diets.

Winters (1947) conducted an experiment feeding rats the type of food eaten by human beings. The food mixture represented that of an average American diet, and 30 percent of the calories were derived from cereal. This same diet was diluted with one-sixth more cereal, and with one-third more cereal so as to provide 33 and 36 percent of the calories from cereals. It was thought that the higher percentage of calories derived from cereals would be more typical of low income diets. At the different cereal levels, the growth of the animals on the enriched and non-enriched flour was approximately the same, and reproduction was consistently poor. According to Westerman and Bayfield (1945) at least 50 percent of the calories must be derived from cereals before rats will show a difference in growth on enriched and non-enriched flour diets.

Beaty and Fairbanks (1948) fed female rats six different types of bread supplemented with cod liver oil. Alpha-tocopherol was given before mating. The growth gains made by rats fed whole wheat bread were equal to those fed enriched nonfat milk bread which was composed of white flour with 6 percent nonfat dry milk solids and enriched with thiamine, riboflavin, niacin, and iron. Also the bread made with enriched flour with no added milk solids promoted slightly better growth than bread made with non-enriched flour, but the differences between these two breads were not significant during the gestation-lactation period. On the basis of the percentage of rats weaned from the third litters, bread made with non-enriched white flour was nutritionally equal to bread made with enriched flour with no added milk solids and significantly superior to both whole wheat bread and whole wheat bread containing 6 percent nonfat dry skim milk solids.

Mitchell, Hamilton, and Shields (1943) carried out some interesting experiments on the contribution of nonfat milk solids to bread. They found that bread made with enriched flour promoted a poorer growth in rats than the breads containing dried skim milk solids. Also the enrichment of the white breads containing skim milk solids did not promote any greater growth, but the hemoglobin concentration in the blood was greater. Enriched white bread containing skim milk solids was equal to whole wheat in growth promotion, hemoglobin production, and especially bone calcification. Their conclusion was that white bread should not only contain the enrichment materials, but 6 percent skim milk solids as well.

Light and Frey (1943) also found that enriched white bread with 6 percent dry skim milk solids promoted growth equal to whole wheat bread. Their results showed that white bread made from high patent flour and without milk was deficient in lysine, valine, riboflavin, and mineral salts.

Sealock, Basinki, and Murlin (1941) used 10 men subjects to test the apparent digestibility of fat, carbohydrate, and "indigestible residue" of white and whole wheat breads. They found that the whole wheat breads with 5 percent nonfat milk solids gave the highest protein value. The ~~white~~ whole wheat breads had 68-76 percent "indigestible residue", and the ~~whole~~ white wheat breads had lower values of 55-62 percent. However, the greater "indigestible residue" of the whole wheat bread did not interfere with the absorption of fats or carbohydrates.

Murlin, Marshall, and Kockakian (1941) did studies on 11 men subjects with diets planned to supply 80 percent of the food nitrogen from whole egg and 80 percent from bread in alternate periods of six days each. It was found that whole wheat breads gave lower true digestibility values for the protein than the white bread, but higher biological values than the white breads. In one case a white bread containing 5 percent nonfat milk solids produced a higher biological value than the whole wheat with the same milk content. French and Matill (1935) in a study of biological values of white, wheat, and rye breads found that the biological values for white and wheat breads were 83 and 80 respectively when consumed by mature rats. The biological value of all three breads was 83 when consumed by human subjects.

Murlin and Matill (1938) studied the digestibility and nutritional values of three breakfast cereals: a wheat endosperm product, a precooked rolled oats, and a whole wheat product. It was found that wheat endosperm had the best apparent digestibility of protein. Whole wheat and precooked oats differed slightly. The name replacement value was given to the value of the cereal protein in comparison with milk as standard protein. Wheat endosperm had the highest replacement value, precooked oats lower, and whole wheat lowest.

Krebs and Mellanby (1942) have studied the digestibility of white flour (75 percent extraction) with National Wheat Meal of Britain (85 percent extraction). They reported values of 97 percent and 94 percent for the dry matter digested in white and wholemeal flours. Nitrogen utilization was 91 percent and 89 percent for the white and wholemeal flours respectively.

McCance and Widdowson (1947) carried out experiments on English and Canadian wheats at 90 and 80 percent extraction on five human subjects. The flour was the only source of protein. At 90 percent extraction, the digestibility of the diets in terms of calories was unaffected by the source of flour and amounted to 93.3 percent. At 80 percent extraction, the digestibility of the diet which contained English wheat amounted to 95.6 percent, and that which contained Manitoba wheat 96.7 percent. The protein in the wheat flour of 90 and 80 percent extraction was completely digested and absorbed.

Chick (1942) also studied the biological value of the proteins in wheat flours. It was found that 10.5 g of the mixture of proteins in whole wheat was as useful to the rat as 13.1 g of white flour protein. Slight differences in digestibility favoring white flour was more than compensated by the greater biological values of the national wheat meal. The national wheatmeal also promoted greater growth in rats.

Sure (1946) did an experiment on the protein efficiency of enriched flour and whole wheat flour using rats. The protein efficiency was expressed as gains in weight per g of protein intake. At 5.8 percent protein intake, the enriched patent flour proteins had an efficiency of 0.88, while on wheat flour the protein efficiency was 0.72.

Iron compounds used for enrichment should be harmless, assimilable, and without deleterious action on flour or bread.

Ferric phytate and sodium iron (ferric) pyrophosphate have been used in the mill enrichment of flour, but both have been replaced by reduced iron. Ferric orthophosphate is generally used when enrichment is carried out at the bakery.

Nakamura and Mitchell (1943) found that the iron in sodium iron pyrophosphate and ferrum reductum were as easily utilized by rats as the iron in ferric chloride. Freeman, Smith, and Burrill (1945) fed depleted rats iron compounds as a supplement to the milk diet fed ad libitum. The rats which received ferric chloride with sugar or bread, showed the greatest iron retention and hemoglobin regeneration. The ability of sodium ferric orthophosphate both as a salt and in bread was only slightly less in the same functions than ferric chloride iron. Reduced iron was somewhat less effective, and sodium iron pyrophosphate was the least effective compound studied.

Blumberg and Arnold (1947) compared the biological availabilities of the iron in ferrous sulfate and ferric orthophosphate as the basis of hemoglobin regeneration in rats made anemic from iron deficiency. The iron compounds fed were incorporated in the enriched breads. It was found that ferrous sulfate iron was four to five times as available as ferric orthophosphate iron when both compounds were tested at four widely spaced levels. Ferric chloride iron was equal in biological availability to the ferrous sulfate iron.

A review of the literature indicated that additional data are needed to prove the value of the enrichment of flour and bread.

Many experiments have shown that larger amounts of thiamine, riboflavin, niacin, and iron are provided in diets when enriched cereals are used. This is particularly true when the cereal component of the diet furnishes a high percentage of the calories. Also experiments need to be conducted using natural foods instead of purified foods.

People having low incomes are most apt to consume large amounts of cereal foods because these are a cheaper source of energy. Therefore, a study based upon the diets of people having low incomes might give further information regarding the benefits of enriched and non-enriched flour.

Dickens (1928) made a study of the diets used by Negro tenants in the Yazoo Mississippi Valley. It is interesting to consider the types of foods eaten by these people, and how they were prepared. It was noted that white flour consumption was higher than cornmeal consumption. It seems that Mississippi people, whether they are white or black, like to eat biscuits. Whole wheat flour was not used by a single family. Milk did not appear on 12½ percent of the Negro records. Eggs averaged about two and one-half per family per day, and this was considered high as this study was conducted during egg season. Meat consumption was low and fat consumption high because of the use of salt pork. The fruit and vegetable consumption was very low. The rural whites and the Negroes in better circumstances usually raise enough sweet potatoes to last well into spring, but at the time of this study, most of the Negro families had used up their supply. A large proportion of calories was furnished by sweets in the form of molasses. Few desserts were used.

Frying and boiling were the methods of preparation in general use. Eggs were well done, even for children. Vegetables were overcooked in fat. Cornbread was usually made of cornmeal, salt, and water, and that too was fried. Most of the meat was fried done and hard. Cooking in the average home was very poor. Since these diets were high in cereals and were consumed by people with low incomes, it was decided to use them as the basis for a series of experiments.

EXPERIMENTAL PROCEDURE

The three experiments conducted in this study were based upon the menus served in the homes of the Negro tenants in the Yazoo Mississippi Delta as reported by Dickens (1928). The menus were divided into three groups: better menus, typical menus, and the most inadequate menus. A weekly menu representative of the foods contained in the better, typical, and most inadequate menus may be seen in Tables 1, 2, and 3 respectively. The typical menu served as the basis for the first two experiments. The third experiment was based upon the better menu and the most inadequate menu.

The weekly menus as shown in Tables 1, 2, and 3 were changed to average daily menus as summarized in Table 4 in order to prepare the diets on the basis of the amount of food consumed per person per day. The servings per person per day were converted to grams per day for experimental use. Since bread was the main item in all three menus, a serving was considered to be between three and four slices which weighs approximately 100 g. Whole wheat, enriched and non-enriched flour were used to represent the cereal component of the diets.

In order to facilitate the preparation of the food under laboratory conditions, certain food groupings had to be made. Cornbread, biscuit pudding, cake and rice were all included as cereals. Salt pork and chitlings were considered as fat. Dried whole milk was used in place of liquid milk in order to reduce the liquid content of the diet. Cabbage, green beans, and spinach were used alternately as the green vegetable. Applesauce was used to represent the fruits. The meat component of the diet was supplied by equal amounts of beef and pork.

In the preparation of the diets, the potatoes, green vegetables, black-eyed peas, and meat were cooked. Then the proper amounts of each of these foods were weighed for the respective diets. The cooked foods were then added to the other weighed wet ingredients of the diet; namely, eggs, molasses, fat, and canned applesauce, and put through a blender. Next the homogeneous wet mixture was mixed with the weighed dry ingredients; namely, flour, dried milk and salt. The wet ingredients of the diet needed to be of a smooth consistency and uniformly distributed with the dry ingredients in order that the rats which consumed these diets could not pick out the individual foods. The diets were made once a week, placed in pint jars, and stored at -4^{o}F. until needed.

In order to calculate the nutritive value of the diets, a table of food composition based upon the data given by Sherman (1946) and by Turner (1946) for 100 g portions was compiled, Table 5. Using this table, the amount of calories, protein, fat, carbohydrate, calcium, iron, vitamin A, thiamine, riboflavin, niacin, and vitamin C in the different diets was computed. The figures for the protein, thiamine, riboflavin, and pantothenic acid content of enriched and non-enriched flour were obtained by laboratory analysis. The flour averaged 12.31 percent protein. The enriched flour contained 6.94, 3.00, and 1.15 ug per g of thiamine, riboflavin, and pantothenic acid respectively and the non-enriched flour 1.35, 0.74, and 1.12 ug per g of these same vitamins.

Young albino rats weighing between 45 and 55 grams were used in these experiments. Each animal was placed in an individual cage on a raised wire screen to prevent consumption of feces. All the rats were fed a B-complex free diet for two weeks before the beginning of each experiment to deplete the body stores of these vitamins. The diet consisted of the following ingredients:

	Percent
Vitamin-free casein	20
Sucrose	60
Fat	12
Salt mixture	5
Cod liver oil	3
Total	100

After the two-week interval on the B-free diet, six to ten animals, distributed equally according to sex and litter mates, were placed on each test diet. A record of the growth of the animals on each diet was obtained by weighing the animals once a week. When the growth period was completed, the animals were mated for reproduction studies. Red blood cell counts and hemoglobin tests were performed during the growth and reproduction periods. Thus there were three methods of evaluating the diets: growth rate of the rats, reproduction, and blood studies, which consisted of the determination of erythrocyte counts and hemoglobin levels.

The first experiment was based upon the typical weekly menu, the content of which is shown in Table 2. This cxperiment was set up as a preliminary study in order to determine whether the mixture of natural foods as contained in the typical menu would be sufficiently palatable to the rats so that they would eat enough to survive. Two Diets, I and II were based upon the typical menu, and the cereal components of the diets were represented by enriched and non-enriched flour respectively. The mutritive value of Diets I and II may be seen in Tables 6 and 7. Fifty-eight percent of the calories were supplied by cereals. Seven rats, three females and four males, were used on each of the diets. As a control, seven rats, four females and three males, were placed on a stock diet which consisted of Purina Dog Chow supplemented with 15 g of lettuce and 6 g of meat per week for each rat.

The animals were kept on growth tests for 10 weeks. Every week each rat was dosed with a mixture of alpha tocopherol and cod liver oil dissolved in corn oil which provided 20 mg of alpha tocopherol, 1888 I U of vitamin A, and 179 I U of vitamin D. At 10 weeks, the rats were mated for reproduction. During this time a record was kept of the number of young born, how long they survived, the number weaned at 22 days, and their average weights at the end of the 22-day period.

Hemoglobin studies were made three times on all the female rats during the growth test. The first tests were performed immediately preceding the placement of the animals on the test diets, and the second and third studies were made after four and eight weeks on the test diets. During reproduction, red blood cell counts and hemoglobin studies were made one to three days before the young were born, the day the young were born or the day afterwards, two weeks later if the young did not survive, and three weeks later if the young lived. If the blood values of the mothers were not back to normal at this time, blood tests were performed every week until the blood values became normal.

A growth study was made on the young born to the mothers on Diets I and II and the stock ration. The second generation study also continued for 10 weeks. Blood studies were not made on these animals.

Since the animals were able to grow and reproduce on the diets in the first experiment, a second experiment was started which was also based upon the typical weekly menu in Table 2. Ten diets were used which varied either in their cereal component or in the added supplements of salt mixture and vitamin-free casein. The nutritive value of Diet I, which derived 58 percent of the total calories from whole wheat, is shown in Table 8; Diet II, which had 58 percent of the total calories from enriched flour, in Table 6; and Diet III, with 58 percent of the total calories from enriched flour with salt mixture added, is shown in Table 9. Diet IV, deriving 55 percent of the total calories from enriched flour with vitamin-free casein added, is shown in Table 10; Diet V, with 55 percent of the total calories from enriched flour with salt mixture and vitamin-free casein added, in Table 11; and Diet VI, which had 53 percent of the total calories from cornstarch with salt mixture and vitamin-free casein added, in Table 12. Diet VII, which derived 58 percent of the total calories from non-enriched flour, is shown in Table 7; Diet VIII, with 58 percent of the total calories from non-enriched flour with salt mixture added, in Table 13; Diet IX, which had 55 percent of the total calories from non-enriched flour with vitamin-free casein added, in Table 14; and Diet X, which derived 55 percent of the total calories from non-enriched flour with vitamin-free casein and salt mixture added, is shown in Table 15. Table 16 shows the summary of the total mutritive value of Diets I through X. Six animals, three males and three females, were placed on each diet, except for Diets VI, IX, and X which had four males and two females.

Enriched and non-enriched flour represented the cereal component of Diets II and VII respectively, and these diets were like Diets I and II in Experiment I. These two diets were considered as standards when comparing the diets with different cereal components or added supplements. Whole wheat has often been compared with enriched and non-enriched flour when fed to rats on purified diets, therefore, a comparison in diets consisting of natural foods was thought even more valuable. Whole wheat represented the cereal component of Diet I. In Diet VI, a purified carbohydrate, cornstarch, was used to replace the cereal in an attempt to find out whether a diet without the cereal component would prove adequate, especially without the B-vitamin content of the flour.

Enriched and non-enriched flour represented the cereal components of Diets III and VIII respectively, but additional minerals were added in the form of salt mixture to both diets. Since the amount of calcium in the diets was low, enough salt mixture was added to bring the calcium level to at least 1 g, the recommended allowance for the adult human being. This necessitated letting the iron fall where it would, for the iron content of the diet was already adequate. In order to detect whether sufficient or insufficient amounts of the B-vitamins were present in the diets, none of the other nutrients should be below recommended amounts.

Diets IV and IX had enriched and non-enriched flour respectively as the cereal components of the diets, but additional protein was added in the form of vitamin-free casein to both diets. The protein content of the diets was not low since 79 g of protein was provided. However, 30 g of protein, in the form of vitamin-free casein, was added to the 79 g of protein supplied by the diet in order that protein would not be one of the limiting factors. In Diets V and X, salt mixture and vitamin-free casein were both added, but in the same amounts as in the other diets. In these two diets neither protein nor the minerals would be limiting factors. Enriched and non-enriched flour represented the cereal components of Diets V and X respectively. In Diet VI which contained cornstarch, enough vitamin-free casein was added to bring the protein level up to 79 grams, the same as in Diets II and VII. Also the same amount of salt mixture was added as in the other diets. By doing this, the cornstarch diet was only lacking in the B-vitamins.

In the second experiment, the animals were kept on growth tests for 12 weeks. They were also given a mixture of alpha tocopherol and cod liver oil weekly which provided 20 mg of alpha tocopherol, 1888 I U of vitamin A, and 179 I U of vitamin D. At 12 weeks, the animals were mated for reproduction. During this time a record was kept of the length of time taken to mate, the number of young born, how long they survived, the number weaned at 28 days, and their average weights at the end of the 28-day period.

Red blood cell counts and hemoglobins were made four times on the female rats during the growth test. The first tests were performed immediately preceding the placement of the animals on the test diets. The second, third, and fourth tests were made after 4, 8, and 12 weeks on the test diets. During reproduction, red blood cell counts and hemoglobin studies were made following the same procedure as used in Experiment 1.

Since the two previous experiments were based upon the typical menu, it was thought that interesting growth rate comparisons could be made if some animals were put on diets based on the better menu in Table 1 and the poor menu in Table 3. Enriched and non-enriched flour represented the cereal components of Diets I and II respectively, which were based on the better menu. Also enriched and non-enriched flour represented the cereal components of Diets III and IV respectively, which were based on the poor menu. The nutritive value of Diets I, II, III, and IV may be seen in Tables 17, 18, 19, and 20, respectively. Table 21 gives a summary of the total nutritive value of Diets I through IV. It may be noted that 45 percent of the calories were supplied by cereal in Diets I and II, and 58 percent in Diets III and IV.

Ten animals, five females and five males were placed on each diet in this experiment. The animals were on growth tests for 12 weeks. During this time, only alpha tocopherol was fed, because the diet contained enough vitamin A for the rat. The animals on all the diets were given a mixture of alpha tocopherol dissolved in corn oil which provided 20 mg of alpha tocopherol per week.

The results obtained for the growth, reproduction, and blood tests are to be discussed under each of the three experiments, and this will be followed by a general comparison and discussion of all the findings.

RESULTS AND DISCUSSION

First Experiment: Flour Furnished 58 Percent of the Total Calories

In the first experiment, the enriched and non-enriched flour in the diet furnished 58 percent of the total calories. A group of rats receiving the stock ration served as a control group. Growth tests were made because food requirements are important during this period. The results of the growth test are indicated in Table 22 and Figure 1 which show the average weight gains of the rats. The total gain made by the rats receiving Diet I which contained enriched flour was 166 g in comparison with 157 g made by the rats on Diet II which contained non-enriched flour. The difference in the total gains made by the rats on Diets I and II was 9 g.

The nutritive value of the diets is shown in Tables 6 and 7.

It may be noted that Diet I containing enriched flour had 3.72, 1.90, and 18.7 mg per day of thiamine, riboflavin, and niacin respectively, as shown in Table 6, whereas Diet II which contained non-enriched flour had 1.33, 0.94, and 7.1 mg per day of thiamine, riboflavin, and niacin respectively, as shown in Table 7. Diets I and II were slightly low in calcium, as 0.639 g per day is below the recommended 0.8 g daily allowance for the human being, but both diets contained sufficient calories, and adequate amounts of protein, fat, and carbohydrate. Since the diets were comparable in all factors except the B-vitamins, the higher B-vitamin content of Diet I may account for the greater total gain made by the rats on this diet in comparison with that made by the rats on Diet II.

The rats receiving the stock ration which consisted of Purina Dog Chow supplemented with 15 g of lettuce and 6 g of meat per week per rat, made a total gain of 174 g. The stock ration appeared to be the most adequate in respect to the B-vitamins for the growing rat, as the total gain made by the rats on the stock ration was 8 g greater than that made by the rats on Diet I containing enriched flour, and 17 g greater than that made by the rats on Diet II containing non-enriched flour. These growth differences are shown in the photographs in Plate I. These show typical rats on the various diets.

After being on test diets for 10 weeks, the animals were mated for reproduction studies. Food requirements during the reproduction period are even more critical than during the growth period, therefore, it was thought that more conclusive comparisons could be made between enriched and non-enriched flour when these represented the cereal component of the diets. The added vitamins in enriched flour might help to increase the size of litters, the weights of the young at birth, and to aid in normal lactation.

The gestation and lactation results are summarized in Table 26. This table shows that three litters were born to the three females on Diet I which contained enriched flour, and three of the four females on the stock ration produced litters. One of the females on the stock ration was incapable of mating with any of the males on the same diet. Two litters were born to the three female rats on Diet II which contained non-enriched flour. One female on Diet II reabsorbed her young. The average number of rats per litter on the stock ration was 9 in comparison with 7 rats per litter on the diet containing enriched flour and 6 rats per litter on the diet containing non-enriched flour. The average birth weight of the young on both Diets I and II was 6 g, whereas the average birth weight of the rats on the stock ration was 7 g. The average weight of the young after the 22 day lactation period was 36 g for those on the stock ration, 23 g for those on Diet I, and 20 g for those on Diet II. The lactation period was terminated at 22 days because of the death of one of the mother rats on Diet I. In order to carry on a comparable second generation experiment, it was thought advisable to separate the young from the mothers on Diet II at the same time.

The percentage of rats weaned was 37 percent on Diet I, 67 percent on Diet II, and 57 percent on the stock ration. The gestation-lactation results were better for the rats on the diet containing enriched flour than those on the diet containing non-enriched flour as far as the number of litters born, and the average weights of the young at the end of the lactation period, Table 26. Why the mortality rate during lactation should be so much greater among the rats on the diet containing enriched flour is not known. The average birth weights of the rats were the same on both the enriched and non-enriched flour diets. The rats on the stock ration gave a better gestation-lactation performance than those on either Diets I or II. The average number of rats per litter, the average birth weight, and the average weight of the young after 22 days of lactation were all higher on the stock ration than on either Diet I or II. It may be that the calcium content of Diets I and II was lower than that of the stock ration which would account for this difference. Also the meat given to the animals on the stock ration probably gave them a more than adequate amount of animal protein.

Diets I and II supplied 4156 I U of vitamin A per day which is below the 5000 I U per day recommended allowance for the human being. According to Lewis et al. (1948) the rat requires 25 to 50 I U of vitamin A per kg of body weight per day, therefore, the amount contained in the diet was adequate for the rat. However, an additional 1888 I U of vitamin A together with 179 I U of vitamin D and 20 mg of alpha tocopherol was given orally to each rat per week from the beginning of the growth test. Goettsch and Pappenheimer (1941) reported that the rat needs 3 mg of vitamin E per day or 21 mg per week. Therefore, vitamins A and E should not have been limiting factors in Diets I and II during the reproduction period.

Blood tests, consisting of hemoglobin studies and red blood cell counts, have been used by Higgins et al. (1943) to see if the fortification of flour with thiamine, riboflavin, and niacin would have stimulating effects on the production of erythrocytes and the hemoglobin level. Blood tests were also performed in this study in order to evaluate any differences between the use of enriched and non-enriched flour in the diets. The blood values for the female rats may be seen in Table 28.

Since this experiment was only a preliminary study, it was thought that a comparison of hemoglobin levels during the growth period would be adequate. No differences were shown between the average hemoglobin values of the rats on Diets I and II and the stock ration immediately preceding the test diets, because all the rats had been on the B-free diet for two weeks. After four and eight weeks on the test diets, the average hemoglobin values, as shown in Table 28, were highest for the rats on the stock ration and this was to be expected. The values for the rats on the diet containing non-enriched flour were higher than those for the rats on the diet containing enriched flour. No reason can be given for these results.

The average color indexes during reproduction, as shown in

Table 28, were higher for the female rats on the diet containing enriched flour than those on the diet containing non-enriched flour before the birth of the young, and two and three weeks after the young were born. Immediately after the young were born, the color indexes were higher for the rats on the diet containing non-enriched flour. The rats on the stock ration had the highest color indexes all through the reproduction period. The higher mineral, animal protein, and B-vitamin content of the stock ration may be the reason for this difference, as all these nutrients are necessary for the formation of red blood cells and hemoglobin. The red blood cell and hemoglobin values for the female rats on the diet containing enriched flour appeared to be better than the values for the female rats on the diet containing non-enriched flour during reproduction. Perhaps this may be attributed to the presence of large amounts of the B-vitamins in enriched flour. The calcium content of Diets I and II was somewhat low, but both diets supplied far more iron than the 12 mg recommended daily allowance for the human being. Large quantities of molasses served as a good source of iron in both diets.

The young that were weaned from the mothers which had been fed Diets I and II and the stock ration were kept on these same diets for 10 weeks in order to compare their growth rates with the first generation. Average weights of the second generation animals are shown in the weight chart in Table 22, and the growth curves are shown in Figure 1. The total gain made by the second generation rats on Diet I which contained enriched flour was 121 g as compared to 166 g of the first generation. On Diet II which contained non-enriched flour, the total gain made by the second generation rats was 111 g as compared to the 157 g gain of the rats of the first generation. In the second generation, the rats on the diet containing enriched flour made greater growth gains than those on the diet containing non-enriched flour, as had been found with the first generation. The second generation rats showed 10 g difference between those on the diets containing enriched and non-enriched flour, and the first generation showed 9 g difference between the rats on the diets containing enriched and non-enriched flour. The total gain for the second generation rats on the stock ration was 174 g which was the same total gain made by the first generation rats on the stock ration. The large differences in total gains between the first and second generation on the diets containing enriched and non-enriched flour was probably due to the fact that diets which are somewhat lacking in essential nutrients do not always produce noticeable deficiency symptoms until the second or third generation.

After the reproduction period was completed, it was thought that an interesting comparison between enriched and non-enriched flour in the diets could be made if the adult rats on Diets I and II were depleted of their stores of the B-vitamins, and the time of recovery on their respective diets noted. Two females and three males on Diets I and II were placed on starvation for one week in order to deplete their body stores of all the nutrients. Only water was given. Then they were placed on a B-free diet for two weeks to further deplete the B vitamins in the tissue. During the time that the B-free diet was fed, the animals would have the opportunity to replace their body stores of protein, fat, carbohydrates, mineral, and vitamins A and D, lost while on the one-week starvation diet. After the two weeks on the B-free diet, the animals were fed Diets I and II until they came back to their respective weights at the beginning of the starvation period. The average weights for the adult rats during the B-vitamin depletion study, may be seen in Table 25. An average of 44 g was lost on each diet after one week of starvation. After one week on the B-free diet, the animals previously on Diet I gained 6 g, whereas those previously on Diet II lost 4 g. The animals previously on Diet I lost 8 g after two weeks on the B-free diet, however, those previously on Diet II lost 16 g. When they were put back on their original diets, the animals on Diet I came back to normal in one week, but it took two weeks for those on Diet II to come back to normal. Therefore, the larger amount of the B-vitamins in the enriched flour diet enabled the animals to recover at a much faster rate after being depleted of their body stores.

The results of this experiment have shown that when the flour furnished 58 percent of the total calories, greater growth gains were made by both the first and second generation rats on the diet containing enriched flour than by the first and second generation rats on the diet containing non-enriched flour, but the stock ration appeared to be the most adequate in respect to the

B-vitamins for the growing rat. The number of litters born and the average weights of the young at the end of the lactation period were greater for the rats on the diet containing enriched flour than those on the diet containing non-enriched flour, but the mortality of the young was much greater for the rats on the diet containing enriched flour. The stock ration gave better gestation and lactation results than either of the diets containing flour. During growth, the female rats on the diet containing non-enriched flour had higher hemoglobin values than those on the diet containing enriched flour. However, the color indexes, which were computed from red blood cell counts and hemoglobin studies performed during reproduction, were higher for the rats on the diet containing enriched flour except for the period immediately after the young were born. The female rats on the stock ration surpassed both the diets containing flour in hemoglobin values during growth and in color index values for the reproduction period. Adult rats, after being depleted of their B-vitamin stores, were able to recover much faster on the diet containing enriched flour than on the diet containing non-enriched flour when these furnished 58 percent of the calories of the diets.

Second Experiment: Flour Furnished 55 to 58 Percent of the Total Calories

The rats in this experiment were kept on growth tests for 12 weeks. Average weights of the rats are shown in the weight chart in Table 23, and the growth curves are shown in Figure 2. The total gain made by the rats on Diet II containing enriched flour was 204 g, in comparison with 180 g made by the rats on Diet VII containing non-enriched flour. Thus there was a 24 g difference in total gain between the rats on these two diets. As shown in Table 6, the thiamine, riboflavin, and niacin content of the diet containing enriched flour were 3.72, 1.90, and 18.7 mg per day, and 1.33, 0.94, and 7.1 mg per day respectively for the diet containing non-enriched flour. It would seem that the higher B-vitamin content of the diet containing enriched flour aided in promoting a greater growth in the rats. The total gain made by the rats on Diet I which contained whole wheat was 187 g. This gain is 17 g less than that made by the rats on the diet containing enriched flour and 7 g more than that made by the rats on the diet containing non-enriched flour. These growth differences are shown in the photographs in Plate II. The thiamine, riboflavin, and niacin content of the diet containing whole wheat, as shown in Table 8, were 3.07, 1.13, and 27.7 mg per day respectively. Diet II contained more thiamine and riboflavin than Diet I, but less niacin. By referring to Table 8, it may be seen that the protein, fat, calcium, iron, and vitamin A content of the diet containing whole wheat were slightly higher than the values for Diets II and VII. Perhaps the diet containing whole wheat was not as well utilized.

The rats on Diet VI containing cornstarch made a total gain of 145 g. Two rats on Diet VI developed severe polyneuritis symptoms in two weeks, and two more rats had polyneuritis symptoms after being on the test diet between three and four weeks. A photograph of one of the rats on Diet VI shortly before the occurrence of the spasms may be seen in Plate III. The paralytic spasms of two of the rats were cured for six to twelve days by giving the rats 10 ug of thiamine orally. During this time the rats would gain some weight and then immediately lose this weight preceding the reoccurrence of the spasms. The other two rats were completely cured with one oral feeding of 10 ug of thiamine. Before Diet II containing enriched flour was substituted for Diet VI in order to see if the animals could make better growth gains on a diet containing more of the B-complex vitamins, two of the rats had developed polyneuritis symptoms four times, two animals once, and the other two not at all. During three weeks on the diet containing enriched flour, the animals that had been previously treated four times with thiamine while on the cornstarch diet, gained 99 g. The animals previously treated once with thiamine gained 78 g, whereas those who were never treated with thiamine gained 56 g. Therefore, the rats who were very low in weight, and had been treated more often with thiamine, made the greatest gains while on the diet containing enriched flour. The rats that had never developed polyneuritis symptoms did not make much change in their growth weights after being given the diet containing enriched flour. All the rats appeared more active and had better appetites after being fed the diet containing enriched flour.

As shown in Table 12, the thiamine, riboflavin, and niacin content of Diet VI containing cornstarch were 0.74, 0.62, and 3.7 mg per day respectively. Thus the greater B-vitamin content of the diet containing enriched flour was responsible for the better growth gains made by the rats when they were placed on Diet II, because the diet containing cornstarch supplied all the other essential nutrients. The caloric value of the diet containing cornstarch, 2848 calories per day, was necessarily high since enough vitamin-free casein was added to bring the protein level up to 79 g, the same as in Diets II and VII. The high carbohydrate content of all the diets would tend to make the B-vitamin content important, because these vitamins are necessary for the metabolism of carbohydrates.

The rats on Diet III containing enriched flour and added salt mixture made a total gain of 222 g in comparison with the 199 g gain made by the rats on Diet VIII containing non-enriched flour and added salt mixture as shown in Table 23 and Figure 2. Thus there was 23 g difference in total gain between the rats on these two diets. The 222 g gain made by the rats on Diet III is 18 g more than the gain made by the rats on Diet II containing only enriched flour. Thus it would seem that the addition of salt mixture to the diets in order to raise the calcium level to 1 g per day enabled the rats to make greater growth gains than had been made by the rats on enriched and non-enriched flour without added supplements.

The rats on Diet IV containing enriched flour and added vitamin-free casein made a total gain of 227 g in comparison with the 150 g gain made by the rats on Diet IX containing non-enriched flour and added vitamin-free casein. Thus there was 77 g difference in total gain between the rats on these two diets. The 227 g gain made by the rats on Diet IV was 5 g more than the gain made by the rats on Diet III containing enriched flour and salt mixture and 23 g more than the gain made by the rats on Diet II containing enriched flour. It appeared that the addition of casein which raised the protein content of Diet IV from 79 g to 109 g per day permitted the rats to make greater growth gains than had been made by the rats on the diet containing only enriched flour. The 150 g gain made by the rats on Diet IX was 49 g less than the gain made by the rats on Diet VIII containing non-enriched flour and added salt mixture, and 30 g less than the gain made by the rats on Diet VII containing non-enriched flour. The lower B-vitamin content of the non-enriched flour appeared to prevent the rats from utilizing the added protein in the form of vitamin-free casein.

The rats on Diet V containing enriched flour plus salt mixture and vitamin-free casein made a total gain of 240 g in comparison with the 188 g gain made by the rats on Diet X containing non-enriched flour plus salt mixture and added vitamin-free casein. These growth differences are shown in the photographs in Plate III. Thus there were 52 g difference in total gain between the rats on these two diets. The rats on Diet V made the greatest total gain in the 12-week growth period of this experiment. The 18 g difference in total gain made between the rats on Diet

III and Diet V, and the 13 g difference in total gain made between the rats on Diet IV and Diet V practically checks with the 36 g difference in total gain made between the rats on Diet II and Diet V. Thus the addition of both salt mixture and vitamin-free casein to Diet V containing enriched flour was responsible for the greater total gain made by the rats on this diet in comparison with the total gain made by the rats on Diet II containing only enriched flour. The 188 g gain made by the rats on Diet X which was 38 g and 8 g more than the gain made by the rats on Diets IX and VII respectively, but 10 g less than the gain made by the rats on Diet VIII. Thus the salt mixture in Diet X enabled the rats to grow faster than those on Diet IX, but the added protein in Diet X inhibited the rats from making as great a growth gain as made by the rats on Diet VIII. The non-enriched flour probably does not contain enough of the B-vitamins for the added protein to be properly utilized by the rat, since the additional protein enabled the rats on the diets containing enriched flour to make greater total gains. The gain made by the rats on Diet X was probably better than that made by the rats on Diet VII because of the added salt mixture in Diet X, not the added casein.

After being on test diets for 12 weeks, the animals were mated for reproduction studies, Table 27. The rats on Diet VI containing cornstarch were not mated because they had been given thiamine to cure polyneuritis symptoms. The animals on the diet containing whole wheat and enriched flour took about the same time to mate, but those on the diet containing non-enriched flour mated sooner. The animals on the diet containing non-enriched flour plus protein took longer to mate than those on the diet containing enriched flour plus protein, but when salt mixture and protein were added, the rats on the diet containing non-enriched flour mated sooner than those on the diet containing enriched flour.

All the female rats on Diets I, II, V, VIII, IX, and X produced litters. There was one case of reabsorption on Diets III, IV, and VII. Thus the females on Diet II containing enriched flour all produced litters, but not those on Diet VII containing non-enriched flour. The females on Diet V containing enriched flour plus protein and salt mixture all produced litters, but not those on Diet III with enriched flour and salt mixture and Diet IV with enriched flour and protein.

Female rats on Diet II containing enriched flour and Diet VII containing non-enriched flour averaged eight rats per litter and those on Diet I containing whole wheat averaged 12 rats per litter as shown in Table 27. The rats on Diet III had an average of 11 rats per litter and those on Diet VIII had eight rats per litter. Thus the addition of salt mixture to the diet containing enriched flour was more beneficial than the addition to the diet containing non-enriched flour. The rats on Diets IV and IX containing enriched and non-enriched flour respectively plus protein averaged 10 rats per litter, whereas those on Diets V and X containing enriched and non-enriched flour respectively plus protein and salt mixture averaged 12 rats per litter.

Although the average number of rats per litter was high on Diet I containing whole wheat, the average number of rats weaned at 28 days was only two, and the average weaning weight was 39 g. The average number of rats weaned on Diet II containing enriched flour was also only two, and their average weaning weight was 29 g. The average number of rats weaned per litter on Diet VII containing non-enriched flour was five, and their average weight at weaning was 28 g. Thus the diet containing enriched flour was better than the diet containing non-enriched flour as far as the number of litters born and the average weaning weight of the young, but more rats were weaned per litter on the diet containing non-enriched flour. The same number of litters were born to the rats on Diets I and II containing whole wheat and enriched flour respectively, but the average number of rats per litter and the average weaning weight at 28 days were higher for the rats on the diet containing whole wheat. Although only two rats were weaned per litter on Diets I and II, a greater percentage of rats were weaned on the diet containing enriched flour than on the diet containing whole wheat for the mortality rate was not as great.

Only one rat was weaned at 28 days on Diet III containing enriched flour plus salt mixture and none were weaned at 28 days on Diet VIII containing non-enriched flour plus salt mixture. Although the average number of rats per litter was high for the rats on Diet III, the lactation results were just as poor as for the rats on Diet VIII. On both diets IV and IX an average of six rats were weaned per litter, but the weaning weight at 28 days was 44 g for Diet IV containing enriched flour plus protein in comparison with 16 g for Diet IX containing non-enriched flour plus protein. The number of rats weaned per litter on Diet V containing enriched flour plus protein and salt mixture was seven in comparison with three on Diet X. The average weaning weight at 28 days was 42 g on Diet V and 23 g on Diet X. Thus the lactation results were much better for the diet containing enriched flour plus protein and salt mixture than for the diet containing non-enriched flour and these same supplements.

During the growth period the rats on Diet IX containing non-enriched flour plus protein made a very poor total gain in comparison to the rats on Diet VIII containing non-enriched flour and salt mixture. Yet during the gestation and lactation period, the results were very poor for Diet VIII in comparison to Diet IX. Also the total gain made by the rats on Diet X containing non-enriched flour plus protein and salt mixture was not as high as that made by the rats on Diet VIII, yet the gestation and lactation results were better for the rats on Diet X than Diet VIII. Thus it would seem that added salt mixture was important during the growth period of the rat for proper bone formation, whereas larger amounts of protein were needed during the reproduction period for the development of the young. This conclusion is also justifiable when one compares Diet IV containing enriched flour plus protein with Diet V containing enriched flour plus protein and salt mixture for which the gestation and lactation results were about equal, whereas the gestation and lactation results for Diet III containing enriched flour plus salt mixture were very poor. However, during growth there was not much difference between Diets III and IV.

The young that were born to the female rats on Diets V and X containing enriched and non-enriched flour respectively plus protein and salt mixture developed fur that was very rusty and sticky. The rats on Diets IV and IX containing enriched and non-enriched flour respectively plus protein also developed this rusty appearing fur but not quite as severe as for the rats on Diets V and X. The rats on Diets IX and X were also small and puny. After the lactation period was completed, it was decided to keep the young on these same diets, and to give a calcium pantothenate supplement to some of the young and no supplement to the others. Unna (1940), Frost, Moore, and Dann (1941), Oleson, Elvehjem, and Hart (1939), and Henderson et al (1942), all agreed that the rat requires 80 to 100 ug of calcium pantothenate for maximum growth. It was calculated that the rat would probably obtain about 40 ug of calcium pantothenate per day from the food, so it was decided to give a 50 ug supplement of calcium pantothenate per day in order that the rats would receive 90 ug per day. On both the enriched and non-enriched flour, the rusty fur of the rats was cured over a five-week period regardless of whether they received the calcium pantothenate supplement or not. At the end of five weeks, the rats on the diets containing enriched flour with and without calcium pantothenate made a total gain of 127 g in comparison to the 52 g gain made by the rats on the diet containing non-enriched flour with the added calcium pantothenate and 48 g by the rats without the added calcium pantothenate. The rustiness of the fur probably developed because the young did not receive an adequate quantity of milk during the lactation period. The mothers always developed the same symptoms as the young during the lactation period. As soon as the young were placed on the test diets, they were probably able to consume enough food to give them an adequate supply of calcium pantothenate.

Blood studies, consisting of hemoglobins and red blood cell counts, were performed during the growth and reproduction periods of this experiment. The color indexes, as shown in Table 29, were all slightly higher for the rats on the diets containing non-enriched flour during the interval immediately preceding the placement of the animals on the test diets, and after four and eight weeks on the test diet. It may be noted that the average red blood cell counts, as shown in Table 29, for the rats on Diets II and VII containing enriched and non-enriched flour respectively, were 8.32 M/mm after eight weeks on the test diet. The value for the rats on Diet I containing whole wheat was about the same, 8.65 M/mm. The rats on the diets containing protein had higher red blood cell counts than the rats on the diets containing salt mixture both four and eight weeks after the beginning of the test diet. The rats on Diet V, containing enriched flour plus protein and salt mixture, had the highest red blood cell count after eight weeks on the test diet. The average hemoglobin values, also shown in Table 29, were higher for the rats on the diets containing non-enriched flour both four and eight weeks after the beginning of the test diets, except for the rats on Diet V which had higher values than those on Diet X.

In comparing the average color index values, as shown in Table 30, after the rats had been on the test diets for 12 weeks, it can be seen that the values for the rats on the diets containing enriched flour, non-enriched flour, and whole wheat were approximately the same. The color index values between Diets III and VIII and between Diets IV and IX were about equal, but the values for the rats on the diets containing protein were higher than those for the rats on the diets containing salt mixture. The red blood cell counts and hemoglobin values as shown in Table 31, were higher for the rats on the diets containing enriched flour than those on the diets containing non-enriched flour after being on the test diets for 12 weeks. The red blood cell counts for the rats on the diets containing salt mixture were higher than those for the rats on the diets containing protein, whereas after four and eight weeks on the test diets, the rats on the diets containing protein had higher red blood cell counts. The red blood cell count for the rats on the diet containing whole wheat was about the same as for the rats on the diet containing enriched flour.

The average color index values shown in Table 30, for the female rats immediately preceding the birth of the young were all somewhat higher than the values computed at 12 weeks except for the rats on Diets IV, V, and IX, all of which contained protein. The color index for the rats on the diet containing enriched flour, 0.99, was slightly lower than the color index, 1.04 for the rats on the diet containing non-enriched flour. The color index for the rats on Diet I containing whole wheat, 1.11 was higher than that for the rats on Diets II and VII containing enriched and non-enriched flour, respectively. There was not much difference between the average color indexes for the rats on Diets IV and IX, but the average color index for the rats on Diet III was much higher than the value for the rats on Diet VIII. The average color index for the rats on Diet X was higher than that for the rats on Diet V. The rats on the diets containing added protein seemed to have lower values.

The average red blood cell counts, as shown in Table 31, fell markedly for the rats on all the diets immediately before the young were born. The red blood cell counts and hemoglobins were higher for the rats on the diets containing enriched flour than for the rats on the diets containing non-enriched flour. The red blood cell count for the rats on the diet containing whole wheat was very low. The red blood cell counts for the rats on Diets III, IV, and V were approximately the same, as were those for the rats on Diets VIII, IX, and X. There was quite a spread in the hemoglobin values between Diets III and VIII, IV and IX, and Diets V and X.

Immediately after the young were born, the color index value for the rats on Diet II containing enriched flour, 0.97, was higher than the value for Diet VII containing non-enriched flour, 0.81, as shown in Table 30. The color index value for the rats on the diet containing whole wheat was about equal to that for the rats on the enriched flour. The color index for the rats on Diet III, 1.23, was higher than that for Diet VIII, 1.14. The color index values for the rats on Diets IV and IX were about equal, and the value for the rats on Diet V was higher than that for Diet X. The rats on the diet containing salt mixture and enriched flour had the highest value, followed by the rats on the diet containing salt mixture, protein, and enriched flour.

The average erythrocyte counts, as shown in Table 31, were higher for the rats on the diets containing non-enriched flour than those on the diet containing enriched flour immediately after the birth of the young. The value for the rats on the diet containing enriched flour, 6.96 M/mm was lower than that for Diet I containing whole wheat, 7.78 M/mm. There was not much difference between the values for the rats on Diets III, IV, and V, and between the values for the rats on Diets VIII, IX, and X. The hemoglobin values for the rats on the diet containing whole wheat was higher than that for the rats on Diets II and VII which were about the same. The hemoglobin values for the rats on Diets VIII, IX, and X containing non-enriched flour were all higher than the values for the rats on Diets III, IV, and V containing enriched flour.

Three weeks after the young were born, the color index values as shown in Table 30, for the rats on the diets containing enriched flour were all higher than the values for the rats on the diets containing non-enriched flour, except for the rats on Diet X, which was higher than that for Diet V. The rats on the diets containing salt mixture had higher color indexes than the rats on the diets containing protein. The color index for the rats on the diet containing whole wheat was the highest of all at this time.

Some of the erythrocyte counts and hemoglobin values for the period three weeks after the young were born, as shown in Table 31, are based upon one rat, so adequate conclusions cannot be drawn from this data. The erythrocyte and hemoglobin values for the rats on the diet containing enriched flour, 9.18 M/~~cc~~mm and 13.99 g/100 ml, were about the same as the values for the rats on the diet containing non-enriched flour, 9.60 M/~~cc~~mm and 13.09 g/100 ml. Also the erythrocyte and hemoglobin values for the rats on the diet containing enriched flour and protein, 8.53 M/~~cc~~mm and 13.19 g/100 ml, were about the same as the values for the rats on the diet containing non-enriched flour and protein, 8.88 M/~~cc~~mm and 13.17 g/100 ml. The red blood cell counts and hemoglobin values for the rats on the diet containing enriched flour and salt mixture, 9.02 M/~~cc~~mm and 15.40 ml/100 ml were somewhat higher than the values for the rats on the diet containing non-enriched flour and salt mixture, 8.73 M/~~cc~~mm and 15.16 g/100 ml.

Results of this experiment have shown that when flour furnished from 55 to 58 percent of the total calories, the rats on the diet containing enriched flour made a greater growth gain than the rats on the diet containing non-enriched flour. The total gain made by the rats on the diet containing whole wheat was approximately the same as that made by the rats on the diet containing non-enriched flour. The animals on the following diets: enriched flour plus salt mixture, enriched flour plus protein, and enriched flour plus salt mixture and protein, made greater growth gains in comparison with the animals on the diets containing non-enriched flour plus salt mixture, non-enriched flour plus protein, and non-enriched flour plus salt mixture and protein. When cornstarch was supplemented for the flour component of the diet, polyneuritis symptoms developed. This was due to a lack of B-complex vitamins, for this diet contained adequate amounts of the other essential nutrients.

The animals on the diets containing enriched flour did not have a shorter mating period except for the rats on Diet IV containing enriched flour and protein which mated in two days in comparison with the seven-day mating period for the rats on Diet IX containing non-enriched flour and protein. The average number of rats per litter were the same between Diets II and VII, Diets IV and IX, and Diets V and X, but higher for Diet III than Diet VIII. The females on Diet I containing whole wheat averaged the same number of rats per litter as those on Diet V. The size of the litters was greater when salt mixture or protein were added to the diets. More rats were weaned per litter on the diet containing non-enriched flour than on the diet containing enriched flour, but the average weaning weight of the young was the same on both diets. The females on the diet containing whole wheat averaged the same number of rats weaned per litter as those on the enriched flour, but the weaning weights of the young were much higher. No rats were weaned on Diets III and VIII, containing enriched flour and non-enriched flour respectively, plus salt mixture. The number of rats weaned per litter was the same for Diets IV and IX, but the average weaning weight of the young was much greater on Diet IV. Both the average number of rats weaned per litter and the average weaning weight of the young were higher on Diet V than on Diet X. The mortality rate of the young was greatest from birth to the third day for all the diets except Diets IV and IX containing protein which had a greater mortality rate later in the lactation period. The young on Diets IV, V, IX, and X, which developed a rusty, sticky fur during lactation were cured after being placed on their respective diets with and without a calcium pantothenate supplement.

The color indexes were all slightly higher for the rats on the diets containing non-enriched flour during the interval immediately preceding the placement of the animals on the test diets and after four and eight weeks on the test diets. After 12 weeks on the test diets, the color indexes were not significantly different between enriched and non-enriched flour with and without salt mixture and protein supplements. However, the rats on the diet containing protein had higher color indexes than the rats on the diets containing salt mixture, whereas four and eight weeks after the beginning of the test diets, the color index values were higher for the rats on the diets containing salt mixture. Even though there was no significant difference in color index values 12 weeks after the beginning of the test diets, the red blood cell counts and hemoglobin values were slightly higher for the rats on the diets containing enriched flour than on the diets containing non-enriched flour.

Immediately preceding the birth of the young, the color index values were all somewhat higher than the normal values at 12 weeks, except for Diets IV, V, and IX, all of which contained protein. The red blood cell counts were much higher for the rats on the diets containing enriched flour than those for the rats on the diets containing non-enriched flour. Hemoglobin values were also much higher for the rats on Diets III, IV, and V, than for the rats on Diets VIII, IX, and X. Immediately after the young were born, the color index values were higher for the rats on the diets containing enriched flour than for those on the diets containing non-enriched flour. The rats on Diet I containing whole wheat had about the same color index value as the rats on Diet II containing enriched flour. The red blood cell counts and hemoglobin values were higher for Diets VIII, IX, and X than Diets III, IV, and V. Three weeks after the young were born, the color index values for the rats on the diets containing enriched flour were all higher than the values for the rats on the diets containing non-enriched flour, which evidently shows the value of the B vitamins in the enriched flour.

Third Experiment: Flour Furnished 45 and 58 Percent of the Total Calories

In the third experiment, the enriched and non-enriched flour in Diets I and II, based upon the better menu in Table 1, furnished 45 percent of the total calories, whereas in Diets III and IV which were based upon the most inadequate menu in Table 3, the enriched and non-enriched flour furnished 58 percent of the total calories. The results of the growth test are indicated in Table 24 and Figure 3 which show the average weight gains of the rats.

The total gain made by the rats receiving Diet I which contained enriched flour was 207 g in comparison with 203 g made by the rats on Diet II which contained non-enriched flour. The difference in total gain made by the rats on Diets I and II was only 4 g. Typical rats on Diets I and II are shown in the photographs in Plate IV. As shown in Tables 17 and 18, both diets contained adequate and equal amounts of calories, protein, fat, carbohydrate, calcium, and vitamin A. Diet I containing enriched flour supplied more iron than Diet II containing non-enriched flour, but both diets contained far more iron than the 12 mg per day recommended allowance. The thiamine, riboflavin, and niacin values for Diet I in mg per day were 3.45, 2.53, and 17.9 whereas those for Diet II in mg per day were 1.33, 1.64, and 7.5, respectively. Thus there was considerable difference in the amount of B-complex vitamins contained in these two diets. When flour furnished 45 percent of the total calories, the higher B-vitamin content of the diet containing the enriched flour did not promote any favorable influence on the growth rate of the rats.

The total gain made by the rats on Diet III containing enriched flour was 120 g in comparison with 80 g made by the rats on Diet IV containing non-enriched flour. The difference in total gain made by the rats on Diets III and IV was 40 g. These growth differences are shown in the photographs of typical rats on Diets III and IV in Plate IV. As shown in Tables 19 and 20, the caloric contents of both diets were low, because the diets did not contain much fat. Protein and carbohydrate were present in adequate amounts but all the protein was derived from cereals and legumes. Both diets supplied 0.14 g calcium per day which is far below the 0.8 g per day recommended allowance. Diet III containing enriched flour supplied 16.6 mg of iron per day, whereas Diet IV containing non-enriched flour supplied 10.0 mg per day which is slightly below the 12 mg per day recommended allowance for the human being. The most inadequate menu did not contain any molasses. Although 1943 I U of vitamin A, as present in Diets III and IV, is far below the 5000 I U recommended allowance, this amount according to Lewis et al (1942) is adequate for the rat.

The thiamine, riboflavin, and niacin content of Diet III containing enriched flour were 2.90, 1.13, and 12.8 mg per day, and for Diet IV containing non-enriched flour, 1.25, 0.44, and 4.7 mg per day, respectively. This large difference in B-vitamin content in the two diets would undoubtedly account for some of the large difference in the growth gains of the rats. However, the low caloric and calcium content, and no animal derived protein would also be somewhat responsible for the poor growth of the rats on Diets III and IV.

Results of this experiment have shown that when 45 percent of the calories are derived from enriched and non-enriched flour, no growth differences are obtained in the rats, but when 58 percent of the calories are derived from flour, the rats on the diet containing enriched flour had a much greater growth gain than those on the diet containing non-enriched flour.

General Discussion of the Three Experiments

In a comparison of the total growth gains made by the rats on the diets containing enriched and non-enriched flour in the first and second experiments, it can be seen that the 182 g gain made by the rats on the diet containing enriched flour in Experiment 2 over a 10-week period was 16 g more than the 166 g gain made by the rats on the diet containing enriched flour in Experiment 1. The rats on the diet containing non-enriched flour in Experiments 1 and 2 both made a 157 g gain over a 10-week period. These diets were all based upon the typical menu given in Table 2 in which 58 percent of the total calories were derived from cereals, therefore, it is not known why a better correlation was not obtained between the rats on the diets containing enriched flour in Experiments 1 and 2.

Although the total gain made by the rats on the stock ration, 174 g, was higher than the 166 g gain made by the rats on Diet I, Experiment 1, containing enriched flour, it was not higher than the 182 g gain made by the rats on Diet II, Experiment 2 containing enriched flour. This latter gain was computed over a 10-week growth period so as to compare it with the total gains made by the rats in Experiment 1. Both of the diets containing enriched flour were based upon the typical menu in Table 2.

It will be remembered that there was no difference in the total gain made by the rats on the diets containing enriched and non-enriched flour when the cereal supplied 45 percent of the total calories, but there is also no difference in total gain made by the rats on the diets containing enriched flour when 45 and 58 percent of the total calories are supplied by cereal. That is, the 207 g gain made by the rats on Diet I, Experiment 3, was about equal to the 204 g gain made by the rats on Diet II, Experiment 2, both diets containing enriched flour. This was not true of the diets containing non-enriched flour when 45 and 58 percent of the total calories are supplied by cereal, for the 203 g gain made by the rats on Diet II, Experiment 3, was 23 g greater than the 180 g gain made by the rats on Diet VII, Experiment 2. The total gains for Experiments 2 and 3 were both obtained over a 12-week growth period.

The total gains made by the rats on Diets III and IV containing enriched and non-enriched flour respectively, in Experiment 3 were far below the total gains made by the rats on Diets II and VII containing enriched and non-enriched flour respectively, in Experiment 2. This would be expected even though 58 percent of the total calories were supplied by cereal in all these diets, because the B-complex vitamin content of Diets II and VII based upon the typical menu was higher than that of Diets III and IV based upon the most inadequate menu. Also inadequate amounts of calories and calcium, and poor sources of protein were responsible for the poor growth gains made by the rats on Diets III and IV in Experiment 3.

When the gestation and lactation results for the rats on the diets containing enriched flour, Diet I, Experiment 1 and Diet II, Experiment 2 are compared, as seen in Tables 26 and 27, it may be noted that the results are approximately identical except that a greater percentage of rats were weaned on Diet I, Experiment 1. When the two diets containing non-enriched flour, Diet II, Experiment 1, and Diet VII, Experiment 2 are compared, it can be seen that the average number of rats per litter and the average weaning weight of the young on Diet II, Experiment 1 were lower than for those on Diet VII, Experiment 2, but the percentage of rats weaned was greater on Diet II, Experiment 1. These diets were all based upon the typical menu in Table 2 in which 58 percent of the total calories were derived from cereal.

In a comparison of the hemoglobin values during the growth period for the rats on Diet 1, Experiment 1, as shown in Table 28, and for those on Diet II, Experiment 2, as shown in Table 29, both diets containing enriched flour, it can be seen that the hemoglobin values were all higher for the rats on Diet II, Experiment 2. This is also true of the hemoglobin values for the rats on Diet VII, Experiment 2 which were higher than those for the rats on Diet II, Experiment 1, both diets containing non-enriched flour. The color indexes for the rats on Diet I, Experiment 1 and on Diet II, Experiment 2, Tables 28 and 29, were almost equal before the birth of the young and two and three weeks after the young were born, but immediately after the birth of the young, the color index values were higher for the rats on Diet II, Experiment 2. Both of these diets contained enriched flour. The color indexes for the rats on Diet VII, Experiment 2, Table 29, were higher than those for the rats on Diet II, Experiment 1, Table 28, before the young were born and two and three weeks after the birth of the young, but the color index values were about identical immediately after the birth of the young. Both of these diets contained non-enriched flour.

This study has shown that when 58 percent of the calories are derived from cereals, the growth of the rats was greater on a diet containing enriched flour than among the rats on a diet containing non-enriched flour. Although a few of the gestation and lactation results and some of the blood values during growth and reproduction were higher for the rats on the diets containing non-enriched flour, in a greater majority of cases the results were better for the rats on the diets containing enriched flour. This study seems to indicate that there is some value in enriching flour with B-complex vitamins, especially when 58 percent of the calories are derived from cereals as in low-income group diets.

SUMMARY

Three experiments were conducted using young albino rats to evaluate the differences in nutritive value of enriched and non-enriched flour, whole wheat, and cornstarch when these represented the cereal component of the diets. The experimental diets were based upon the menus served in the homes of Negro tenants in the Yazoo Mississippi Delta. The menus were divided into three groups: better menus, typical menus, and the most inadequate menus. In the better menu, 45 percent of the total calories were derived from cereal, whereas in the typical and most inadequate menus, 55 and 58 percent of the total calories were derived from cereal.

Natural foods were used in making up the diets. A calculation of the nutritive value of all the diets was made, and any differences in essential nutrients were compared and discussed. Three methods were employed to evaluate the diets: growth rate of the rats, reproduction, and blood studies, which consisted of red blood cell counts and hemoglobins.

Under the conditions of these experiments, the first and second generation rats on the diets containing enriched flour made greater growth gains than those on the diets containing non-enriched flour when 58 percent of the calories were derived from cereal. Growth gains were also greater on the diets containing enriched flour when salt mixture or protein were added as supple-

ments, and 55 and 58 percent of the total calories were derived from cereal. The rats on the diet containing enriched flour made greater growth gains than those on the diet containing whole wheat. The diet containing cornstarch was definitely lacking in B-complex vitamins for the rats developed polyneuritis symptoms on this diet. When 45 percent of the total calories were derived from cereal, there was no difference in the growth gains made by the rats on the diets containing enriched and non-enriched flour.

Results of the reproduction study have shown that the number of litters born and the average weaning weight of the young were greater on the diet containing enriched flour, but more rats were weaned per litter on the diet containing non-enriched flour. The average number of rats per litter and the average weaning weight of the young were greater on the diet containing whole wheat, but a greater percentage of rats were weaned on the diet containing enriched flour. The gestation and lactation results were much better on the diet containing added protein than on the diet containing added salt mixture. Also the gestation and lactation results were better for the rats on the diet containing enriched flour plus protein and salt mixture than for those on the diet containing non-enriched flour and these same supplements.

Results of the blood studies have shown that the red blood cell counts and hemoglobins were higher for the rats on the diets containing enriched flour than on the diets containing non-enriched flour after being on the test diets for 12 weeks even though there were only slight differences in the color index values at this time. Also the rats on the diet containing protein had higher color indexes than those on the diet containing salt mixture. Immediately preceding the birth of the young, the red blood cell and hemoglobin values were higher for the rats on the diets containing enriched flour than for those on the diets containing non-enriched flour. Immediately after the birth of the young and two and three weeks later, the color indexes were higher for the rats on the diets containing enriched flour than on the diets containing non-enriched flour.

Table 1. A better menu for Negro tenants of Mississippi.[1]

Breakfast	Dinner	Supper
Monday		
Fried eggs	Rabbit	Rabbit
Salt pork	Cornbread	Biscuit
Biscuit	Rice pudding	Tea cakes
Molasses	Milk	
Milk		
Tuesday		
Fried eggs	Chitlings	Chitlings
Biscuit	Cornbread	Baker's bread
Molasses	Molasses	Milk
Rice pudding	Milk	
Wednesday		
Sausage	Peas[2]	Sweet potato pie
Cornbread	Cornbread	Biscuit
Molasses	Milk	Butter
Milk		Molasses
		Milk
Thursday		
Canned peaches	Salt pork	Cornbread
Rice	Cornbread	Butter
Biscuit	Rice pudding	Molasses
Butter	Milk	Milk
Friday		
Fried eggs	Cabbage	Fried eggs
Fried potatoes	Cornbread	Biscuit
Biscuit	Peach pie	Butter
Butter	Milk	Molasses
Molasses		Milk
Saturday		
Biscuit	Fried potatoes	Fried eggs
Butter	Salt pork	Biscuit
Molasses	Cornbread	Butter
Milk	Milk	Molasses
Sunday		
Fried steak	Cabbage	Cabbage
Biscuit	Cornbread	Cornbread
Butter	Tomato pie	Molasses
Molasses	Milk	Milk
Tea cakes		
Milk		

[1]Dickens, 1928. [2]Peas are black-eyed peas.

Table 2. A typical menu for Negro tenants of Mississippi.[1]

Breakfast	Dinner	Supper
Monday		
Fried eggs	Peas[2]	Peas
Biscuit	Cornbread	Cornbread
Sorghum		
Tuesday		
Salt pork	Turnip greens	Milk
Biscuit	Biscuit	Biscuit pudding
Sorghum	Biscuit pudding	
Wednesday		
Biscuit	Salt pork	Fried potatoes
Sorghum	Cornbread	Biscuit
	Biscuit pudding	Sorghum
	Milk	
Thursday		
Fried eggs	Peas	Fried eggs
Biscuit	Cornbread	Biscuit
Milk	Cake	Sorghum
		Cake
Friday		
Pears (canned)	Rice	Salt pork
Biscuit	Gravy	Biscuit
Milk	Cornbread	Sorghum
Saturday		
Rice	Milk	Fried steak
Biscuit	Cornbread	Rice
Sorghum	Tomato pie	Gravy
		Biscuit
Sunday		
Salt pork	Sausage	Sausage
Biscuit	Rolled cabbage	Rice
Sorghum	Rice	Cornbread
	Cornbread	

[1]Dickens, 1928.

[2]Peas are black-eyed peas.

Table 3. An inadequate menu for Negro tenants of Mississippi.[1]

Breakfast	Dinner	Supper[2]
Monday		
Rice	Peas[3]	
Cornbread	Cornbread	
Coffee		
Tuesday		
Rice	Peas	
Cornbread	Cornbread	
Coffee		
Wednesday		
Rice	Peas	
Cornbread	Cornbread	
Coffee		
Thursday		
Rice	Peas	
Cornbread	Cornbread	
Coffee		
Friday		
Rice	Peas	
Cornbread	Cornbread	
Coffee		
Saturday		
Rice	Peas	
Cornbread	Cornbread	
Coffee		
Sunday		
Rice	Peas	
Cornbread	Cornbread	
Coffee		

[1]Dickens, 1928.

[2]Dinner served at 4:00 p.m., no supper served.

[3]Peas are black-eyed peas.

Table 4. Menus for Negro tenants of Mississippi.[1]

	Better menu			Typical menu			Most inadequate menu		
	Servings per person per week	Serving per person per day	Wt. g	Servings per person per week	Serving per person per day	Wt. g	Servings per person per week	Serving per person per day	Wt. g
Bread and rice	27	3.85	385	30	4.28	428	21	3.0	300
Fat or salt pork	13	1.1 pat butter .7 (other)	81	4.1	.58	58	4.1	.58	58
Molasses	12	1.70	170	8	1.1	110			
Meat	4	.57	57	3	.42	42			
Milk[2]	16	2.28	68	5	.7	21			
Eggs	5	.70	35	3	.42	21			
Black eyed peas	1	.14	14	3	.42	42	7	1.0	100
Potatoes	3	.42	42	1	.14	14			
Green vegetables	4	.57	57	3	.42	42			
Fruit	2	.28	28	1	.14	14			

[1] Dickens, Dorothy. Bulletin No. 254, August 1928.

[2] Milk - 1 cup is a serving. Liquid milk has 12.4 percent of milk solids.

Table 5. Nutritive value of 100 g edible portions of selected foods.

Food	Calories	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Apple	64	0.3	0.4	14.9	.007	0.3	80	0.04	0.02	0.2	6
Black eyed peas	351	22.9	1.4	61.6	.080	7.8		0.83	0.23	2.2	2
Green vegetable[2]	33	2.4	0.2	5.4	.083	1.5	3845	0.09	0.15	0.6	60
Egg	158	12.8	11.5	0.7	.056	2.9	1320	0.12	0.35	0.1	
Butter or margarine	733	0.6	81.0	0.4	.016	0.2	3350		0.01	0.1	
Non-enriched flour	355		0.9	75.9	.017	0.7		0.14	0.07	0.8	
Enriched flour	355		0.9	75.9	.017	2.9		0.69	0.30	3.5	
Whole wheat	361	12.1	1.9	73.9	.048	3.9	22	0.54	0.12	5.6	
Meat[3]	284	16.8	24.0		.011	2.6	30	0.58	0.19	4.7	
Dried whole milk	496	25.8	26.7	38.0	.949	0.6	1400	0.30	1.46	0.7	7
Molasses	240			60.0	.246	9.3					
Potato, white	85	2.0	0.1	19.1	.011	0.7	20	0.11	0.04	1.2	16
Potato, sweet	125	1.8	0.7	27.9	.033	0.7	4800	0.10	0.06	0.7	19

[1]Average of figures given in Chemistry of Food and Nutrition, Sherman (1948) and Handbook of Diet Therapy, Turner (1946).

[2]Green vegetable. These are averaged figures on cabbage, green beans, and spinach.

[3]Meat. These figures are calculated on the basis of 1/2 beef (stew meat) and 1/2 pork (roast) per serving.

Table 6. Nutritive value of Diet I used in Experiment 1 and Diet II used in Experiment 2 in which enriched flour furnished 58 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	4.28	428	53.5	1519	57.4	52.6*	3.9	324.9	.073	12.4		2.97	1.28	15.0	
Molasses	1.10	110	13.7	264	10.0			66.0	.271	10.2					
Fat	0.58	58	7.3	424	16.0	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.3	119	4.5	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.7	104	3.9	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.7	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.3	147	5.6	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.8	12	0.5	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.3	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.8	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.8												
Total		799	100.2	2645	99.9	79.0	69.9	432.2	.639	28.5	4156	3.72	1.90	18.7	31

*Analysis of flour showed 12.3 percent protein.

Table 7. Nutritive value of Diet II used in Experiment 1 and Diet VII used in Experiment 2 in which non-enriched flour furnished 58 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Cal-ories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	4.28	428	53.5	1519	57.4	52.6*	3.9	324.9	.073	3.0		0.58	0.32	3.4	
Molasses	1.10	110	13.7	264	10.0			66.0	.271	10.2					
Fat	0.58	58	7.3	424	16.0	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.3	119	4.5	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.7	104	3.9	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.7	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.3	147	5.6	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.8	12	0.5	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.3	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.8	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.8												
Total		799	100.2	2645	99.9	79.0	69.9	432.2	.639	19.1	4156	1.33	0.94	7.1	31

*Analysis of flour showed 12.3 percent protein.

Table 8. Nutritive value of Diet I used in Experiment 2 in which whole wheat furnished 58 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Whole wheat	4.28	428	53.5	1545	57.8	59.9*	8.1	316.3	.206	16.7	95	2.32	0.51	24.0	
Molasses	1.10	110	13.7	264	9.9			66.0	.271	10.2					
Fat	0.58	58	7.3	424	15.9	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.3	119	4.5	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.7	104	3.9	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.7	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.3	147	5.5	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.8	12	0.5	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.3	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.8	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.8												
Total		799	100.2	2671	100.0	86.3	74.1	423.6	.772	32.8	4251	3.07	1.13	27.7	31

*Analysis of wheat showed 14.00 percent protein.

Table 9. Nutritive value of Diet III used in Experiment 2 in which enriched flour furnished 58 percent of the total calories and salt mixture was added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	4.28	428	53.3	1519	57.4	52.6*	3.9	324.9	.073	12.4		2.97	1.28	15.0	
Molasses	1.10	110	13.7	264	10.0			66.0	.271	10.2					
Fat	0.58	58	7.2	424	16.0	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.2	119	4.5	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.6	104	3.9	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.6	33	1.3	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.2	147	5.6	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.7	12	0.5	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.2	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.8												
Salt mixture		4	0.5						.557	14.5					
Total		802	99.7	2645	100.0	79.0	69.9	432.2	1.196	43.0	4156	3.72	1.90	18.7	31

*Analysis of flour showed 12.3 percent protein.

Table 10. Nutritive value of Diet IV used in Experiment 2 in which enriched flour furnished 55 percent of the total calories and protein was added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	4.28	428	51.6	1519	55.0	52.6*	3.9	324.9	.073	12.4		2.97	1.28	15.0	
Molasses	1.10	110	13.2	264	9.5			66.0	.271	10.2					
Fat	0.578	58	7.0	424	15.3	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.1	119	4.3	7.1	10.1		.005	1.1	13	0.24	.08	2.0	
Milk (dried)	0.70	21	2.5	104	3.8	5.4	5.6	7.9	.197	0.1	294	0.06	.31	0.2	2
Egg	0.42	21	2.5	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	.07		
Black eyed peas	0.42	42	5.1	147	5.3	9.5	0.6	25.9	.034	3.3		0.35	.10	0.9	1
Potatoes	0.14	14	1.7	12	0.4	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.1	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	.7												
Vitamin-free casein		30	3.6	120	4.3	30.0									
Total		828	99.8	2765	99.9	109.0	69.9	432.2	.639	28.5	4156	3.72	1.90	18.7	31

*Analysis of flour showed 12.3 percent protein.

Table 11. Nutritive value of Diet V used in Experiment 2 in which enriched flour furnished 55 percent of the total calories and salt mixture and protein were added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	4.28	428	51.4	1519	55.0	52.6*	3.9	324.9	.073	12.4		2.97	1.28	15.0	
Molasses	1.10	110	13.2	264	9.5			66.0	.271	10.2					
Fat	0.58	58	7.0	424	15.3	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.0	119	4.3	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.5	104	3.8	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.5	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.0	147	5.3	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.7	12	0.4	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.0	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.7												
Salt mixture		4	0.5						.557	14.5					
Vitamin-free casein		30	3.6	120	4.3	30.0									
Total		832	99.8	2765	99.9	109.0	69.9	432.2	1.196	43.0	4156	3.72	1.90	18.7	31

*Analysis of flour showed 12.3 percent protein.

Table 12. Nutritive value of Diet VI used in Experiment 2 in which cornstarch furnished 53 percent of the total calories and salt mixture and protein were added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Cornstarch	4.28	378*	46.9	1512	53.1			378.0							
Molasses	1.10	110	13.7	264	9.3			66.0	.271	10.2					
Fat	0.58	58	7.2	424	14.9	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.2	119	4.2	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.6	104	3.7	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.6	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.2	147	5.2	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.7	12	0.4	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.2	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.7												
Salt mixture		4	0.5						.557	14.5					
Vitamin-free casein		53	6.5	210	7.4	52.6									
Total		805	99.7	2848	100.2	79.0	66.0	465.3	1.123	30.6	4156	0.75	0.62	3.7	31

*The amount of cornstarch is 378 g which provides 1512 calories; the amount of flour in the other diets is 428 g which provides 1519 calories. The cornstarch was reduced so that the total calories in this diet would be about the same as in the other diets.

Table 13. Nutritive value of Diet VIII used in Experiment 2 in which non-enriched flour furnished 58 percent of the total calories and salt mixture was added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	4.28	428	53.3	1519	57.4	52.6*	3.9	324.9	.073	3.0		0.58	0.32	3.4	
Molasses	1.10	110	13.7	264	10.0			66.0	.271	10.2					
Fat	0.58	58	7.2	424	16.0	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.2	119	4.5	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.6	104	3.9	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.6	33	1.3	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.2	147	5.6	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.7	12	0.5	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.2	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.7												
Salt mixture		4	0.5						.557	14.5					
Total		802	99.6	2645	100.0	79.0	69.9	432.2	1.196	33.6	4156	1.33	0.94	7.1	31

*Analysis of flour showed 12.3 percent protein.

Table 14. Nutritive value of Diet IX used in Experiment 2 in which non-enriched flour furnished 55 percent of the total calories and protein was added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	4.28	428	51.6	1519	55.0	52.6*	3.9	324.9	.073	3.0		0.58	0.32	3.4	
Molasses	1.10	110	13.3	264	9.6			66.0	.271	10.2					
Fat	0.58	58	7.0	424	15.3	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.1	119	4.3	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.5	104	3.8	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.5	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.1	147	5.3	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.7	12	0.4	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.1	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.7												
Vitamin-free casein		30	3.6	120	4.3	30.0									
Total		828	99.9	2765	100.0	109.0	69.9	432.2	.639	19.1	4156	1.33	0.94	7.1	31

*Analysis of flour showed 12.3 percent protein.

Table 15. Nutritive value of Diet X used in Experiment 2 in which non-enriched flour furnished 55 percent of the total calories and salt mixture and protein were added.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	4.28	428	51.4	1519	55.0	52.6*	3.9	324.9	.073	3.0		0.58	0.32	3.4	
Molasses	1.10	110	13.2	264	9.5			66.0	.271	10.2					
Fat	0.58	58	7.0	424	15.3	0.4	47.0	0.2	.009	0.1	1943			0.1	
Meat	0.42	42	5.0	119	4.3	7.1	10.1		.005	1.1	13	0.24	0.08	2.0	
Milk (dried)	0.70	21	2.5	104	3.8	5.4	5.6	7.9	.197	0.1	294	0.06	0.31	0.2	2
Egg	0.42	21	2.5	33	1.2	2.7	2.4	0.2	.012	0.6	277	0.03	0.07		
Black eyed peas	0.42	42	5.0	147	5.3	9.5	0.6	25.9	.034	3.3		0.35	0.10	0.9	1
Potatoes	0.14	14	1.7	12	0.4	0.3	0.1	2.7	.002	0.1	3	0.02		0.2	2
Green vegetables	0.42	42	5.0	14	0.5	1.0	0.1	2.3	.035	0.6	1615	0.04	0.06	0.3	25
Apples	0.14	14	1.7	9	0.3		0.1	2.1	.001		11	0.01			1
Salt	1 t	6	0.7												
Vitamin-free casein		30	3.6	120	4.3	30.0									
Salt mixture		4	0.5						.557	14.5					
Total		832	99.8	2765	99.9	109.0	69.9	432.2	1.196	33.6	4156	1.33	0.94	7.1	31

*Analysis of flour showed 12.3 percent protein.

Table 16. Nutritive value of diets used in Experiment 2 in which 55 and 58 percent of the total calories were derived from cereals.

Diet	Wt. g	Calories	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
I Whole wheat	799	2671	86.3	74.1	423.6	0.772	32.8	4251	3.07	1.13	27.7	31
II Enriched flour	799	2645	79.0	69.9	432.2	0.639	28.5	4156	3.72	1.90	18.7	31
III Enriched flour + salt mixture	802	2645	79.0	69.9	432.2	1.196	43.0	4156	3.72	1.90	18.7	31
IV Enriched flour + casein*	828	2765	109.0	69.9	432.2	0.639	28.5	4156	3.72	1.90	18.7	31
V Enriched flour + casein + salt mixture	832	2765	109.0	69.9	432.2	1.196	43.0	4156	3.72	1.90	18.7	31
VI Cornstarch + casein + salt mixture	805	2848	79.0	66.0	485.3	1.123	30.6	4156	0.75	0.62	3.7	31
VII Non-enriched flour	799	2645	79.0	69.9	432.2	0.639	19.1	4156	1.33	0.94	7.1	31
VIII Non-enriched flour + salt mixture	802	2645	79.0	69.9	432.2	1.196	33.6	4156	1.33	0.94	7.1	31
IX Non-enriched flour + casein	828	2765	109.0	69.9	432.2	0.639	19.1	4156	1.33	0.94	7.1	31
X Non-enriched flour + casein + salt mixture	832	2765	109.0	69.9	432.2	1.196	33.6	4156	1.33	0.94	7.1	31

*Vitamin-free casein.

Table 17. Nutritive value of Diet I used in Experiment 3 in which enriched flour furnished 45 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Cal- ories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	3.85	385	40.8	1367	44.8	47.4*	3.5	292.2	.065	11.2		2.66	1.16	13.5	
Molasses	1.70	170	18.0	408	13.4			102.0	.418	15.8					
Fat	1.1 pat butter .7 (other)	81	8.6	594	19.5	0.5	65.6	0.3	.013	0.2	2714		0.01	0.1	
Meat	0.57	57	6.0	162	5.3	9.6	13.7		.006	1.4	17	0.33	0.11	2.7	
Milk (dried)	2.28	68	7.2	337	11.0	17.5	18.2	25.8	.645	0.4	952	0.20	0.99	0.5	5
Egg	0.70	35	3.7	55	1.8	4.5	4.0	0.2	.020	1.0	462	0.04	0.12		
Black eyed peas	0.14	14	1.5	49	1.6	3.2	0.2	8.6	.011	1.1		0.12	0.03	0.3	
White potatoes	0.28	28	3.0	24	0.8	0.6		5.3	.003	0.2	6	0.03	0.01	0.3	4
Sweet potatoes	0.14	14	1.5	18	0.6	0.3	0.1	3.9	.005	0.1	644	0.01	0.01	0.1	3
Green vegetables	0.57	57	6.0	19	0.6	1.4	0.1	3.1	.047	0.9	2192	0.05	0.09	0.3	34
Apples	0.28	28	3.0	18	0.6		0.1	4.2	.002	0.1	2	0.01		0.1	2
Salt	1 t	6	0.6												
Total		943	99.9	3051	100.0	85.0	105.5	445.6	1.235	32.4	6989	3.45	2.53	17.9	48

*Analysis of flour showed 12.3 percent protein.

Table 18. Nutritive value of Diet II used in Experiment 3 in which non-enriched flour furnished 45 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	3.85	385	40.8	1367	44.8	47.4*	3.5	292.2	.065	2.7		0.54	0.27	3.1	
Molasses	1.70	170	18.0	408	13.4			102.0	.418	15.8					
Fat	1.1 pat butter .7 (other)	81	8.6	594	19.5	0.5	65.6	0.3	.013	0.2	2714		0.01	0.1	
Meat	0.57	57	6.0	162	5.3	9.6	13.7		.006	1.4	17	0.33	0.11	2.7	
Milk (dried)	2.28	68	7.2	337	11.0	17.5	18.2	25.8	.645	0.4	952	0.20	0.99	0.5	5
Egg	0.70	35	3.7	55	1.8	4.5	4.0	0.2	.020	1.0	462	0.04	0.12		
Black eyed peas	0.14	14	1.5	49	1.6	3.2	0.2	8.6	.011	1.1		0.12	0.03	0.3	
White potatoes	0.28	28	3.0	24	0.8	0.6		5.3	.003	0.2	6	0.03	0.01	0.3	4
Sweet potatoes	0.14	14	1.5	18	0.6	0.3	0.1	3.9	.005	0.1	644	0.01	0.01	0.1	3
Green vegetables	0.57	57	6.0	19	0.6	1.4	0.1	3.1	.047	0.9	2192	0.05	0.09	0.3	34
Apples	0.28	28	3.0	18	0.6		0.1	4.2	.002	0.1	2	0.01		0.1	2
Salt	1 t	6	0.6												
Total		943	99.9	3051	100.0	85.0	105.5	445.6	1.235	23.9	6989	1.33	1.64	7.5	48

*Analysis of flour showed 12.3 percent protein.

Table 19. Nutritive value of Diet III used in Experiment 3 in which enriched flour furnished 58 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Enriched flour	3.0	300	64.7	1065	57.8	36.9	2.7	227.7	.051	8.7		2.07	0.9	10.5	
Black eyed peas	1.0	100	21.6	351	19.1	22.9	1.4	61.6	.080	7.8		0.83	0.23	2.2	2
Fat	0.58	58	12.5	425	23.1	0.4	47.0	0.2	.009	0.1	1943			0.1	
Salt	1 t	6	1.3												
Total		464	100.1	1841	100.0	60.2	51.1	289.5	.140	16.6	1943	2.90	1.13	12.8	2

Table 20. Nutritive value of Diet IV used in Experiment 3 in which non-enriched flour furnished 58 percent of the total calories.

Food	Serving per day	Wt. g	Wt. %	Calories	Cal. %	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
Non-enriched flour	3.0	300	64.7	1065	57.8	36.9	2.7	227.7	.051	2.1		0.42	0.21	2.4	
Black eyed peas	1.0	100	21.6	351	19.1	22.9	1.4	61.6	.080	7.8		0.83	0.23	2.2	2
Fat	0.58	58	12.5	425	23.1	0.4	47.0	0.2	.009	0.1	1943			0.1	
Salt	1 t	6	1.3												
Total		464	100.1	1841	100.0	60.2	51.1	289.5	.140	10.0	1943	1.25	0.44	4.7	2

Table 21. Nutritive value of diets used in Experiment 3 in which 45 and 58 percent of the total calories were derived from cereals.

Diet	Wt. g	Calories	Prot. g	Fat g	CHO g	Ca g	Fe mg	Vit A I U	Vit B_1 mg	Ribo mg	Niacin mg	Vit C mg
I Enriched flour	943	3051	85.0	105.5	445.6	1.235	32.4	6989	3.45	2.53	17.9	48
II Non-enriched flour	943	3051	85.0	105.5	445.6	1.235	23.9	6989	1.33	1.64	7.5	48
III Enriched flour	464	1841	60.2	51.1	289.5	0.140	16.6	1943	2.90	1.13	12.8	2
IV Non-enriched flour	464	1841	60.2	51.1	289.5	0.140	10.0	1943	1.25	0.44	4.7	2

Table 22. Average weights of rats in Experiment 1.

Diet	Weeks 0	1	2	3	4	5	6	7	8	9	10	Total gain g
					First generation							
I Enriched flour	46	67	83	93	111	133	151	178	192	205	212	166
II Non-enriched flour	44	62	77	87	102	117	137	160	175	189	201	157
Stock ration	45	78	109	132	150	168	181	195	205	217	219	174
					Second generation							
I Enriched flour	53	64	78	94	113	126	137	147	157	165	174	121
II Non-enriched flour	47	56	67	75	90	101	115	124	134	149	158	111
Stock ration	56	80	107	130	148	168	186	197	216	226	230	174

Table 23. Average weights of rats in Experiment 2.

Diet	Weeks													Total gain
	0	1	2	3	4	5	6	7	8	9	10	11	12	g
I Whole wheat	46	79	99	125	146	165	180	196	208	219	226	230	233	187
II Enriched flour	46	80	98	121	140	162	176	193	206	217	228	242	250	204
III Enriched flour + salt mixture	46	79	100	122	143	165	187	205	222	231	249	258	268	222
IV Enriched flour + protein	45	85	113	138	159	183	201	216	227	239	251	264	272	227
V Enriched flour + protein + salt mixture	45	89	117	145	169	193	213	229	243	256	266	272	285	240
VI Cornstarch + casein + salt mixture	46	56	60	67	76	90	97	107	114	120	148	159	191	145
VII Non-enriched flour	46	73	90	107	122	141	155	168	179	193	203	210	226	180
VIII Non-enriched flour + salt mixture	47	69	95	113	135	155	167	188	197	209	223	236	246	199
IX Non-enriched flour + protein	47	73	94	108	122	128	136	156	162	172	174	188	197	150
X Non-enriched flour + protein + salt mixture	46	69	89	106	127	146	164	187	198	210	211	229	234	188

Table 24. Average weights of rats in Experiment 3.

Diet	Weeks													Total gain g
	0	1	2	3	4	5	6	7	8	9	10	11	12	
							Better menu							
I Enriched flour	60	95	126	150	172	190	207	220	230	242	251	258	267	207
II Non-enriched flour	60	94	126	148	172	188	206	217	227	237	245	257	263	203
							Most inadequate menu							
III Enriched flour	60	85	100	113	127	129	139	147	150	151	156	165	180	120
IV Non-enriched flour	60	70	78	84	93	102	108	117	120	126	128	133	140	80

Table 25. B-vitamin depletion and recovery of adult rats in Experiment 1.

Diet	Starvation began	End of 1 week starvation	Loss	1 week B-free diet	Gain or loss	2 weeks B-free diet	Gain or loss	1 week on diet	Gain	2 weeks on diet	Gain or loss
					Weight gm						
I Enriched flour	265	221	44	227	+6	219	-8	272	53	270	- 2
II Non-enriched flour	242	199	43	195	-4	179	-16	222	43	251	+29

Table 26. The results of gestation and lactation of rats in Experiment 1.

Items compared	Diets: I Enriched flour	Diets: II Non-enriched flour	Diets: Stock ration
		Gestation	
No. of litters born	3	2	3
No. of rats	22	12	29
Av. No. of rats per litter	7	6	9
Av. birth weight, g	6	6	7
		Lactation	
Av. weight at 7 days, g	10	10	12
Av. weight at 5 days, g	16	16	22
Av. weight at 22 days, g	23	20	36
Av. No. of rats weaned per litter	3	4	5
Av. weaning weight, g	23(22 days)	20(22 days)	47(28 days)
Percentage of rats weaned	37	67	57

Table 27. The results of gestation and lactation of rats in Experiment 2.

Items compared	Diet: I Whole wheat	II Enriched flour	III Enriched flour + salt mixture	IV Enriched flour + protein	V Enriched flour + protein + salt mixture	VII Non-enriched flour	VIII Non-enriched flour + salt mixture	IX Non-enriched flour + protein	X Non-enriched flour + protein + salt mixture
Gestation									
Length of time to mate	5 days	4 days	4 days	2 days	9 days	2 days	4 days	7 days	7 days
No. of litters born	3	3	2	2	3	2	2	2	2
No. of rats	37	25	22	21	35	25	16	20	26
Av. No. of rats per litter	12	8	11	10	12	8	8	10	13
Lactation									
Av. weight at 7 days, g	13	9	14	10	11	7		8	9
Av. weight at 15 days, g	21	17	28	22	23	14		13	14
Av. weight at 22 days, g	28	23	46	36	34	22		15	21
Av. No. of rats weaned per litter	2	2	0.5	6	7	5	0	6	2.5
Av. weaning weight, g	39	29	69	44	42	28		16	23
Percentage of rats weaned	19	24	5	57	62	40	0	65	13

Table 28. Blood values of female rats at monthly intervals and during reproduction in Experiment 1.

I Enriched flour

Interval weeks	Rat No.	RBC M/mm	Hbg g/100 ml	Color index
0	3539		11.02	
	3544		10.24	
	3551		11.45	
Av.			10.90	
4	3539		9.75	
	3544		6.58	
	3551		9.02	
Av.			8.45	
8	3539		10.30	
	3544		10.48	
	3551		10.24	
Av.			10.34	
Before Yg	3539	6.47	13.16	1.219
	3544	7.71	10.55	.8201
	3551	8.16	12.61	.9262
Av.		7.45	12.10	.9885
0-1 days after Yg	3539	5.64	7.70	.8182
	3544	7.50	9.25	.7392
	3551	6.26	10.01	.9584
Av.		6.47	8.99	.8386
2 weeks after Yg	3544	10.27	14.29	.8340
	3551	8.30	15.29	1.1041
Av.		9.28	14.79	.9690
3 weeks after Yg	3539	9.41	14.12	.8994

II Non-enriched flour

Interval weeks	Rat No.	RBC M/mm	Hbg g/100 ml	Color index
0	3550		10.61	
	3557		10.86	
	3560		9.01	
Av.			10.16	
4	3550		9.43	
	3557		11.73	
	3560		8.51	
Av.			9.89	
8	3550		10.64	
	3557		10.64	
	3560		12.00	
Av.			11.09	
Before Yg	3550	7.52	10.38	.8273
	3560	7.58	10.48	.8287
Av.		7.55	10.43	.8279
0-1 days after Yg	3550	5.88	11.02	1.1233
	3560	6.26	9.55	.9144
Av.		6.07	10.29	1.0188
2 weeks after Yg	3550	1.001	14.29	.8969
3 weeks after Yg	3560	9.99	11.65	.6989

Stock diet

Interval weeks	Rat No.	RBC M/mm	Hbg g/100 ml	Color index
0	3541		10.09	
	3547		12.32	
	3567		8.78	
Av.			10.40	
4	3541		9.99	
	3547		9.58	
	3567		13.89	
Av.			11.15	
8	3541		13.86	
	3547		--	
	3567		13.47	
Av.			13.67	
Before Yg	3541	--	--	--
	3547	5.87	9.97	1.0180
	3567	7.89	13.04	.9906
Av.		6.88	11.51	1.0042
0-1 days after Yg	3541	5.50	10.30	1.1224
	3547	6.31	10.36	.9841
	3567	5.75	11.05	1.1518
Av.		5.85	10.57	1.0860
3 weeks after Yg	3541	7.27	13.68	1.1278
	3547	8.57	14.29	.9994
	3567	7.84	14.95	1.1429
Av.		7.89	14.31	1.0900

Table 29. Average blood values of female rats at monthly intervals and during reproduction in Experiment 2.

Interval (weeks)	0			4			8			12			Before Yg			After Yg (0-1 days)			2 weeks later			3 weeks later			4 weeks later			5 weeks later			6 weeks later		
Diet	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index	RBC M/cc	Hbg g/100 ml	Color index
I Whole wheat	8.90	11.19	.7536	7.62	11.09	.8722	8.65	14.93	1.0344	9.63	15.46	.9622	6.62	12.28	1.1122	7.78	12.33	.9495	7.91	13.75	1.0419	7.86	14.43	1.1004	8.33	16.62	1.1957	8.32	14.97	1.0784	10.25	15.45	.9034
II Enriched flour	6.58	11.78	1.0730	7.23	12.05	.9988	8.32	13.74	.9897	9.51	14.84	.9356	8.10	13.35	.9878	6.96	11.32	.9748	10.85	17.60	.9723	9.18	13.99	.9134	8.27	13.92	1.0088	10.01	17.25	1.0328			
III Enriched flour + salt mixture	7.84	10.42	.7965	7.41	11.85	.9584	7.94	12.78	.9647	9.69	15.09	.9337	7.13	14.78	1.2424	5.85	11.99	1.2273	7.85	16.12	1.2307	9.02	15.40	1.0233									
IV Enriched flour + protein	7.51	12.18	.9719	8.34	11.61	.8343	8.16	12.88	.9450	7.73	14.88	1.1541	7.18	12.99	1.0843	5.85	9.26	.9495				8.53	13.19	.9267	8.53	13.99	.9830	8.55	16.10	1.1286			
V Enriched flour + salt mixture + protein	7.76	12.76	.9855	7.87	14.91	1.1354	9.63	12.87	.8010	8.61	15.95	1.1102	7.85	14.02	1.0704	5.68	10.65	1.1232				8.68	12.48	.8618	8.51	13.79	.9712	9.14	13.61	.8925	9.16	16.10	1.05346
VI Cornstarch	8.93	10.91	.7322	5.96	13.61	1.3686	8.51	13.38	.9423	8.07	14.28	1.0605																					
VII Non-enriched flour	7.57	13.71	1.0841	8.46	14.20	1.0059	8.33	14.24	1.0234	8.45	14.06	.9972	7.52	13.15	1.0480	8.20	11.14	.8142				9.60	13.09	.8173	8.57	13.72	.9595						
VIII Non-enriched flour + salt mixture	7.91	11.58	.8775	7.26	12.74	1.0517	6.86	12.77	1.1157	8.67	14.78	1.0217	6.24	11.57	1.1104	7.07	13.49	1.1436	7.71	16.53	1.2850	9.31	15.18	.9773									
IX Non-enriched flour + protein	7.29	12.02	.9883	8.47	13.05	.9234	8.56	14.08	.9858	7.70	14.60	1.1364	6.62	11.78	1.0657	7.42	11.27	.9128				8.88	13.17	.8889	9.00	15.85	1.0555	9.96	16.86	1.0145			
X Non-enriched flour + salt mixture + protein	7.78	13.15	1.0117	6.92	13.33	1.1528	8.32	12.18	.8773	8.29	14.43	1.0432	6.34	12.85	1.2138	7.72	12.95	1.0066	8.23	13.18	.9598	6.87	16.01	1.3966	9.34	16.08	1.0318						

Table 30. Average color indexes for female rats during reproduction in Experiment 2.

Diet	Period			
	Normal 12 wks.	Before Yg 15 wks.	After Yg	3 weeks after Yg
I Whole wheat	0.96	1.11	0.95	1.10
II Enriched flour	0.94	0.99	0.97	0.91
VII Non-enriched flour	0.99	1.04	0.81	0.82
III Enriched + salt mixture	0.93	1.24	1.23	1.02
VIII Non-enriched + salt mixture	1.02	1.11	1.14	0.97
IV Enriched + protein	1.15	1.08	0.95	0.93
IX Non-enriched + protein	1.14	1.06	0.91	0.89
V Enriched + protein + salt mixture	1.11	1.07	1.12	0.86
X Non-enriched + protein + salt mixture	1.04	1.21	1.00	1.03

Table 31. Erythrocyte and hemoglobin values for female rats during reproduction in Experiment 2.

Diet	Period: Normal 12 weeks M/cmm	Period: Before Yg 15 weeks M/cmm	Period: After Yg M/cmm	Period: 3 weeks after Yg M/cmm	Period: Normal 12 weeks g/100 ml	Period: Before Yg 15 weeks g/100 ml	Period: After Yg g/100 ml	Period: 3 weeks after Yg g/100 ml
I Whole wheat	9.63[1] 8.90-10.91[2]	6.62 5.61-7.41	7.78 7.03-8.82	7.86 7.35- 8.19	15.46[1] 15.29-15.57[3]	12.28 9.81-15.43	12.33 11.17-13.74	14.43 13.78-15.06
II Enriched flour	9.51 8.51-10.25	8.10 7.10-8.68	6.96 6.91-7.20	9.18	14.84 14.17-15.52	13.35 12.05-15.13	11.32 10.81-11.73	13.99
VII Non-enriched flour	8.45 8.13- 8.68	7.52 6.22-8.82	8.20 7.20-9.20	9.60 8.64-10.57	14.06 12.81-15.53	13.15 12.56-13.74	11.14 11.10-11.17	13.09 12.98-13.21
III Enriched + salt mixture	9.69 8.72-11.29	7.13 6.49-7.77	5.85 4.64-7.07	9.02 8.59- 9.44	15.09 14.41-16.35	14.78 13.44-16.12	11.99 10.99-13.00	15.40 14.76-16.05
VIII Non-enriched + salt mixture	8.67 8.46- 8.89	6.24 5.55-6.94	7.07 6.18-7.96	8.73 8.16- 9.31	14.78 14.50-15.06	11.57 11.48-11.65	13.49 11.19-15.80	15.16 15.15-15.18
IV Enriched + protein	7.73 6.92- 8.26	7.18 6.71-7.65	5.85 4.87-6.82	8.53 7.94- 9.12	14.88 13.82-16.12	12.99 12.87-13.11	9.26 6.95-11.56	13.19 12.48-13.89
IX Non-enriched + protein	7.70 6.69- 8.71	6.62 6.16-7.09	7.42 6.71-8.13	8.88 7.90- 9.87	14.60 12.34-16.86	11.78 10.54-13.02	11.27 10.30-12.23	13.17 11.78-14.55
V Non-enriched + protein + salt mixture	8.61 7.98- 9.24	7.85 7.06-8.96	5.68 4.31-7.08	8.68 8.44- 9.12	15.95 15.13-16.77	14.02 12.81-15.76	10.65 8.39-13.18	12.48 10.20-15.06
X Non-enriched + protein + salt mixture	8.29 8.17-8.42	6.34 6.05-6.64	7.72 6.81-8.62	6.87	14.43 13.61-15.25	12.85 12.23-13.46	12.95 12.16-13.75	16.01

[1]Average

[2]Range in erythrocyte values

[3]Range in hemoglobin values

EXPLANATION OF PLATE I

Females in Experiment 1 after a 10-week growth period on the test diets.

1. Stock ration.
2. Diet I, containing enriched flour.
3. Diet II, containing non-enriched flour.

PLATE I

EXPLANATION OF PLATE II

Males in Experiment 2 after a 12-week growth period on the test diets.

1. Diet I, containing whole wheat.
2. Diet II, containing enriched flour.
3. Diet V, containing enriched flour plus salt mixture and protein.

PLATE II

EXPLANATION OF PLATE III

Males in Experiment 2 after a 12-week growth period on the test diets.

4. Diet VI, containing cornstarch.
5. Diet VII, containing non-enriched flour
6. Diet X, containing non-enriched flour plus salt mixture and protein.

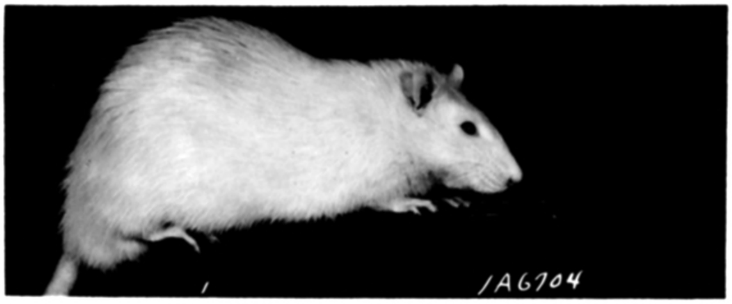
PLATE III

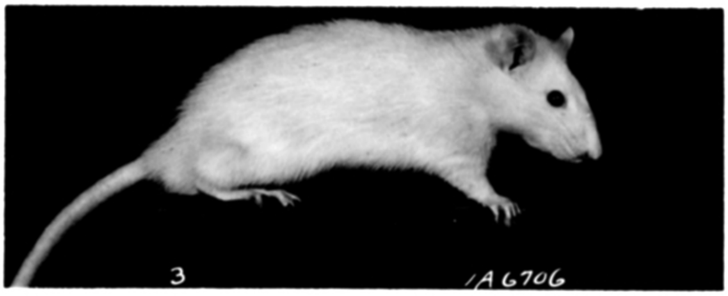
EXPLANATION OF PLATE IV

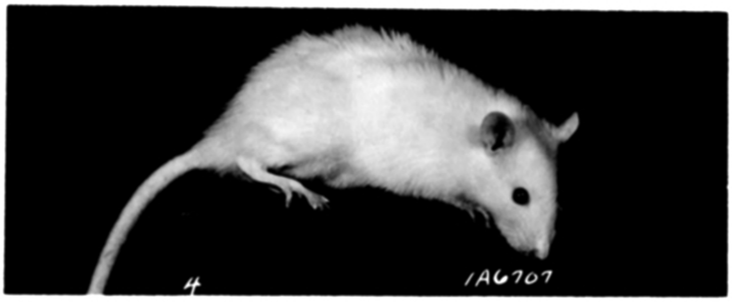
Males in Experiment 3 after a 12-week growth period on the test diets.

1. Diet I, containing enriched flour.
2. Diet II, containing non-enriched flour.
3. Diet III, containing enriched flour.
4. Diet IV, containing non-enriched flour.

PLATE IV







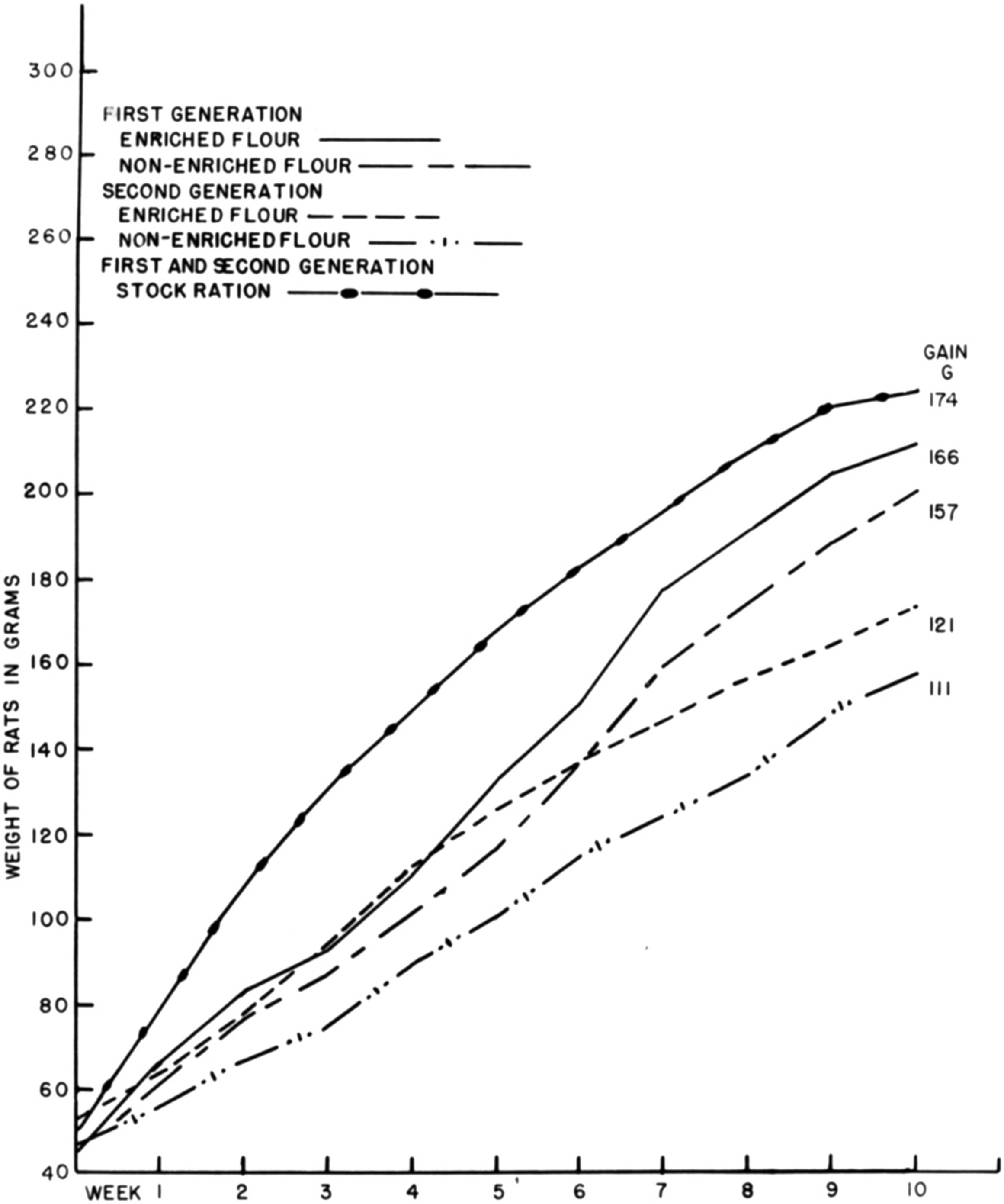

FIRST GENERATION
ENRICHED FLOUR
NON-ENRICHED FLOUR
SECOND GENERATION
ENRICHED FLOUR
NON-ENRICHED FLOUR
FIRST AND SECOND GENERATION
STOCK RATION
GAIN
G
174
166
157
121
111
WEIGHT OF RATS IN GRAMS
300
280
260
240
220
200
180
160
140
120
100
80
60
40
WEEK 1
2
3
4
5
6
7
8
9
10

FIGURE I

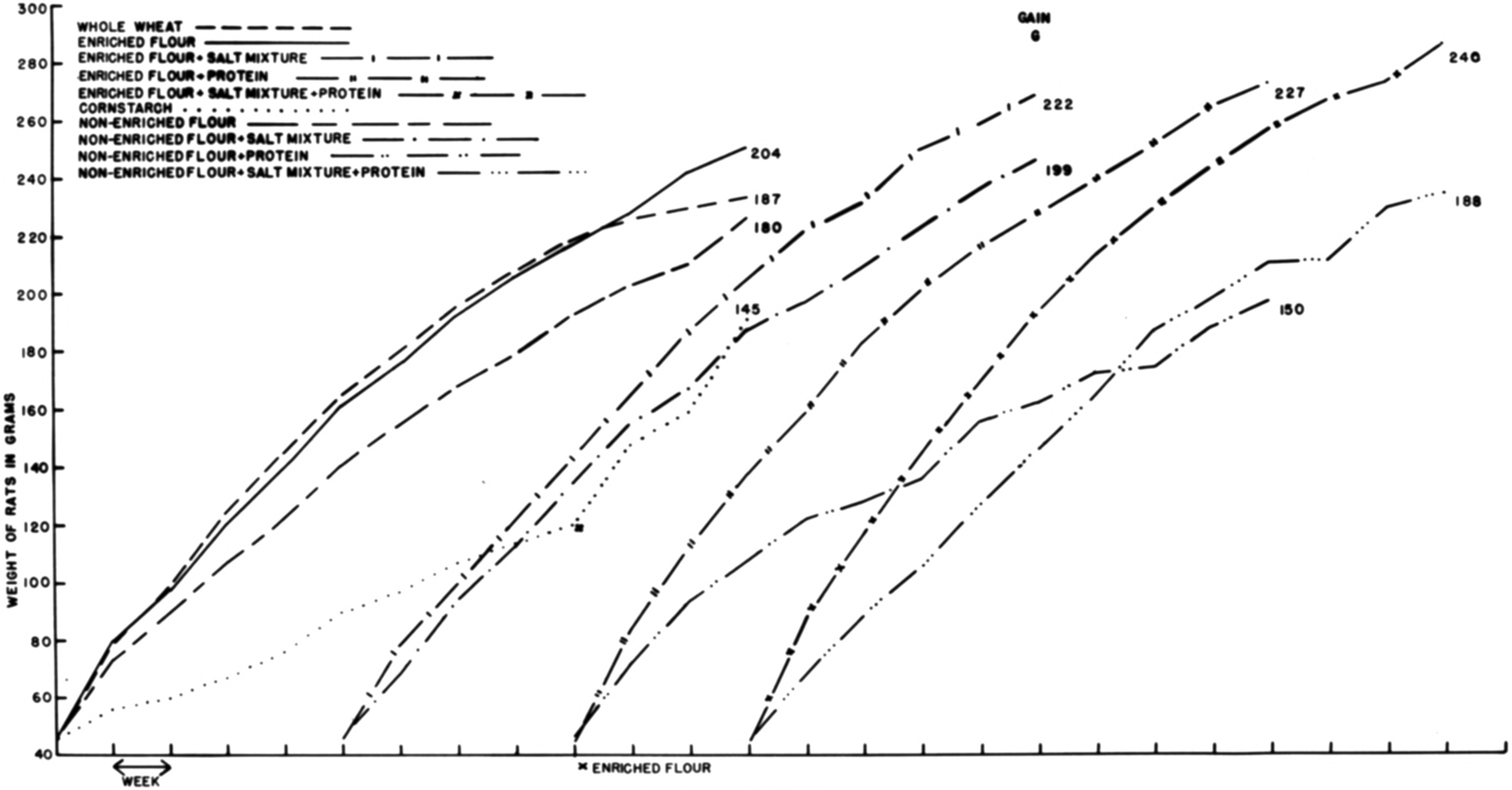

WHOLE WHEAT
ENRICHED FLOUR
ENRICHED FLOUR + SALT MIXTURE
ENRICHED FLOUR + PROTEIN
ENRICHED FLOUR + SALT MIXTURE + PROTEIN
CORNSTARCH
NON-ENRICHED FLOUR
NON-ENRICHED FLOUR + SALT MIXTURE
NON-ENRICHED FLOUR + PROTEIN
NON-ENRICHED FLOUR + SALT MIXTURE + PROTEIN
GAIN
G
204
187
180
145
222
199
227
240
188
150
WEIGHT OF RATS IN GRAMS
300
280
260
240
220
200
180
160
140
120
100
80
60
40
WEEK
× ENRICHED FLOUR

FIGURE 2

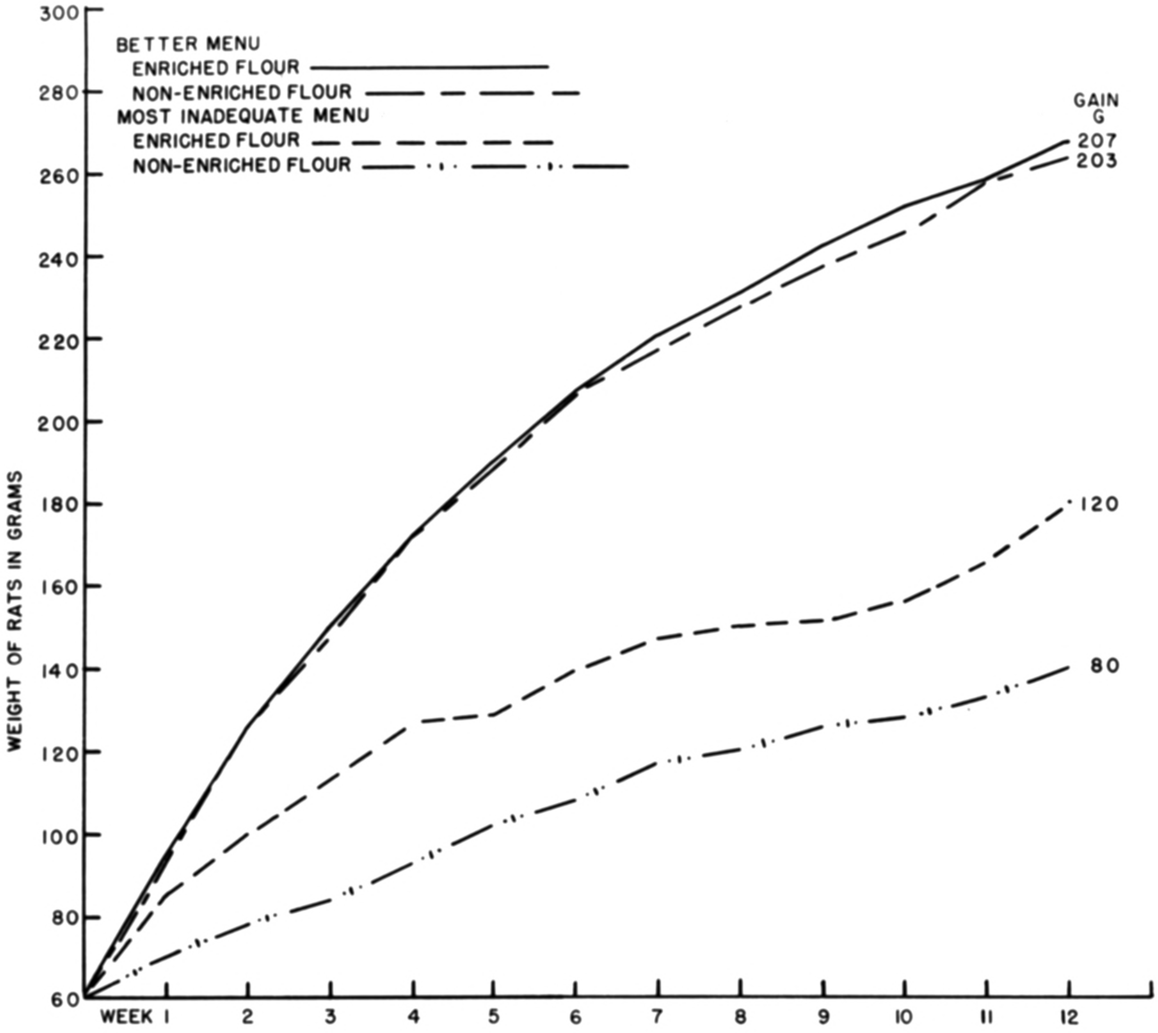

300
280
260
240
220
200
180
160
140
120
100
80
60
WEIGHT OF RATS IN GRAMS
BETTER MENU
ENRICHED FLOUR
NON-ENRICHED FLOUR
MOST INADEQUATE MENU
ENRICHED FLOUR
NON-ENRICHED FLOUR
GAIN
G
207
203
120
80
WEEK 1
2
3
4
5
6
7
8
9
10
11
12

FIGURE 3

ACKNOWLEDGMENT

Appreciation is expressed to Dr. Beulah D. Westerman, Professor of Foods and Nutrition, for her guidance and interest during this study.

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